FOREWORD

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Many persons have contributed to the making of this report
and the development of the program which it reflects. In addition to
the authors, the most important contributors were:

ABSTRACT

A documentation system has been established for abstracting, indexing, and retrieving data relating to the electrical and electronic properties of insulator and semiconductor materials. The system is a coordinate index type immediately usable as a manual system and adaptable to machine methods of data storage and retrieval. The data acquired and indexed is published in the form of property tables, data sheets, and summary reviews. Methods used in the documentation, compilation, and evaluation of the data are described and examples of format illustrated. Appended are an index to semiconductor and insulation material names and a glossary of selected properties and symbols.

This technical documentary report has been reviewed and is approved.

D. A. Shinn
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Application Laboratory
Directorate of Materials and Processes

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I. INTRODUCTION

The immense growth of science and technology in recent years is nowhere more clearly reflected than in the field of electronics. Entire new fields of inquiry have been established and industries based upon them. The volume of research results, both published and unpublished, has grown to such an extent that workers in a field find it progressively more difficult to become aware of those results, particularly in the area of basic materials data.

This report describes the first year's work on a program designed to provide ready access to electrical and electronic property data of all materials important to today's technology. The program has been divided into two phases. Phase I consists of determining and establishing the systems, procedures and facilities for (1) searching, acquiring, abstracting and indexing literature; (2) storing, retrieving, compiling, and evaluating data; (3) publishing and disseminating bibliographies, property tables, data sheets and summary reviews of important topics. Phase II consists of performing the above tasks for two categories of materials, insulators, materials and semiconductors. Future work on the program is intended to comprehend all other categories of materials relevant to electronics. The systems developed are intended to apply to all future categories as well as the two upon which the first year's work has been concentrated.

II. THE DOCUMENTATION SYSTEM

Documentation comprises searching, acquiring, abstracting and indexing the literature. Establishment of a documentation system required a study to develop an appropriate vocabulary for insulator and semiconductor material and property names together with an indexing scheme capable of storing, identifying and rapidly retrieving property data. It was thought desirable to develop an index both flexible and highly specific which would be immediately usable as a manual system and highly adaptable to machine methods of storage and retrieval.

A. The Index

Several avenues of indexing were open for consideration, ranging from the general subject heading approach to the specificity of the unit term approach. At the beginning of the program, it was decided that a subject heading approach would be too unwieldy, for it would have to incorporate lengthy headings dealing with multiple material or property names (i. e. , SODIUM PHOSPHIDE – ABSORPTION DUE TO IRRADIATION). To index to this degree of specificity would require an over-abundance of subject headings in the system, many of which would apply to only one or two articles.

For these reasons it was thought desirable to use headings of individual materials and/or properties. However, to simply do this and nothing more would make articles dealing with comparative properties of one material, or one property compared in several materials difficult to find. Therefore some kind of matching between these individual materials and property names had to be possible and the system would have to be one of "coordinate indexing. "

Having chosen a coordinate indexing system, the question became one of whether or not to use unit terms (terms consisting of only one word, either a property or a material). If unit terms were used then coordination could take place between cards listing, individually, the desired material and property. However, there would be certain disadvantages to such an approach. For example, under a heading such as RESISTIVITY there would be hundreds of articles. To post these articles would probably require several cards. Then when it was desired to coordinate this property with a material, it would prove bulky and tedious to find the same article listed under both RESISTIVITY and the material. Also, imagine the number of times a user might take the trouble to coordinate a material term with a property term only to find no articles in the system.

To accomplish the specificity required and to eliminate the disadvantages of unit terms, a modified coordinate indexing scheme was chosen. The finalized system consisted of "precoordinated" descriptors of one material or one material and one property

(i. e. , <u>INDIUM PHOSPHIDE</u> – <u>ABSORPTION</u>). Advantages of the
system over unit terms include quicker retrieval since usually only
one card with the "precoordinated"descriptor has to be consulted.
There is also a lower density of posted articles under any given
term. For example, assume that there are 15 articles dealing with
the property <u>ABSORPTION</u> of the material <u>INDIUM PHOSPHIDE</u>. If
each of these articles is listed under both terms, the article (or its
accession number) is posted 30 times. On the other hand, by
"precoordinating" these terms into one descriptor (<u>INDIUM</u>
<u>PHOSPHIDE</u> – <u>ABSORPTION</u>) the accession number is posted only
15 times. Thus posting and its attendant clerical errors is reduced
by 50 percent.

The final index consists of two card files. One, the <u>Accessions</u>
<u>File</u>, is arranged by an identifying or accession number assigned to
each document entered into the system. Each card in the Accessions
File contains the bibliographic entry, property data, and a descriptive
abstract of the document to which it pertains. A second file, the
<u>Descriptor File</u>, consists of subject descriptor cards. Input for
indexing is generated on standard forms by subject specialists who
extract and summarize the content of the literature. The accession
number is posted on the appropriate subject descriptor cards. For
example, under a descriptor term such as <u>INDIUM PHOSPHIDE</u> –
<u>ABSORPTION</u> are listed accession numbers of all the pieces of
indexed literature containing data on that subject.

Retrieval on searches involving more than one property at a
time is accomplished through matching the accession numbers on the
relevant subject descriptor cards. Numbers found in common on the
matched cards identify literature containing data on the two or more
properties concerned. The same procedure would be followed in
retrieving literature on alloys and mixtures of two or more materials.

Figure 1 is an example of the Descriptor cards. They are
arranged within each category alphabetically by material name, and
within material name by property name. The semiconductor alphabet
is divided into elements, inorganic compounds and organic com-
pounds. The insulation materials alphabet is not sub-divided. The
accession numbers identifying the pieces of literature are printed in
columns under each subject name by terminal digit for easy matching.

This system is inherently more efficient than the other ap-
proaches. It will minimize "false drops," both nonsignificant coor-
dinations and those due to clerical errors. At the same time the
degree of specificity is more than adequate, allowing arbitrary con-
trol to suit the purposes of the program.

Although it is still fairly early to measure accurately the system
efficiency, studies have been begun. On the representative searches
conducted so far the percent of "false drops" has varied from a low

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INDIUM PHOSPHIDE

0	1	2	3	4	5	6	7	8	9
390	551	662	553	324	435	126	107	158	549
400	2371	2502	713	364	465	246	2207	398	2139
2240	2501		763	474	555	296	2507	888	2259
2260			903	504	915	446		2208	2409
2340			2203	664	2205	586		2238	
2400				784		2206			
2410				2204		2506			
2510				2254					
2520				2504					

INDIUM PHOSPHIDE
– ABSORPTION

0	1	2	3	4	5	6	7	8	9
390		662	763	364	465	126	107	158	2139
2260		2502		474	555	446		398	
2520									

INDIUM PHOSPHIDE
– DIELECTRIC CONSTANT

0	1	2	3	4	5	6	7	8	9
					2205		2207	158	

INDIUM PHOSPHIDE
– DIFFUSION

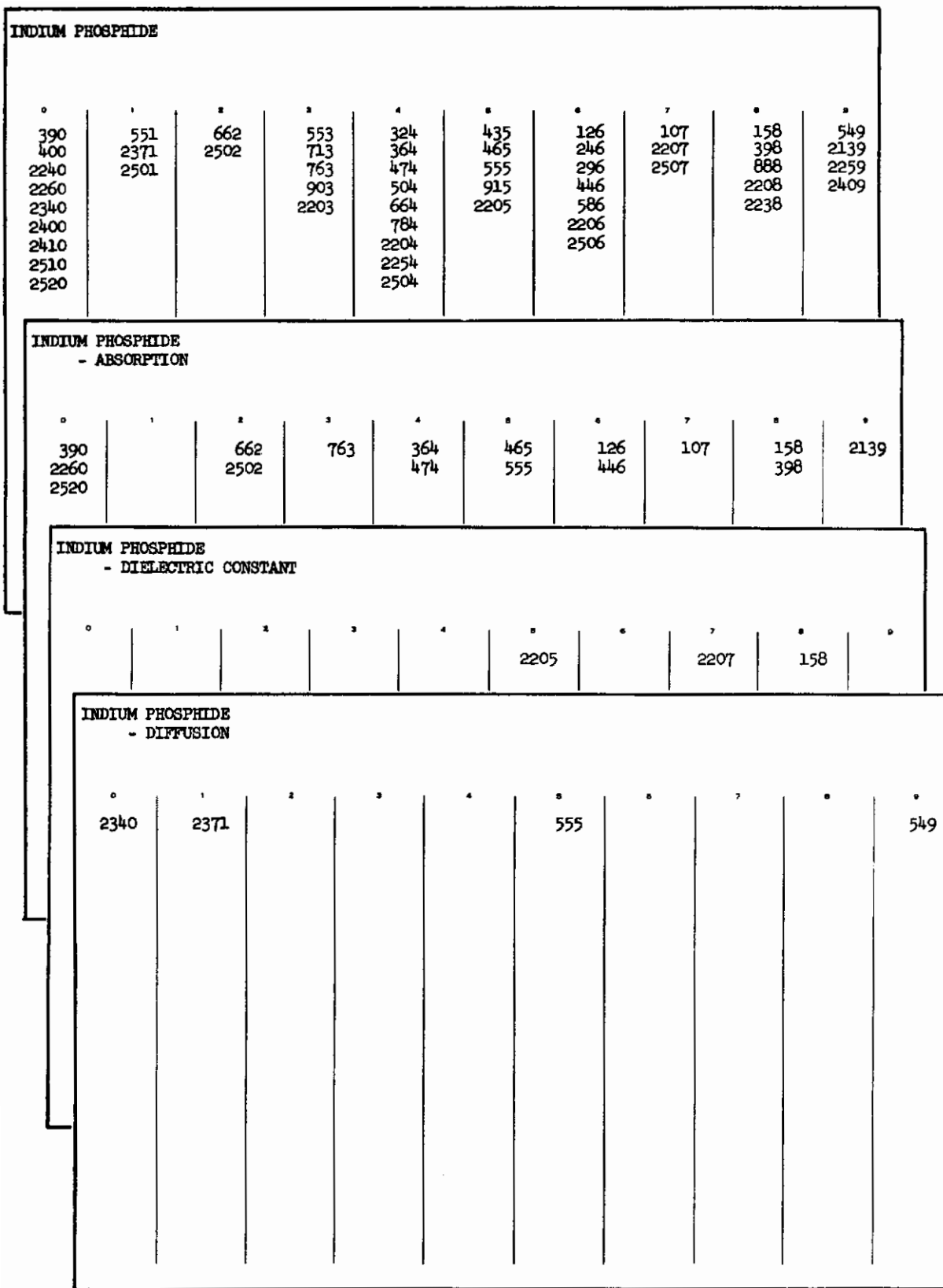| 0	1	2	3	4	5	6	7	8	9
2340	2371				555				549

FIGURE 1. DESCRIPTOR CARDS.

of 0 percent to a high of 7 percent. A preliminary analysis indicates that not one of these "false drops" was due to a weakness in the system; rather they were due to error (i.e., transposition of digits in the accession number, posting the wrong number, and similar errors) or to human judgment in indexing. Since the human element will always be present in any system, future studies will be aimed at reducing this type of "false drop" by a thorough analysis of routines and indexing skills.

Also under consideration are studies aimed at increasing the capabilities of the basic system. The representative searches mentioned above were made with a full knowledge of the system capabilities and therefore impossible searches were not attempted. For instance, the system can be manipulated only through materials, not through properties. Yet it would seem valuable to add property manipulation. A desirable example might be the capability of asking the system for a material that meets certain property requirements. This cannot presently be done.

1.   Data Processing Printout on Descriptor Cards

Posting of accession numbers on descriptor cards (Figure 1) is done through the use of data processing equipment, including sorters, collators, reproducers, interpreters, and card printers, with an IBM 1401 doing the actual posting. The punched card file is now well established numbering about 38,000 cards (Figures 2 and 3) each properly punched either as a master (material or material and property) or a detail (accession number — article) card. Quick visual distinction between these two can be made through the blue-lined top and clipped -upper-left-hand corner for the master cards and plain, clipped-upper-right-hand corner for the detail cards. Machine distinction is made through a punch on the masters in the X80 position (80th column above the zero).

The master card is to provide for the printout of the descriptor on the descriptor card. The detail cards represent the article in that the accession number of the article is punched on the card. For each descriptor card there will be a punched master card. However, for each article there will be several detail cards, one for each descriptor assigned to the article. One of these punched cards will be filed behind each of the appropriate master cards punched for the associated descriptor.

The card deck for each of the major categories of materials (semiconductors, insulators, etc.) is filed separately and coded under that category. Master cards are coded at the left of the card for the printing of the material or property in the upper left-hand corner. They are also coded in columns 69 to 75 for the material and property, the material occupying 69 to 73 and the property 74-75. Thus INSULATION MATERIALS which was arbitrarily assigned the code

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FIGURE 2.   MASTER PUNCHED CARDS.

1030250301172

1030250301375

1030250301069

FIGURE 3.   DETAIL PUNCHED CARDS.

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Accession Number	Material		Code Number
02	Absorption	32	Lifetime
04	Cross-sections	34	Magnetic Susceptibility
06	Debye Temperature	35	Magnetoelectric Properties
08	Dielectric Constant	38	Mean Free Path
10	Diffusion	40	Mobility
12	Effective Mass	45	Photoelectronic Properties
14	Electrical Conductivity	47	Piezoelectric Properties
16	Electroacoustic Properties	50	Reflection
18	Emission	52	Refractive Index
20	Energy Bands	54	Resistivity
22	Energy Gap	57	Surface Properties
24	Energy Levels	58	Thermal Conductivity
28	Hall Coefficient	59	Thermoelectric Properties
30	Irradiation Effects	61	Thermomagnetic Properties
14 May 1962 Semiconductor Properties		62	Work Function

FIGURE 4.   SEMICONDUCTOR PROPERTY CODE CARD

Accession Number	Material		Code Number
03	Arc Resistance	21	Irradiation Effects
06	Corona Effects	24	Loss Factor
09	Dielectric Constant	27	Power Factor
12	Dielectric Strength	30	Storage Factor
15	Dissipation Factor	33	Surface Resistivity
18	Insulation Resistance	36	Volume Resistivity

14 May 1962
Insulator Properties

FIGURE 5.   INSULATOR PROPERTY CODE CARD

number 03005 shows this number in columns 69 to 73 and shows 00 in 74 and 75 denoting no property. The number 0300500 is also printed above for visual use. Note that the first 0 is not printed but is punched in column 69. The property is coded in 74 and 75 using the codes on the Insulator Property code card, Figure 5. INSULATION MATERIALS – ARC RESISTANCE will be 0300503, CORONA EFFECTS 0300506, and so on through the properties for INSULATION MATERIALS.

The materials under the general category of INSULATION MATERIALS are coded in columns 71 and 72. While INSULATION MATERIALS is 03005, ACETAL PLASTICS becomes 3025. ACETAL PLASTICS – ARC RESISTANCE is 302503.

Continuing on through the deck all master cards continue to be coded in alphabetical fashion. This is to assure that all printouts (descriptor cards, master tab runs of materials, etc.) will be alphabetically arranged. Note that there is generous space allowed between the numbers assigned the properties and materials. For example, ARC RESISTANCE is 03, CORONA EFFECTS is 06 instead of 04 (Figure 5). This space is to allow the addition of future materials and properties in alphabetical order without having to reassign any numbers.

The detail or article cards appear in the deck behind the applicable master card. Columns 69 to 75 repeat the material and property. Columns 76 to 80 show the accession number of the indexed article and columns 66 to 68 show the horizontal line number to be printed on the descriptor card. While the terminal digit of the accession number indicates in which column on the descriptor card the number will appear, the line number determines its position, e.g., row within the column. Again note that zeros preceding the first digit do not appear printed on the tab card but are punched in. The total code appearing on a detail card will appear like this: 0010302503011172: 001 – line number, 03025 – material, 03 – property, 01172 – accession number of the article.

The monthly updating program for the descriptor cards goes as follows (see Figure 6):

New master cards (2) are punched and sorted into order and then merged and sequenced (3) with the existing file (1). New detail cards (4) are also punched (except for columns 66-68) and sorted into order. These two files are then matched against each other (5) in columns 69 to 75 (materials and properties) and sorted into four groups. By the matching process with the new detail cards, the merged main file and new master cards are separated into those areas (master card plus associated detail cards) which do not require updating (6) and those areas which will be updated (7). The new detail cards from block (4) are continued into block (8) except for those revealed by the matching
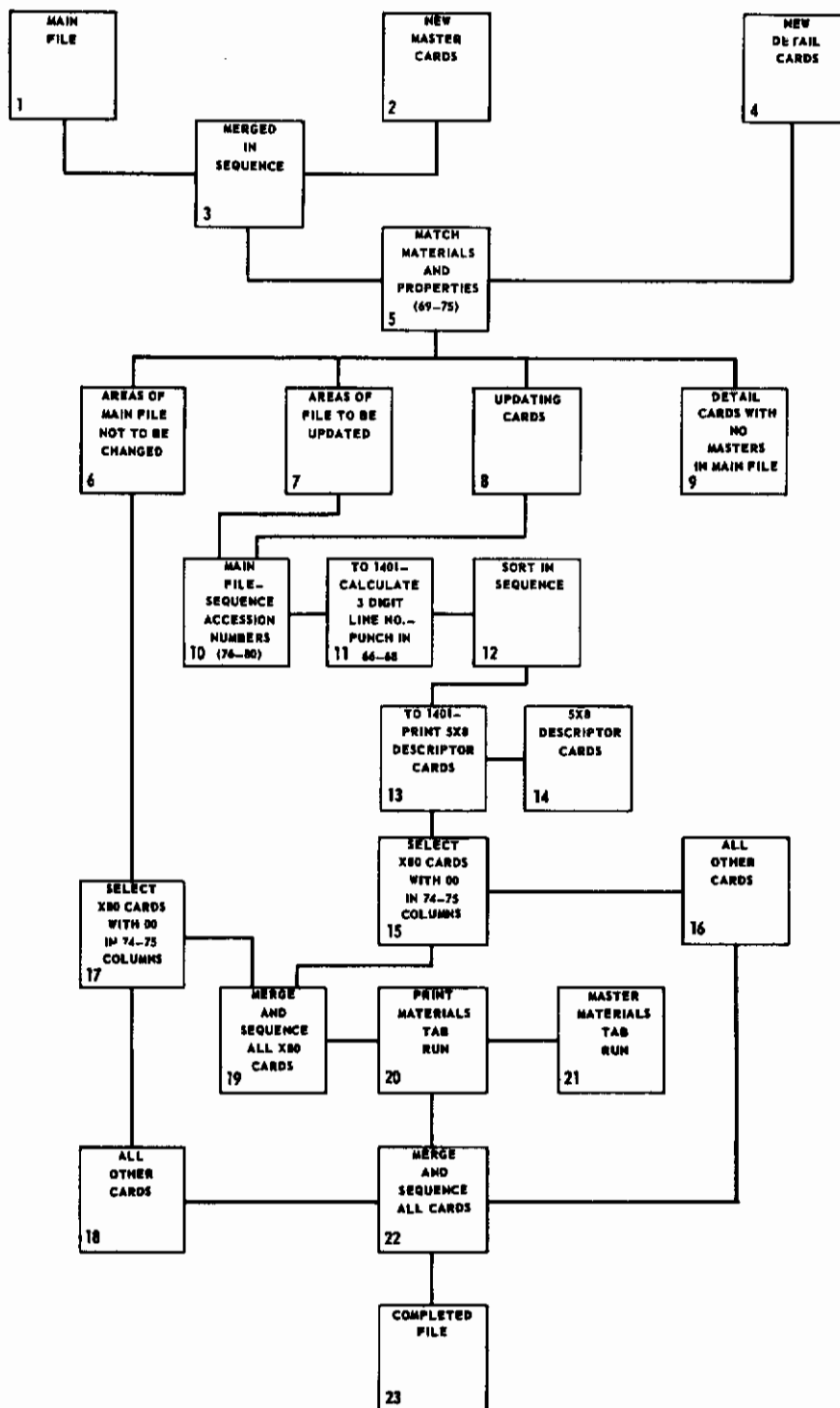
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PUNCHED CARD PROGRAM FOR POSTING DESCRIPTOR CARDS

MAIN FILE
1

NEW MASTER CARDS
2

NEW DETAIL CARDS
4

MERGED IN SEQUENCE
3

MATCH MATERIALS AND PROPERTIES (69—75)
5

AREAS OF MAIN FILE NOT TO BE CHANGED
6

AREAS OF FILE TO BE UPDATED
7

UPDATING CARDS
8

DETAIL CARDS WITH NO MASTERS IN MAIN FILE
9

MAIN FILE— SEQUENCE ACCESSION NUMBERS
10 (76—80)

TO 1401— CALCULATE 3 DIGIT LINE NO.— PUNCH IN
11 66—68

SORT IN SEQUENCE
12

TO 1401— PRINT 5X8 DESCRIPTOR CARDS
13

5X8 DESCRIPTOR CARDS
14

SELECT X80 CARDS WITH 00 IN 74—75 COLUMNS
15

ALL OTHER CARDS
16

SELECT X80 CARDS WITH 00 IN 74—75 COLUMNS
17

MERGE AND SEQUENCE ALL X80 CARDS
19

PRINT MATERIALS TAB RUN
20

MASTER MATERIALS TAB RUN
21

ALL OTHER CARDS
18

MERGE AND SEQUENCE ALL CARDS
22

COMPLETED FILE
23

FIGURE 6.

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process to have no masters in the file. These are sorted out (9), and discarded as errors or held until masters are made. The cards of (7) and (8) are now merged and sequenced into one file (10). Those cards from (7) are already in order by material, accession numbers, property, accession numbers, and so on. The detail cards from (8) are also in this order but without masters. Note that as the detail cards are filed behind the master they are filed first by the terminal digit, then by the rest of the number. Note also that, since accession numbers are being assigned by numerical order to the articles as they enter the indexing system, any new detail card will automatically file at the end of those cards with the same terminal digit because the rest of the accession numbers to be posted in that descriptor card column will be lower (i. e., the articles have previously entered the system). This simplifies the next step (11) on the IBM 1401 where the vertical line number in that column on the descriptor card is automatically punched in and printed on the tab card in columns 66-68. For example, if that particular master card already has two subordinate detail cards with accession numbers ending in 1, the associated descriptor card will have two accession numbers in column 1. The detail card for the first accession number will show a line number (columns 66-68) of 001, the second 002, and the updating card will automatically be filed behind these two and then be punched by the IBM 1401 as 003 for the line number.

However, the detail cards filed after the masters are still not in the correct order to print the descriptor cards, since the IBM 1401 will not print column 1 and then column 2 and on across, but rather will print the first line of accession numbers across all columns at once, then go to the second line, and on down the card. Each set of detail cards after each master has to be resorted to an order first by the line number and then by terminal digit of the accession number. This is accomplished in (12) and the cards are then ready to be taken to the IBM 1401 for printout of the descriptor cards.

The printout (13) is as follows: Each master card represents a descriptor to be printed at the top of the descriptor card. The descriptor may be a material only (i. e., INDIUM PHOSPHIDE) or a material and a property in a pre-coordinated term (i. e., INDIUM PHOSPHIDE — ABSORPTION). The detail cards behind each master card represent the articles indexed under that descriptor by accession number. As the cards are run through the IBM 1401, the master appears first and the descriptor is printed at the top of the descriptor card. Then as the detail cards appear, the first line of accession numbers is printed across the descriptor card, then the second line, and on down the card. For the benefit of programmers interested in the actual IBM 1401 printout program, flow charts are presented in Figures 7 and 8. After the printout the 5 x 8 descriptor cards are ready to file since they are already in alphabetical order. The old cards which needed updating are pulled out of the descriptor file and the new ones inserted in their place.
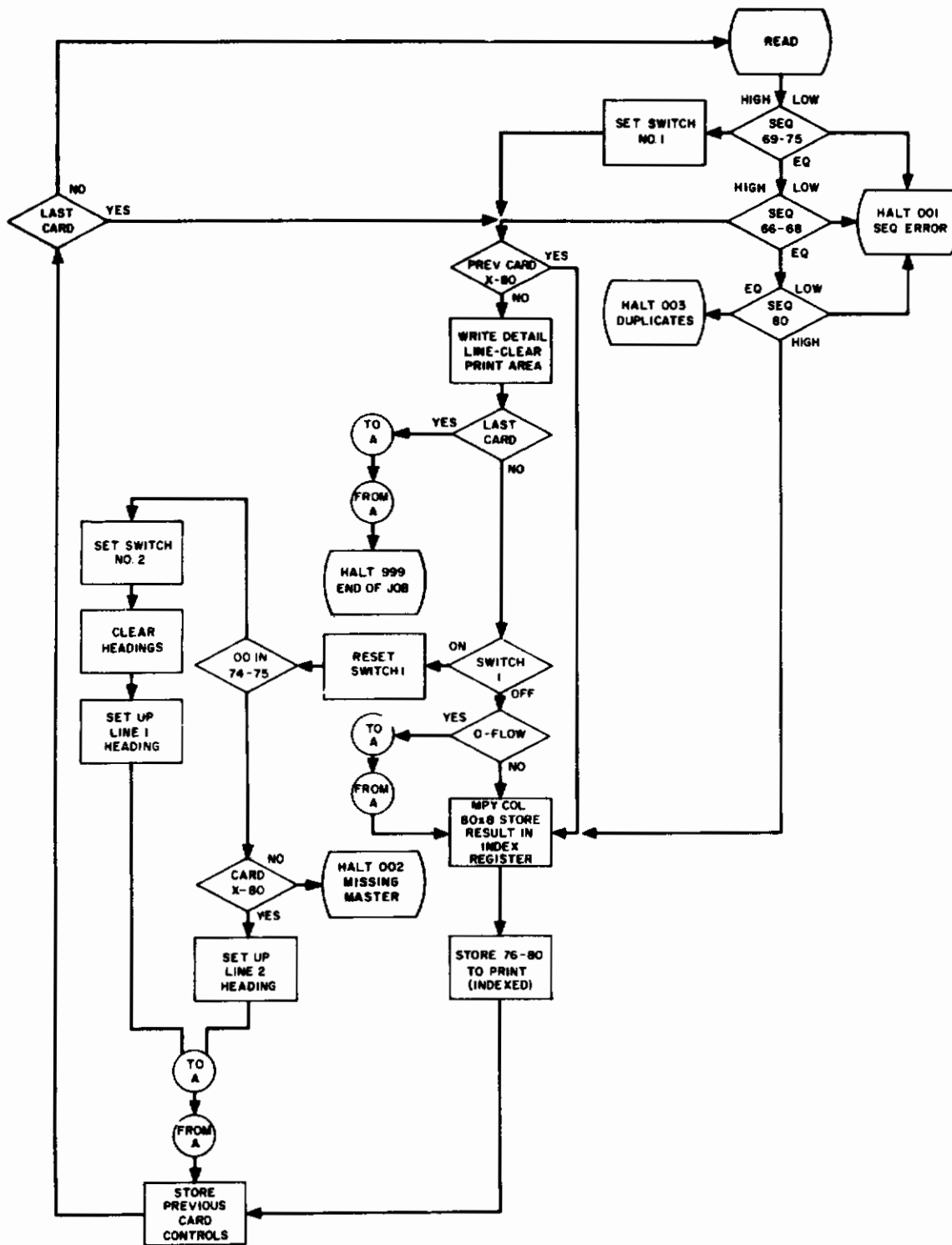
READ

SEQ 69-75 — HIGH / LOW / EQ

SET SWITCH NO. 1

SEQ 66-68 — HIGH / LOW / EQ

HALT 001 SEQ ERROR

SEQ 80 — EQ / LOW / HIGH

HALT 003 DUPLICATES

LAST CARD — NO / YES

PREV CARD X-80 — YES / NO

WRITE DETAIL LINE-CLEAR PRINT AREA

LAST CARD — YES / NO

TO A

FROM A

HALT 999 END OF JOB

SET SWITCH NO. 2

CLEAR HEADINGS

SET UP LINE 1 HEADING

00 IN 74-75

RESET SWITCH 1

SWITCH 1 — ON / OFF

O-FLOW — YES / NO

TO A

FROM A

MPY COL. 80×8 STORE RESULT IN INDEX REGISTER

CARD X-80 — NO / YES

HALT 002 MISSING MASTER

SET UP LINE 2 HEADING

STORE 76-80 TO PRINT (INDEXED)

TO A

FROM A

STORE PREVIOUS CARD CONTROLS

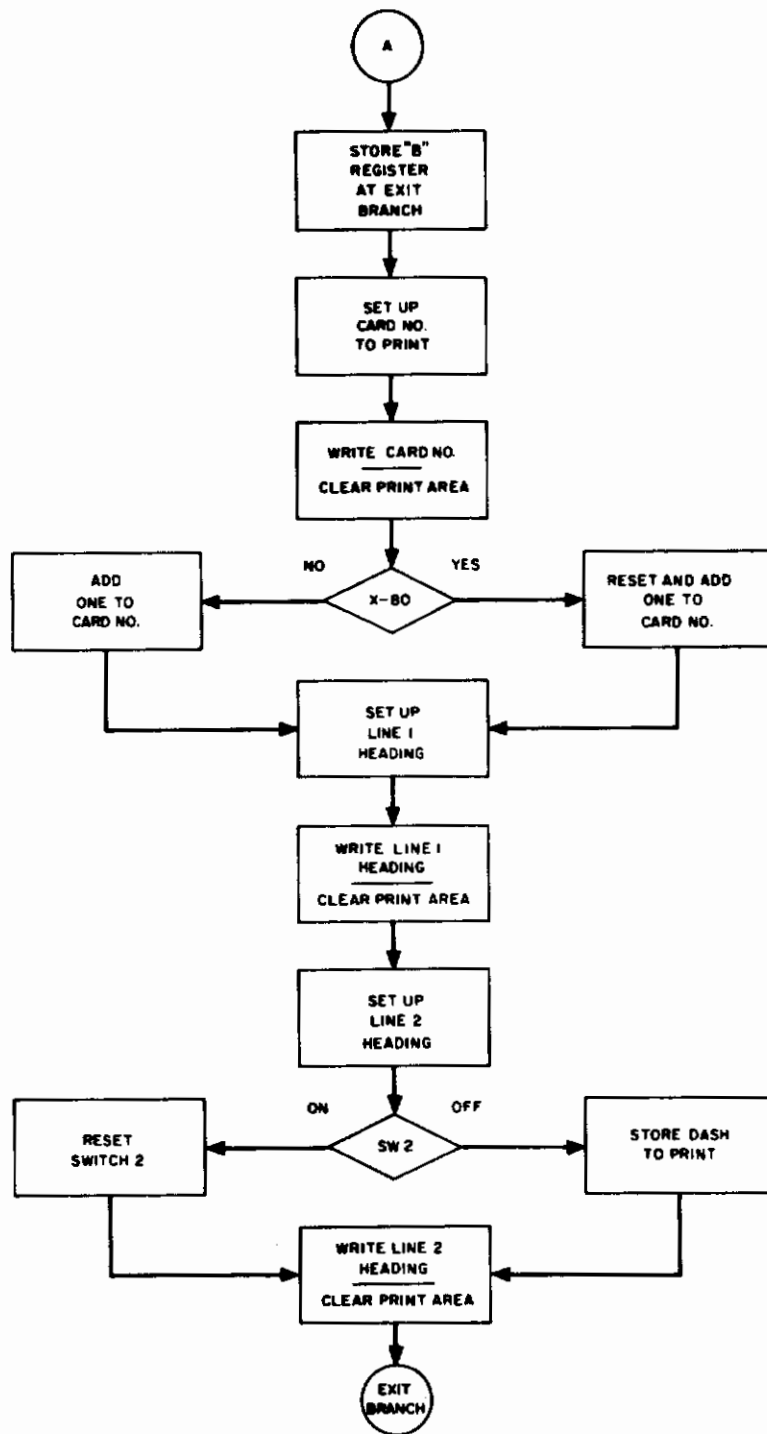FIGURE 7. FLOW CHART OF IBM 1401 PROGRAM FOR POSTING DESCRIPTOR CARDS.

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FIGURE 8. SUBROUTINE OF IBM 1401 PROGRAM FOR POSTING
DESCRIPTOR CARDS.

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An additional feature of the data processing system is the capability of printing lists of materials and/or properties. Since the properties lists are not lengthy nor subject to frequent change, they are seldom printed but the monthly procedure of updating the descriptor cards includes printing an up-to-date tab run of all materials in the system.

In order to do this all X80 (master) cards with 00 in the 74 and 75 columns (no property) are sorted from each of the two files (i. e. , the updating file (15) and the rest of the main file (17). These are merged in sequence (19) while the rest of the two files bypass this step (16 and 17). These cards are then run through a printer to produce a master tab run of materials (21).

After the tab run of materials, all cards are merged and sequenced (22) for a single completed file (23).

There are many advantages to using a data processing system for updating descriptor cards. Some of these, such as the capability of producing tab runs of descriptors, are already implied. However, not only can tab runs of materials and properties be made, but also useful counts and comparisons, such as the average number of descriptors per article or total descriptors in the system, can be easily made. The accomplishment of such tasks from the manual file would be extremely cumbersome.

In addition, both clerical cost and clerical error are significantly reduced. This is particularly true where multiple copies are made and maintained. Since the punched deck is always maintained up-to-date, it provides a back-up file for the descriptor card catalog. A new catalog may be made any time either for an additional set or because of accidental destruction of the first, and at a much lower cost than clerical copying or reproduction. Yet, while a new catalog or part of an existing catalog is being run, it is unnecessary to remove any descriptor cards from the file, as is necessary with manual posting. The descriptor file is always intact for users of the system.

A by-product of posting through data processing is the generation of large numbers of punched cards individually coded to "connect" an accession number with a descriptor term. As it becomes feasible and desirable to automate the storage and retrieval of the indexed information accumulated in this project, these cards will provide an invaluable source of input information.

As an interim step to more complete automation, a tape updating program is now being studied. Obviously, the thousands of IBM cards which will soon accumulate in connection with the program will pose a storage problem. Also, it seems possible that some steps now necessary with punched cards might be eliminated through using tape units associated with the IBM 1401 and thus reduce costs.

2. Material and Property Naming

Materials and properties lists have been developed by subject specialists using, in addition to their own experience, encyclopedias, dictionaries, handbooks, indexing and abstracting publications, basic reference texts and the pertinent serial literature. The list of properties and appropriate cross-references established for indexing semiconductor literature is given in Appendix I. Appendix II contains the corresponding lists for insulation materials.

The property names established for indexing the two categories of materials are intended to include various contributory effects and measurements under relatively broad headings attributable to the materials themselves. Apart from irradiation effects, environmental effects are intended to be indexed under the properties affected. In arriving at an appropriate list of property and material names the chief difficulties encountered in the semiconductor category centered around the large number and variety of properties, effects and measurements which could be indexed as distinctive entities or subsumed under broader headings. For the insulation materials category the chief difficulties lay with naming the materials themselves. Appendix III presents the insulation material names established for the index together with alternative forms and trade names in a common alphabet.

As a part of the effort in arriving at an optimum system of naming materials and properties a glossary of properties and effects was assembled to assist all personnel involved in the project. This is given as Appendix IV. An attempt has been made to give simple explanations and descriptions of those properties and effects most relevant to the scope of the program. In addition, supplementary background information in the form of notes, diagrams, equations and related terminology is included. The glossary has proven most useful both to the documentation and data evaluation activities.

3. The Use of the Index

A regularly updated set of the index is maintained at the Directorate of Materials and Processes, Wright-Patterson AFB, Ohio and at Hughes Aircraft Company, Culver City, California. The Provision of an updated index gives access to basic data prior to its cumulation in data sheets and other formats. Because of sparse and uneven reporting many materials will not be compiled into data sheets for an extended period.

After data sheets are compiled on given materials, new literature will enter the system, be indexed, and thus will be accessible to persons interested in those materials. It is expected that the index will prove to be at least as valuable if not more valuable than the data sheets, particularly as mechanization of storage and retrieval is applied to it.

B.   Searching the Literature

Searching to establish the existence of publications containing electrical and electronic property data may be divided into two distinct procedures, retrospective searching and current searching.

1.   Retrospective Searching

Indexing and abstracting sources are systematically explored for the various time periods most relevant to the data sought for the different categories of materials. In general the procedure followed for each category consists of a year by year search, working backward in time from the most recent period in the most comprehensive abstract sources for that category; a further exploration is made of the bibliographies contained in the articles, documents, et al., found for each year. The literature thought to contain data is recorded on 3 x 5" cards and checked for duplication against search and holdings records. The literature is paged from Hughes Aircraft Company library shelves, borrowed from other libraries, or ordered from ASTIA and other sources, and is then appraised by a subject specialist for relevant content. About one third of the literature selected on the basis of a promising title and/ or abstract is rejected upon appraisal as containing no data useful for the project. The 3 x 5 " search cards are retained in cumulative search files containing both accepted and rejected items.

When the major index sources for each category have been explored the less remunerative sources will be searched. Searching for insulation materials and semiconductors has been concentrated largely during the first year in a few remunerative sources. These include:

ASTIA Technical Abstract Bulletin	Nuclear Science Abstracts
Ceramic Abstracts	Physics Abstracts
Chemical Abstracts	Semiconductor Abstracts
Digest of Literature on Dielectrics	Semiconductor Electronics
Engineering Index	Solid State Abstracts
Electrical Engineering Abstracts	U.S. Government Research Reports

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In addition certain specialized bibliographies, ASTIA demand bibliographies and bibliographies contained in books and broad review articles have been searched. More than thirty thousand titles and abstracts have been appraised in the first twelve months of the program. The semiconductor category search has covered the years 1952-1961. The insulator search has covered the years 1947-1961. It is estimated that 80% of the semiconductor literature and 70% of the insulating materials literature relevant to this project has been searched.

2. Current Searching

When the retrospective search for a category has been completed for the major sources, systematic exploration is initiated in the unindexed current issues of journals, serials, report series, etc., which are indicated to be remunerative sources through an examination of a cumulative source file maintained as an auxiliary aid to searching and indexing. A system of direct inquiry for information concerning current research programs is under development through leads furnished by the search results, contacts in the United States and abroad, Government and Defense agencies. Efforts are being made to obtain the data developed under such programs, on a current basis.

C. Acquisition of Literature

Literature selected and acquired through the search procedures is reproduced or ordered directly for permanent retention. Literature not held by Hughes Aircraft Company libraries is purchased, borrowed or ordered from other libraries or issuing agencies. "Demand bibliographies" are ordered from ASTIA. A continuing effort is made to be placed on distribution lists for reports issued on current research relevant to the project. Reports issued as part of Government contracts are ordered largely from ASTIA. Other reports are ordered directly from the issuing agency.

Each piece of literature selected for the project is assigned an accession number which is recorded on the item and on an Index-Abstract form (Figures 9 and 10). The bibliographic entry is typed at the top of the form. Those portions of the forms containing the bibliographic entry, material and property names are reproduced onto 5 x 8" card stock. Files of cards are maintained under author, source (e. g. , journal name) and accession number. These files provide for checks against duplication as well as cumulative bibliography and information concerning the most valuable or recurrent sources of data.

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Materials:

___ Arc Resistance	___ Irradiation Effects
___ Corona Effects	___ Loss Factor
___ Dielectric Constant	___ Power Factor
___ Dielectric Strength	___ Storage Factor
___ Dissipation Factor	___ Surface Resistivity
___ Insulation Resistance	___ Volume Resistivity

ABSTRACT:

AF33(616)-8438   Index - Abstract Form (Insulators)

GLA: 1326 900 02 24   Name_____ Hours_____ Date_____

FIGURE 9

INDEX-ABSTRACT FORM FOR INSULATING MATERIALS

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Materials:

___ Absorption	___ Lifetime
___ Cross-sections	___ Magnetic Susceptibility
___ Debye Temperature	___ Magnetoelectric Properties
___ Dielectric Constant	___ Mean Free Path
___ Diffusion	___ Mobility
___ Effective Mass	___ Photoelectronic Properties
___ Electrical Conductivity	___ Piezoelectric Properties
___ Electroacoustic Properties	___ Reflection
___ Emission	___ Refractive Index
___ Energy Bands	___ Resistivity
___ Energy Gap	___ Surface Properties
___ Energy Levels	___ Thermal Conductivity
___ Hall Coefficient	___ Thermoelectric Properties
___ Irradiation Effects	___ Thermomagnetic Properties
	___ Work Function

ABSTRACT:

AF33(616)-8438   Index - Abstract Form (Semiconductor Materials)

GLA: 1326 900 02 14   Name:_____ Hours:_____ Date:_____

FIGURE 10

INDEX-ABSTRACT FORM FOR SEMICONDUCTING MATERIALS

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D.   Indexing and Abstracting the Literature

Abstracting and indexing is done by subject specialists on standard forms for each material category (Figures 9 and 10). Both functions are performed at the same time by the same person. Upon receiving the reproduced copy, reprint, or otherwise expendable copy of the publication and the standard form bearing the bibliographic entry, the specialist determines the materials involved and enters their names in the block so labeled, checks the appropriate property headings, indicates the portions of the text to be excised and pasted-up with charts, tables and other data, provides an abstract text where needed, and provides an English translation of the abstract and other portions of the text if necessary. An example of a completed abstract form is given as Figure 11.

Each specialist is provided with the lists of material and property names and glossary shown here as Appendixes I, II, III and IV, and a Guide for Abstractors exhibited here as Figure 12. When the subject specialist has completed the index-abstract form, the abstract is typed and appropriate text pasted-up in the standard format adopted for the Accession cards. These layouts are then reproduced on 8 x 10" cards, forming the Accessions File of the index. The indicated indexing is coded onto the code cards shown in Figures 4 and 5, providing the input for data processing.

1.   Foreign Language Problems

The project is currently staffed to routinely provide translations of author abstracts in the major European tongues or an English summary of the content. Other languages offer special problems. For example, there is every indication that Chinese work in solid state physics is becoming progressively more important and voluminous. There are not many individuals available who can deal with the specialized vocabulary required. At present the translations available through CIA, DOD and other sources do not cover many of the publications being produced. Similar difficulties to a lesser degree exist with respect to Czech, Hungarian, Roumanian, Japanese and several other languages. Evaluation of the literature and data require complete translations where an abstract or short summary is insufficient. It is estimated that at least half of the literature in the "minor" languages will require complete translations if the data is to be properly evaluated.

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2520 OSWALD, F. Uber die optischen Eigenschaften von Indiumphosphid im Infraroten. [On the Optical Properties of Indium Phosphide in the Infrared] Zeitschrift für Naturforschung, vol. 9 a, no. 2, p. 181, February 1954.

Materials: Indium Phosphide

✓ Absorption	___ Lifetime
___ Cross-sections	___ Magnetic Susceptibility
___ Debye Temperature	___ Magnoelectric Properties
___ Dielectric Constant	___ Mean Free Path
___ Diffusion	___ Mobility
___ Effective Mass	___ Photoelectronic Properties
✓ Electrical Conductivity	___ Piezoelectric Properties
___ Electroacoustic Properties	✓ Reflection
___ Emission	✓ Refractive Index
✓ Energy Bands	___ Resistivity
___ Energy Gap	___ Surface Properties
___ Energy Levels	___ Thermal Conductivity
___ Hall Coefficient	___ Thermoelectric Properties
___ Irradiation Effects	___ Thermomagnetic Properties
	___ Work Function

ABSTRACT:

Studies were made on a n-conducting sample obtained by fusion of the components. Specific resistivity was $0.1 \, \Omega$ cm.

The determination of the reflecting power and the permeability was made on particles of 0.3 mm and 1.0 mm thickness with the help of an infrared spectrometer in the wave length region of 0.8 to 15.2 mu. Figure 1 shows the progress of the determined absorption constants and the refractive index. A sharp absorption constant is seen at lambda = 1.0 mu, which corresponds to a width of the forbidden zone of 1.25 eV. This value is higher than the corresponding value for silicon (1.14 eV) and germanium (0.73). After longer waves, the absorption constant decreases to amounts less than $0.2 \, cm^{-1}$, so that the permeability of the samples, similarly to that of germanium, is determined practically through the reflection loss on the surfaces. These reflection losses at an average refractive index of $n \approx 3$ amount to about 25% per surface and are, therefore, lower than for germanium, whose reflection is 36%. For wave lengths over 14.5 mu, indium phosphide shows a noticeable absorption, whereby it cannot yet be decided whether this is caused by a defect point level with $\Delta E \approx 0.08$ eV, or by the lattice movements of the indium phosphide.

Fig. 1 Optical constants of indium phosphide n-conducting sample. $\rho = 0.1 \, \Omega$ cm Wavelength, absorption K, refractive index, photon energy.

AF33(616)-8438   Index - Abstract Form (Semiconductor Materials)

GLA: 1326 900 02 14 Name: F. Neuberger   Hours: 0.5 Date: 3/24/62

FIGURE 11 SAMPLE ABSTRACT

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GUIDE FOR ABSTRACTORS

(1)   Each piece of literature supplied for abstracting is accompanied by an Index-Abstract form which contains the bibliographic entry, a list of property names, a space for beginning the text of the abstract, the GLA code to which time spent is to be charged, and spaces for name of abstractor, hours spent (to nearest 1/10th of an hour) and date.

(2)   The abstractor will enter the names of the materials covered in the literature, check the relevant property names, and provide a legible text sufficiently explicit and detailed for comparison and evaluation of the data given with like data from other literature.

(3)   In order to provide a uniform input and facilitate future evaluation it is suggested that abstract texts be divided into three general topics:
(a)   Materials and Sample Preparation,
(b)   Apparatus and Method,
(c)   Individual Properties.

The Materials and Sample Preparation section contains detailed information on the specific materials tested or evaluated or indicates the lack of same.   Include any information which will clarify the graphs and tables.

The Apparatus and Methods section contains a description of the names and types of apparatus used in performing the tests.   Again, lack of specification should be noted.

The Individual Properties section cites the tables, charts and graphs and provides statements useful for future comparison and evaluation.

(4)   The charts and tables cited in the abstract should be indicated with arrows in the margins of the literature text.   Equations which, like the graphs and tables, may be cut out and pasted up, may be cited in the abstract text by a circled number (e. g. ④ , and in the body of the literature by the same circled number with an arrow (⟶) in the margin.   This will obviate copying out such information.

(5)   Articles which are found to contain no data or reviews of data useful for the purposes of the project may be rejected.   In such cases write, "No useful information" after the word ABSTRACT: on the Index - Abstract form.

FIGURE 12

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2. Index Vocabulary Problems

The need for more exact definitions of indexing terms to delineate their range and inclusiveness has been apparent from the beginning of the program and has led to the development of the glossary and cross-reference lists exhibited here as Appendixes I through IV. The clear delineation of terms provides an opportunity to review the present scheme, provides a reference framework within which both indexing and retrieval may be accomplished and reduces the range of ambiguity to which both are subject.

For indexing purposes, three of the most important aspects of an indexing term to be considered are definition, level of specificity, and cross-references. As an example, let us examine the terms EMISSION and IRRADIATION EFFECTS now being used in connection with semiconductor indexing. EMISSION includes as a see also, Irradiation Effects, while IRRADIATION EFFECTS, in turn, includes EMISSION and RADIATION EFFECTS as a see also reference. Should the term IRRADIATION EFFECTS include the effects of alpha, beta, and gamma radiation, x-rays, electromagnet radiation of various wavelengths, etc? Should these effects include those of energy exchange, particle or photon absorption, scattering, or emission? If the result of electromagnetic radiation on a semiconductor surface is luminescence or photoemission, should this be indexed under EMISSION or IRRADIATION EFFECTS as well as PHOTOELECTRONIC PROPERTIES?

The Atomic Energy Commission in its Nuclear Science Abstracts uses the term RADIATION EFFECTS for indexing the action on materials of a broad spectrum of radiation, including alpha, beta, and gamma radiations. Electromagnetic radiations are divided into several areas: ELECTROMAGNETIC WAVES is used for the radio frequency part of the spectrum; visible light is covered in the term LIGHT: other areas are covered by the terms INFRARED RADIATION, ULTRAVIOLET RADIATION, GAMMA RADIATION, and X RADIATION. The more general term RADIATION contains see also references to: ALPHA PARTICLES, BETA PARTICLES, ELECTROMAGNETIC WAVES, GAMMA RADIATION, INFRA-RED RADIATION, NUCLEAR PARTICLES, RADIO WAVES, THERMAL RADIATION, ULTRAVIOLET RADIATION, and X RADIATION. Surprisingly enough, CHERENKOV RADIATION is not included. The effects of radiation of various kinds are covered by three headings: RADIATION DAMAGE, RADIATION INJURIES, and RADIATION EFFECTS. For work in solid state physics it might be well to differentiate among the various processes involved and to define and delineate the coverage of each subject heading or indexing term used.

Another group of indexing terms of interest as examples of the sort of difficulties encountered in indexing materials are the classes of alloys, systems, compounds, etc. In general, alloys are solid solutions of materials mutually soluble in each other and are named, for indexing purposes, in alphabetical order of the constituents:

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BISMUTH-RHODIUM ALLOYS

or

BISMUTH-SILVER-TIN ALLOYS

In an analogous manner, non-metals, or materials some of whose components are non-metals, or whose components are not mutually soluble, are termed "systems", and are designated as:

BISMUTH-GERMANIUM-TELLURIUM SYSTEMS

BISMUTH-THORIUM CARBIDE SYSTEMS

BISMUTH-TELLURIUM SYSTEMS

It is obvious, of course, that a major problem is the determination of which is a "system" and which is an "alloy". In the designation of chemical compounds, the terminology is simpler for most substances. A good number of substances of interest in thermoelectric work, for example, seem to be borderline materials: alloys, systems, or compounds.

BISMUTH TELLURIDES

BISMUTH BROMIDES

It is customary to designate a class of things in the plural, as shown above, Elements, however, are designated in the singular, BISMUTH, CARBON, etc. In the naming of plastics, ceramics, and similar materials, other and similar problems with regard to definition of indexing terms arise. In the course of this project these will continue to be carefully examined, defined, and delineated in order that the system will not be impaired by flawed indexing terms and concepts.

III. COMPILATION AND EVALUATION OF DATA

The compilation-evaluation of data is the most difficult and crucial part of the program. The value of the results depends upon the adequacy of the data as presented and upon the skill and knowledge of the subject specialists doing the work. Judgments must be made concerning the adequacy and comparative merits of experimental results. Most probable values must be sought and chosen.

A. Procedure

When a given material is chosen for data compilation, the index is used to retrieve all literature for that material. The bibliographies contained in that literature are checked to ensure that all relevant references are in hand. The assembled literature together with copies of the relevant Accession cards from the index are given to a subject specialist for compilation and evaluation.

1. Data Worksheet

The specialist assigned to a material is given data work sheets identifying the material and property and containing the bibliographic references to the literature giving data on the property. An example of the form is presented as Figure 13 The specialist indicates on the work sheets which data are to be used, provides evaluative statements and gives directions for the assembly of the data into data sheets.

2. Criteria of Evaluation

Evaluation is confined to primary source data except when only secondary citations are available. If equally valid data are available from more than one investigation, all are given. Data are rejected when judged questionable because of faulty or dubious measurements, unknown sample composition, or if more reliable data are available from another source. Selection of data is based upon that which is judged most representative, precise and reliable covering the widest range of variables. The addition of new data to a previously evaluated property requires a reappraisal of the reported values. Older data may be deleted if the new data is judged more accurate or representative.

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MATERIAL:					PROPERTY:	
HAC Acc. No.	Investigator	Date	Specimen Description	Temp. &/or Freq. Range	Data Evaluation	Directions

FIGURE 13

DATA WORK SHEET

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3.   Data Sheets

      The completed data work sheets are reviewed for accuracy and completeness for all properties of a given material and then are processed for data sheet layout.   Examples of data sheets for indium phosphide are presentedin Appendix V.   Appendix VI presents a standard list of symbols which is used for the semiconductor category.   The sheets are arranged in alphabetical order by property name.   Each set of sheets for a given material includes a list of references.   The references cite only those items of bibliography from which data has been taken for the sheets.   For example, of the 45 pieces of literature used in the compilation of indium phosphide, 20 are cited in the list of references supplied with the data sheets for that material.

IV. OPERATIONS SUMMARY

A. Documentation Accomplishments

The first year's work has involved the searching of more than 30,000 titles and abstracts, acquisition of more than 6,000 pieces of literature, abstracting of more than 4,000 titles and indexing of more than 3500 titles. It is estimated that the retrospective documentation of the semiconductor category is 60% complete and for the insulation materials category 50% complete.

B. Compilation - Evaluation Accomplishments

Compilation of data was completed for ten semiconductor materials and six insulation materials. Publication and dissemination of data sheets on these materials were initiated. Compilation work is in progress on an additional number of materials.

C. Operations Flow Chart

A detailed analysis of the major activities of this project is presented as Figure 14 in the form of an operations flow chart. Sufficient detail is provided to illustrate the division of labor and the assignment of tasks to the personnel of the project.
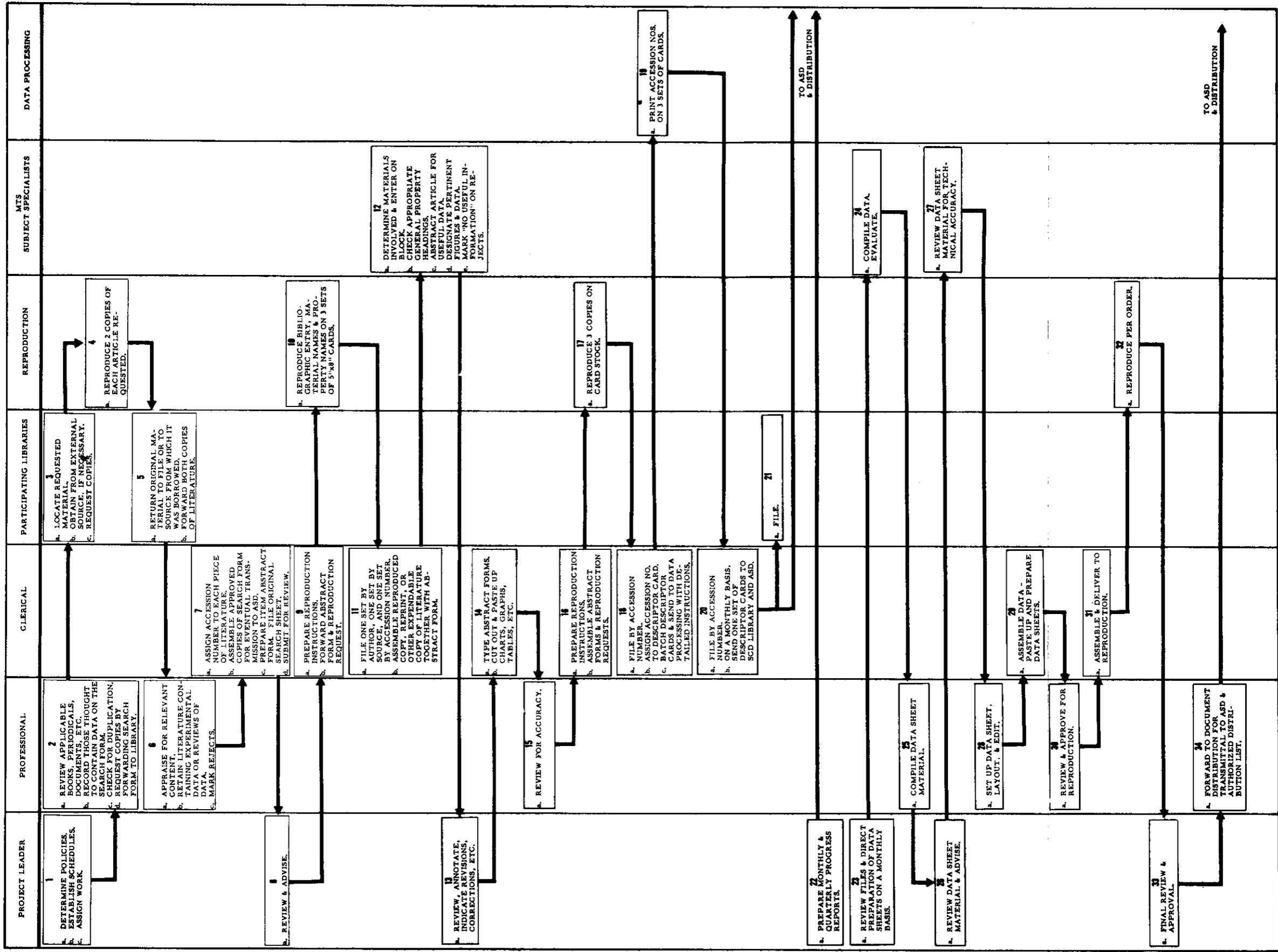
OPERATIONS FLOW CHART
CONTRACT AF 33(616)-8438

FIGURE 14

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V. CONCLUSIONS AND RECOMMENDATIONS

Experience with the systems and procedures so far developed for the program indicates that the documentation system is sound and that the same methods can be applied to other categories of materials. The specificity of the index descriptor system provides quick and sure retrieval. The provision of full extracts of the literature including the actual data saves much time in deciding whether a given piece of literature is of interest and often supplants the need to consult the original literature.

Development of the documentation system has involved a much greater study effort than was originally anticipated. A similar effort will be required when work is begun on new categories of materials. It is currently planned to initiate documentation on seven categories in September 1962. These include ferroelectric dielectrics, metals, ferrites, ferromagnetics, electroluminescent materials, thermionic emitters and superconductors. It is important that sufficient lead time be afforded for the elaboration of a viable system of material and property names together with cross-reference lists and other necessary auxiliary aids.

The search effort required for the acquisition of the six thousand pieces of literature now in the system is greater than was planned. On the other hand it is clear that the amount of literature containing useful data is smaller than was estimated. As the less remunerative sources are searched the investment of searching time per piece acquired rises. At present the proportion of pieces searched to pieces acquired is very close to six to one.

The publications program of the project is just beginning. Publication of data sheets, property tables, bibliographies, surveys of current research and reviews of subject areas will be made as soon as and as often as the information is cumulated through the documentation and compilation procedures. Publications issued will be considered as contributions to a series of handbooks covering the diverse categories. The value of the data sheets so far compiled cannot be estimated at this time. It is reasonable to expect changes in format and content as the reactions of recipients of the sheets are evaluated.

APPENDIX I
PROPERTIES OF SEMICONDUCTING MATERIALS

ABSORPTION
    Including: Absorption Coefficient
                     Absorption Edge
                     Absorption Spectrum
                     Beta-Particle Counting
                     Exciton Levels
                     Infrared Absorption
                     Optical Absorption
                     Optical Transmission
                     Spectral Absorption

CROSS SECTIONS
    Including: Collision Cross Section
                     Equivalent Cross Section
                     Impurity Cross Section
                     Recombination Cross Section
                     Scattering Cross Section

DEBYE TEMPERATURE

DIELECTRIC CONSTANT (PERMITTIVITY)
    Including: Dielectric Relaxation Time
                     Electric Susceptibility
                     Polarization

DIFFUSION
    Including: Diffusion Coefficient
                     Diffusion Length

EFFECTIVE MASS
    Including: Cyclotron Resonance
                     Minority Carrier Effective Mass
                     Voigt Effect

ELECTRICAL CONDUCTIVITY
    Including: Activation Energy
                     Intrinsic Conductivity
    See also::   Resistivity

ELECTROACOUSTIC PROPERTIES
    Including: Acoustic Properties
                     Acoustoelectric Effect
                     Phonon Drag
                     Phonon Energy Levels

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EMISSION

Including:	Electroluminescence
	Emission Spectra
	Field Emission
	Fluorescence
	Luminescence
	Phosphorescence
	Photoemission
	Photoluminescence
	Radiation Effects
	Recombination Emission
	Secondary Emission
	Thermionic Emission
See also:	Irradiation Effects

ENERGY BANDS

Including:	Band Structure

ENERGY GAP

Including:	Band Gap
	Forbidden Band Width
	Forbidden Energy Gap

ENERGY LEVELS

Including:	Field Effect
	Ionization Energy
	Nuclear Magnetic Resonance
	Zeeman Effect

HALL COEFFICIENT

Including:	Hall Constant
	Hall Effect
	Hall Voltage
	Leduc Effect
	Suhl Effect
See also:	Magnetoelectric Properties

IRRADIATION EFFECTS

See also:	Emission

LIFETIME

Including:	Generation-Recombination Noise
	Mean Free Time
	Minority Carrier Lifetime
	Recombination
	Recombination Centers
	Recombination Noise
	Recombination Spectra
	Relaxation Time

MAGNETIC SUSCEPTIBILITY (PERMEABILITY)
 Including: De Haas-Van Alphen Effect
     Paramagnetic Susceptibility

MAGNETOELECTRIC PROPERTIES
 Including: Acoustomagnetoelectric Effect
     Corbino Disk Measurement
     Ettinghausen Effect
     Galvanomagnetic Properties
     Magnetoresistance
 See also: Hall Coefficient

MEAN FREE PATH

MOBILITY
 Including: Dember Effect
     Drift Mobility
     Drift Velocity
     Electron Mobility
     Field Effect Mobility
     Hall Mobility
     Hole Mobility
     Impurity Mobility
     Intrinsic Mobility
     Transport of Carriers

PHOTOELECTRONIC PROPERTIES
 Including: Photoconductivity
     Photoelectromagnetic Effect
     Photomagnetoelectric Effect
     Photovoltaic Effect
     Spectral Response

PIEZOELECTRIC PROPERTIES
 Including: Piezoelectricity
     Piezoresistance

REFLECTION
 Including: Reflectivity

REFRACTIVE INDEX
 Including: Refraction

RESISTIVITY
 Including: Electric(al) Resistivity
     Extrinsic Resistivity
     Intrinsic Resistivity
     Temperature Coefficient of Resistivity
 See also: Electrical Conductivity

SURFACE PROPERTIES

THERMAL CONDUCTIVITY
      Including: Thermal Resistivity

THERMOELECTRIC PROPERTIES
      Including: Kelvin Effect
                 Peltier Coefficient
                 Seebeck Coefficient
                 Seebeck Effect
                 Seebeck Voltage
                 Thermoelectric Figure of Merit
                 Thermoelectric Power
                 Thomson Coefficient

THERMOMAGNETIC PROPERTIES
      Including: Nernst Effect
                 Nernst-Ettinghausen Effect
                 Righi-Leduc Effect

WORK FUNCTION
      Including: Contact Potential

CROSS-REFERENCES TO PROPERTIES OF SEMICONDUCTING MATERIALS

FROM:	REFER TO:
Absorption Coefficient	ABSORPTION
Absorption Edge	ABSORPTION
Absorption Spectrum	ABSORPTION
Acoustic Properties	ELECTROACOUSTIC PROPERTIES
Acoustoelectric Effect	ELECTROACOUSTIC PROPERTIES
Acoustomagnetoelectric Effect	MAGNETOELECTRIC PROPERTIES
Activation Energy	ELECTRICAL CONDUCTIVITY
Band Gap	ENERGY GAP
Band Structure	ENERGY BANDS
Beta-Particle Counting	ABSORPTION
Carrier Concentration	ELECTRICAL CONDUCTIVITY; MOBILITY
Carrier Properties	DIFFUSION; EFFECTIVE MASS; LIFETIME; MOBILITY; SURFACE PROPERTIES
Collision Cross Section	CROSS SECTIONS
Conductivity	ELECTRICAL CONDUCTIVITY; THERMAL CONDUCTIVITY
Contact Potential	WORK FUNCTION
Corbino Disk Measurement	MAGNETOELECTRIC PROPERTIES
Cyclotron Resonance	EFFECTIVE MASS
De Haas-Van Alphen Effect	MAGNETIC SUSCEPTIBILITY
Dember Effect	MOBILITY
Dielectric Properties	DIELECTRIC CONSTANT; PIEZO-ELECTRIC PROPERTIES
Dielectric Relaxation Time	DIELECTRIC CONSTANT
Diffusion Coefficient	DIFFUSION
Diffusion Length	DIFFUSION
Drift Mobility	MOBILITY
Drift Velocity	MOBILITY
Electric(al) Resistivity	RESISTIVITY
Electric Susceptibility	DIELECTRIC CONSTANT
Electroluminescence	EMISSION
Electron Mobility	MOBILITY
Emission Spectra	EMISSION
Equivalent Cross Section	CROSS SECTIONS
Ettinghausen Effect	MAGNETOELECTRIC PROPERTIES
Exciton Levels	ABSORPTION
Extrinsic Resistivity	RESISTIVITY

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FROM:	REFER TO:
Faraday Effect	EFFECTIVE MASS; ENERGY LEVELS
Faraday Rotation	ENERGY LEVELS
Field Effect	ENERGY LEVELS
Field Effect Mobility	MOBILITY
Field Emission	EMISSION
Figure of Merit	THERMOELECTRIC PROPERTIES
Fluorescence	EMISSION
Forbidden Band Width	ENERGY GAP
Forbidden Energy Gap	ENERGY GAP
Galvanomagnetic Properties	MAGNETOELECTRIC PROPERTIES
Generation-Recombination Noise	LIFETIME
Hall Constant	HALL COEFFICIENT
Hall Effect	HALL COEFFICIENT
Hall Mobility	MOBILITY
Hall Voltage	HALL COEFFICIENT
Hole Mobility	MOBILITY
Impurity Cross Section	CROSS SECTIONS
Impurity Mobility	MOBILITY
Infrared Absorption	ABSORPTION
Ionization Energy	ENERGY LEVELS
Intrinsic Conductivity	ELECTRICAL CONDUCTIVITY
Intrinsic Mobility	MOBILITY
Intrinsic Resistivity	RESISTIVITY
Ionization Energy	ENERGY LEVELS
Kelvin Effect	THERMOELECTRIC PROPERTIES
Leduc Effect	HALL COEFFICIENT
Luminescence	EMISSION
Magnetic Properties	MAGNETIC SUSCEPTIBILITY; MAGNETOELECTRIC PROPERTIES
Magnetic Resonance	EFFECTIVE MASS; MAGNETO-ELECTRIC PROPERTIES
Magnetoabsorption	EFFECTIVE MASS
Magnetoresistance	MAGNETOELECTRIC PROPERTIES
Mean Free Time	LIFETIME
Minority Carrier Effective Mass	EFFECTIVE MASS
Minority Carrier Lifetime	LIFETIME

FROM:	REFER TO:
Nernst Effect	THERMOMAGNETIC PROPERTIES
Nernst-Ettinghausen Effect	THERMOMAGNETIC PROPERTIES
Nuclear Magnetic Resonance	ENERGY LEVELS
Optical Absorption	ABSORPTION
Optical Properties	ABSORPTION; EMISSION; PHOTO-ELECTRONIC PROPERTIES; RE-FLECTION; REFRACTIVE INDEX
Optical Transmission	ABSORPTION
Paramagnetic Susceptibility.	MAGNETIC SUSCEPTIBILITY
Peltier Coefficient	THERMOELECTRIC PROPERTIES
Permeability	MAGNETIC SUSCEPTIBILITY
Permittivity	DIELECTRIC CONSTANT
Phonon Drag	ELECTROACOUSTIC PROPERTIES
Phonon Energy Levels	ELECTROACOUSTIC PROPERTIES
Phosphorescence	EMISSION
Photoconductivity	PHOTOELECTRONIC PROPERTIES
Photoelectromagnetic Effect	PHOTOELECTRONIC PROPERTIES
Photoemission	EMISSION
Photoluminescence	EMISSION
Photomagnetoelectric Effect	PHOTOELECTRONIC PROPERTIES
Photovoltaic Effect	PHOTOELECTRONIC PROPERTIES
Piezoelectricity	PIEZOELECTRIC PROPERTIES
Piezoresistance	PIEZORESISTANCE
Polarization	DIELECTRIC CONSTANT
Radiation Effects	EMISSION
Recombination	LIFETIME
Recombination Centers	LIFETIME
Recombination Cross Section	CROSS SECTIONS
Recombination Emission	EMISSION
Recombination Noise	LIFETIME
Recombination Spectra	LIFETIME
Reflectivity	REFLECTION
Refraction	REFRACTIVE INDEX
Relaxation Time	LIFETIME
Righi-Leduc Effect	THERMOELECTRIC PROPERTIES
Scattering Cross Section	CROSS SECTIONS
Secondary Emission	EMISSION
Seebeck Coefficient	THERMOELECTRIC PROPERTIES
Seebeck Effect	THERMOELECTRIC PROPERTIES
Seebeck Voltage	THERMOELECTRIC PROPERTIES

FROM:	REFER TO:
Spectral Absorption	ABSORPTION
Spectral Response	PHOTOELECTRONIC PROPERTIES
Suhl Effect	HALL COEFFICIENT
Surface Conductivity	SURFACE PROPERTIES
Surface Recombination Velocity	SURFACE PROPERTIES
Susceptibility	DIELECTRIC CONSTANT; MAGNETIC SUSCEPTIBILITY
Temperature Coefficient of Resistivity	RESISTIVITY
Thermal Properties	DEBYE TEMPERATURE; THERMAL CONDUCTIVITY; THERMOELECTRIC PROPERTIES; THERMOMAGNETIC PROPERTIES
Thermal Resistivity	THERMAL CONDUCTIVITY
Thermionic Emission	EMISSION
Thermoelectric Figure of Merit	THERMOELECTRIC PROPERTIES
Thermoelectric Power	THERMOELECTRIC PROPERTIES
Transport of Carriers	MOBILITY
Thomson Coefficient	THERMOELECTRIC PROPERTIES
Voigt Effect	EFFECTIVE MASS
Zeeman Effect	ENERGY LEVELS

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APPENDIX II
PROPERTIES OF INSULATING MATERIALS

ARC RESISTANCE
CORONA EFFECTS
DIELECTRIC CONSTANT
DIELECTRIC STRENGTH
DISSIPATION FACTOR
INSULATION RESISTANCE
IRRADIATION EFFECTS
LOSS FACTOR
STORAGE FACTOR
SURFACE RESISTIVITY
VOLUME RESISTIVITY

CROSS REFERENCES

Absolute Dielectric Constant
  Indexed under DIELECTRIC CONSTANT

Absorption
  Indexed under DISSIPATION FACTOR

ARC RESISTANCE

Arc-Resistance Breakdown Voltage
  Indexed under ARC RESISTANCE

Arc-Resistance Time
  Indexed under ARC RESISTANCE

Breakdown Resistance
  Indexed under DIELECTRIC STRENGTH

Breakdown Voltage
  Indexed under ARC RESISTANCE or DIELECTRIC STRENGTH

Complex Dielectric Constant
  Indexed under DIELECTRIC CONSTANT

Conductivity
  Indexed under VOLUME RESISTIVITY

Corona Discharge
  Indexed under CORONA EFFECTS

CORONA EFFECTS

Corona Point Voltage
  Indexed under CORONA EFFECTS

Corona Resistance
     Indexed under CORONA EFFECTS

Cotangent θ
     Indexed under DISSIPATION FACTOR

Degradation Effects of Corona
     Indexed under CORONA EFFECTS

Dielectric Breakdown Voltage
     Indexed under DIELECTRIC STRENGTH

DIELECTRIC CONSTANT

Dielectric Loss Angle
     Indexed under DISSIPATION FACTOR

Dielectric Loss Factor
     Indexed under LOSS FACTOR

Dielectric Loss Tangent
     Indexed under DISSIPATION FACTOR

DIELECTRIC STRENGTH

DISSIPATION FACTOR

Electrical Conductivity
     Indexed under VOLUME RESISTIVITY

Electric (al) Resistance
     Indexed under INSULATION RESISTANCE

Electric (al) Resistivity
     Indexed under SURFACE RESISTIVITY or VOLUME RESISTIVITY

Electric Strength
     Indexed under DIELECTRIC STRENGTH

High-Voltage, Low-Current Arc Resistance
     Indexed under ARC RESISTANCE

Imaginary Dielectric Constant
     Indexed under LOSS FACTOR

INSULATION RESISTANCE

IRRADIATION EFFECTS

Loss Angle
     Indexed under DISSIPATION FACTOR

LOSS FACTOR

Loss Tangent
     Indexed under DISSIPATION FACTOR

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Permittivity
> Indexed under DIELECTRIC CONSTANT

Phase Angle
> Indexed under DISSIPATION FACTOR

Phase Defect Angle
> Indexed under DISSIPATION FACTOR

POWER FACTOR

Quality Factor
> Indexed under STORAGE FACTOR

Radiation Effects
> Indexed under IRRADIATION EFFECTS

Radiation Resistance
> Indexed under IRRADIATION EFFECTS

Relative Capacitance
> Indexed under DIELECTRIC CONSTANT

Relative Dielectric Constant
> Indexed under DIELECTRIC CONSTANT

Relative Permittivity
> Indexed under DIELECTRIC CONSTANT

Resistivity
> Indexed under SURFACE RESISTIVITY or VOLUME RESISTIVITY

Specific Capacity
> Indexed under DIELECTRIC CONSTANT

Specific (Inductive) Capacity
> Indexed under DIELECTRIC CONSTANT

Specific Resistivity
> Indexed under VOLUME RESISTIVITY

STORAGE FACTOR

Surface Arc Resistance
> Indexed under ARC RESISTANCE

Surface Breakdown Voltage Ratio
> Indexed under ARC RESISTANCE

Surface Resistance
> Indexed under SURFACE RESISTIVITY

SURFACE RESISTIVITY

Tangent δ
> Indexed under DISSIPATION FACTOR

Temperature Resistance
>   Indexed under INSULATION RESISTANCE

Tracking
>   Indexed under ARC RESISTANCE

Voltage Breakdown
>   Indexed under DIELECTRIC STRENGTH

Volume Resistance
>   Indexed under VOLUME RESISTIVITY

VOLUME RESISTIVITY

APPENDIX III
SEMICONDUCTOR MATERIALS NAMES

As is true with some other classes of materials, the semiconductors comprise an array of elements, compounds, mixtures, and systems that include many of the elements of the periodic table. In indexing these materials it is important to be able to correctly name the specific material at hand. A material composed of aluminum, copper, and sulfur may be a true compound, an aluminum copper sulfide, a mixture of aluminum sulfide and copper sulfide, or a three-element system whose phase diagram will indicate certain areas within which specific compounds exist. The naming system should be able to distinguish these differences.

In assigning the descriptor names, a system has been used in which the order of the elements in the name follows their order in the periodic table: the metallic or more "electropositive" elements first, followed by the other elements in the order of increasing number of valance electrons. This order of the elements follows standard and accepted chemical nomenclature.

For a binary compound the descriptor "bismuth selenide" would be used rather than "selenium bismuthide" as bismuth is in Group V and selenium is in Group VI. It should be noted also that the descriptor name is not always identical with the chemical name in a strict sense. Thus, "copper sulfide" includes both cupric and cuprous sulfide. For materials which are identified as ternary or quaternary compounds, the same method of naming and ordering of the constituent elements is followed: $CuGaSe_2$ — copper gallium selenide, and $CuPbAsS_2$ — copper lead arsenic sulfide. Since, as mentioned above, the descriptor name is not uniquely the chemical name, the descriptor "copper antimony sulfide" would include compounds such as $CuSbS_2$, Cu_3SbS_4, and others. Thus, the descriptors do not define unique compounds, but rather similar compounds based on the same elements.

Many materials which contain two elements are binary alloys. Some of these alloys are said to be intermetallic compounds since the atoms occur in stoichiometric ratios. If the two metals between them contribute just sufficient electrons to fill the valence band, e.g., InAs, the compound may be made semiconducting. For systems such as this, the choice of correct descriptor name requires some care. For example, the system Ce-Te (cerium-tellurium) forms an intermetallic compound, CeTe, at 47.66 wt.% tellurium. If excess tellurium is used in its preparation, the excess is voltatilized; but, if excess cerium is used, a solution of cesium in CeTe will result. For the stoichiometric compound CeTe the descriptor name would be CESIUM TELLURIDE; for other compositions the descriptor name CESIUM TELLURIUM SYSTEMS would be used. In a similar manner,

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CESIUM ARUIDE would be used correctly only for the compounds $CeAu_3$, $CeAu_2$, CeAu, and Ce_2Au. Other compositions would be designated CESIUM GOLD SYSTEMS. Therefore, the terms SYSTEMS is used here as broadly encompassing alloys and solid solutions. A technical paper devoted to a complete study of germanium and silicon systems would necessarily include the descriptors GERMANIUM and SILICON as well as GERMANIUM SILICON SYSTEMS because at one end of the phase diagram there would be 100 percent germanium and at the other end, 100 percent silicon. The same would be true in a study of copper sulfur zinc systems. This would include the descriptors COPPER SULFIDE and ZINC SULFIDE as well as COPPER ZINC SULFIDE and COPPER SULFUR ZINC SYSTEMS. It should be noted that when the term SYSTEMS is used, the various elements comprising it are in alphabetical order by element (not alphabetical by either symbol or valence group). In assigning descriptors to systems in the past the suffix "-X" has been used. The following list uses the word SYSTEMS instead. For systems consisting of two binary compounds such as $Bi_2Te_3 - Ag_2S$, a descriptor such as BISMUTH TELLURIDE — SILVER SULFIDE SYSTEMS is used This method for naming systems is considered to be more compatible with the methods used for other material categories.

The following list includes some materials not usually thought of as semiconductors. They are included because under certain physical conditions they exhibit semiconductor properties. For example, the alkali halides, while not used commercially as insulators, have insulating properties. However, under ultraviolet irradiation they become semiconductors. Similarly, barium titanate, a ferro-electric dielectric and ceramic, exhibits semiconductor properties when doped with lanthanum.

Doping may be said to consist of the introduction of an impurity in a definite and controlled amount. For semiconductors, this impurity level is very minute. It is never large enough to be considered as a constituent of a compound or system. For this reason, the doping agent is not identified in the descriptor naming system.

SEMICONDUCTOR MATERIALS NAMES

SEMICONDUCTOR MATERIALS

ALUMINUM ANTIMONIDE

ALUMINUM ARSENIDE

ALUMINUM BISMUTHIDE

ALUMINUM BORIDE

Aluminum Copper Selenium Systems
    See COPPER ALUMINUM SELENIUM SYSTEMS

Aluminum Copper Tellurium Systems
    See COPPER ALUMINUM TELLURIUM SYSTEMS

ALUMINUM GALLIUM ANTIMONIDE

ALUMINUM OXIDE

ALUMINUM PHOSPHIDE

ALUMINUM SELENIDE

Aluminum Selenium Silver Systems
    See SILVER ALUMINUM SELENIUM SYSTEMS

Aluminum Silver Selenium Systems
    See SILVER ALUMINUM SELENIUM SYSTEMS

Aluminum Silver Tellurium Systems
    See SILVER ALUMINUM TELLURIUM SYSTEMS

ALUMINUM SULFIDE

Aluminum Sulfide — Copper Sulfide Systems
    See COPPER SULFIDE — ALUMINUM SULFIDE SYSTEMS

ALUMINUM TELLURIDE

ANTIMONY

ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Antimony Bismuth Telluride
    See BISMUTH ANTIMONY TELLURIDE

ANTIMONY BISMUTH TELLURIUM SYSTEMS

Antimony Copper Selenide
    See COPPER ANTIMONY SELENIDE

Antimony Copper Sulfide
    See COPPER ANTIMONY SULFIDE

Antimony Copper Telluride
    See COPPER ANTIMONY TELLURIDE

ANTIMONY IODIDE

Antimony Lead Silver Tellurium Systems
    See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

ANTIMONY SELENIDE

Antimony Silver Selenide
    See SILVER ANTIMONY SELENIDE

Antimony Silver Sulfide
    See SILVER ANTIMONY SULFIDE

Antimony Silver Telluride
    See SILVER ANTIMONY TELLURIDE

ANTIMONY SULFIDE

ANTIMONY TELLURIDE

Antimony Telluride — Bismuth Telluride Systems
    See BISMUTH TELLURIDE — ANTIMONY TELLURIDE SYSTEMS

Arsenic Copper Sulfide
    See COPPER ARSENIC SULFIDE

Arsenic Copper Lead Sulfur Systems
    See COPPER LEAD ARSENIC SULFUR SYSTEMS

Arsenic Gallium Indium Systems
    See GALLIUM INDIUM ARSENIC SYSTEMS

Arsenic Gallium Phosphide
    See GALLIUM ARSENIC PHOSPHIDE

Arsenic Indium Phosphide
    See INDIUM ARSENIC PHOSPHIDE

ARSENIC PHOSPHIDE

ARSENIC SELENIDE

ARSENIC SELENIUM TELLURIUM SYSTEMS

Arsenic Silver Selenide
    See SILVER ARSENIC SELENIDE

Arsenic Silver Telluride
    See SILVER ARSENIC TELLURIDE

ARSENIC SULFIDE

ARSENIC TELLURIDE

BARIUM OXIDE

BARIUM OXIDE – STRONTIUM OXIDE SYSTEMS

BARIUM SELENIDE

BARIUM SULFIDE

BARIUM TELLURIDE

BARIUM TITANATE

BARIUM TITANATE – STRONTIUM TITANATE SYSTEMS

BISMUTH

BISMUTH ANTIMONIDE

Bismuth Antimony Selenium Tellurium Systems
    See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

BISMUTH ANTIMONY TELLURIDE

Bismuth Antimony Tellurium Systems
    See ANTIMONY BISMUTH TELLURIUM SYSTEMS

Bismuth Copper Telluride
    See COPPER BISMUTH TELLURIDE

Bismuth Copper Selenide
    See COPPER BISMUTH SELENIDE

BISMUTH IODIDE

Bismuth Lead Selenide
    See LEAD BISMUTH SELENIDE

Bismuth Lead Telluride
    See LEAD BISMUTH TELLURIDE

BISMUTH SELENIDE

BISMUTH SELENIDE — TELLURIUM SELENIDE SYSTEMS

BISMUTH SELENIUM TELLURIUM SYSTEMS

Bismuth Silver Selenide
    See SILVER BISMUTH SELENIDE

Bismuth Silver Telluride
    See SILVER BISMUTH TELLURIDE

BISMUTH SULFIDE

BISMUTH SULFUR TELLURIUM SYSTEMS

BISMUTH TELLURIDE

BISMUTH TELLURIDE — ANTIMONY TELLURIDE SYSTEMS

BISMUTH TELLURIUM SELENIDE

Bismuth Tin Selenide
    See TIN BISMUTH SELENIDE

Bismuth Tin Systems
    See TIN BISMUTH SYSTEMS

Bismuth Tin Telluride
    See TIN BISMUTH TELLURIDE

BISMUTH TRIOXIDE

BORON

BORON NITRIDE

BORON PHOSPHIDE

CADMIUM ANTIMONIDE

CADMIUM ARSENIDE

Cadmium Copper Selenium Systems
See COPPER CADMIUM SELENIUM SYSTEMS

CADMIUM IODIDE

CADMIUM MAGNESIUM ALLOYS

CADMIUM MERCURY TELLURIUM SYSTEMS

CADMIUM OXIDE

CADMIUM PHOSPHIDE

CADMIUM SELENIDE

CADMIUM SELENIUM SULFIDE

CADMIUM SULFIDE – SELENIUM SULFIDE SYSTEMS

CADMIUM STANNIDE

CADMIUM SULFIDE

CADMIUM TELLURIDE

CADMIUM TIN ARSENIDE

CADMIUM ZINC SULFIDE

CADMIUM SULFIDE – ZINC SULFIDE SYSTEMS

CALCIUM OXIDE

CALCIUM SILICIDE

CALCIUM STANNIDE

CALCIUM SULFIDE

CALCIUM TITANATE

CALCIUM TUNGSTATE

CARBON, DIAMOND

CARBON, GRAPHITE

CESIUM ANTIMONIDE

CESIUM AURIDE

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CESIUM BISMUTHIDE

CESIUM BROMIDE

CESIUM CHLORIDE

CESIUM IODIDE

Cesium Silver Oxide
      See SILVER CESIUM OXIDE

CESIUM SULFIDE

CESIUM TELLURIDE

Chromium Oxygen Zinc Systems
      See ZINC CHROMIUM OXYGEN SYSTEMS

CHROMIUM SILICIDE

CHROMIUM SULFIDE

COBALT ANTIMONIDE

Cobalt Lithium Oxygen Systems
      See LITHIUM OXYGEN COBALT SYSTEMS

COBALT OXIDE

COBALT SILICIDE

COPPER ALUMINUM SELENIUM SYSTEMS

COPPER ALUMINUM TELLURIUM SYSTEMS

COPPER ANTIMONIDE

COPPER ANTIMONY SELENIDE

COPPER ANTIMONY SULFIDE

COPPER ANTIMONY TELLURIDE

COPPER ARSENIC SULFIDE

Copper Arsenic Lead Sulfur Systems
      See COPPER LEAD ARSENIC SULFUR SYSTEMS

COPPER BISMUTH SELENIDE

COPPER BISMUTH TELLURIDE

COPPER BROMIDE

COPPER CADMIUM SELENIUM SYSTEMS

COPPER GALLIUM SELENIDE

COPPER GALLIUM SULFIDE

COPPER GALLIUM TELLURIDE

COPPER GERMANIUM SELENIDE

COPPER GERMANIUM SULFIDE

COPPER GERMANIUM TELLURIDE

COPPER INDIUM SELENIDE

Copper Indium Silver Tellurium Systems
    See COPPER SILVER INDIUM TELLURIUM SYSTEMS

COPPER INDIUM SULFIDE

COPPER INDIUM TELLURIDE

COPPER IRON SELENIDE

COPPER IRON SULFIDE

COPPER IRON TELLURIDE

COPPER LEAD ARSENIC SULFUR SYSTEMS

COPPER LITHIUM OXYGEN SYSTEMS

COPPER OXIDE

Copper Oxygen Lithium Systems
    See COPPER LITHIUM OXYGEN SYSTEMS

COPPER PHOSPHIDE

Copper Selenium Cadmium Systems
    See COPPER CADMIUM SELENIUM SYSTEMS

COPPER SILICIDE

COPPER SILICON TELLURIDE

COPPER SILVER INDIUM TELLURIUM SYSTEMS

COPPER SILVER TELLURIDE

COPPER SULFIDE

COPPER SULFIDE — ALUMINUM SULFIDE SYSTEMS

COPPER TELLURIDE

COPPER TELLURIUM SELENIDE

COPPER TIN ALLOYS

COPPER TIN SELENIDE

COPPER TIN SULFIDE

COPPER TIN TELLURIDE

Diamond
    See CARBON, DIAMOND

ERBIUM SELENIDE

ERBIUM TELLURIDE

GADOLINIUM TELLURIDE

Gallium Aluminum Antimonide
    See ALUMINUM GALLIUM ANTIMONIDE

GALLIUM ANTIMONIDE

GALLIUM ARSENIC INDIUM SYSTEMS

GALLIUM ARSENIC PHOSPHIDE

GALLIUM ARSENIDE

GALLIUM BISMUTHIDE

Gallium Copper Selenide
    See COPPER GALLIUM SELENIDE

Gallium Copper Sulfide
    See COPPER GALLIUM SULFIDE

Gallium Copper Telluride
> See COPPER GALLIUM TELLURIDE

GALLIUM INDIUM ANTIMONIDE

GALLIUM INDIUM ARSENIC SYSTEMS

GALLIUM IRON OXIDE

GALLIUM PHOSPHIDE

GALLIUM SELENIDE

Gallium Silver Selenide
> See SILVER GALLIUM SELENIDE

Gallium Silver Telluride
> See SILVER GALLIUM TELLURIDE

GALLIUM SULFIDE

GALLIUM TELLURIDE

GERMANIUM COPPER SELENIDE

GERMANIUM COPPER SULFIDE

GERMANIUM COPPER TELLURIDE

GERMANIUM OXIDE

GERMANIUM SELENIDE

GERMANIUM SILICON ALLOYS

GERMANIUM STANNIDE

GERMANIUM SULFIDE

GERMANIUM TELLURIDE

Germanium Zinc Arsenide
> See ZINC GERMANIUM ARSENIDE

Graphite
> See CARBON, GRAPHITE

Gray Tin
> See TIN, GRAY

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INDIUM ANTIMONIDE

Indium Arsenic Gallium Systems
    See GALLIUM INDIUM ARSENIC SYSTEMS

INDIUM ARSENIC PHOSPHIDE

INDIUM ARSENIDE

INDIUM BISMUTHIDE

Indium Copper Selenide
    See COPPER INDIUM SELENIDE

Indium Copper Silver Tellurium Systems
    See COPPER SILVER INDIUM TELLURIUM SYSTEMS

Indium Copper Sulfide
    See COPPER INDIUM SULFIDE

Indium Copper Telluride
    See COPPER INDIUM TELLURIDE

Indium Gallium Antimonide
    See GALLIUM INDIUM ANTIMONIDE

Indium Gallium Arsenic Systems
    See GALLIUM INDIUM ARSENIC SYSTEMS

Indium Mercury Selenide
    See MERCURY INDIUM SELENIDE

Indium Mercury Telluride
    See MERCURY INDIUM TELLURIDE

INDIUM OXIDE

INDIUM PHOSPHIDE

INDIUM SELENIDE

Indium Selenium Zinc Systems
    See ZINC INDIUM SELENIUM SYSTEMS

Indium Silver Copper Tellurium Systems
    See COPPER SILVER INDIUM TELLURIUM SYSTEMS

Indium Silver Selenide
    See SILVER INDIUM SELENIDE

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Indium Silver Sulfide
    See SILVER INDIUM SULFIDE

Indium Silver Telluride
    See SILVER INDIUM TELLURIDE

INDIUM SULFIDE

INDIUM TELLURIDE

Indium Zinc Selenium Systems
    See ZINC INDIUM SELENIUM SYSTEMS

IODINE

Iron Copper Selenide
    See COPPER IRON SELENIDE

Iron Copper Sulfide
    See COPPER IRON SULFIDE

Iron Copper Telluride
    See COPPER IRON TELLURIDE

Iron Gallium Oxide
    See GALLIUM IRON OXIDE

IRON OXIDE

Iron Silver Selenide
    See SILVER IRON SELENIDE

Iron Silver Telluride
    See SILVER IRON TELLURIDE

IRON SULFIDE

IRON TELLURIDE

LANTHANUM CHLORIDE

LANTHANUM SELENIDE

LANTHANUM TELLURIDE

Lead Antimony Silver Tellurium Systems
    See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

Lead Arsenic Copper Sulfur Systems
    See COPPER LEAD ARSENIC SULFUR SYSTEMS

LEAD BISMUTH SELENIDE

LEAD BISMUTH TELLURIDE

Lead Copper Arsenic Sulfur Systems
    See COPPER LEAD ARSENIC SULFUR SYSTEMS

LEAD IODIDE

LEAD OXIDE

LEAD SELENIDE

LEAD SELENIUM TELLURIDE

Lead Silver Antimony Tellurium Systems
    See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

LEAD SULFIDE

LEAD TELLURIDE

LEAD TITANATE

LEAD ZIRCONATE

LITHIUM BISMUTHATE

LITHIUM COBALT OXYGEN SYSTEMS

Lithium Copper Oxygen Systems
    See COPPER LITHIUM OXYGEN SYSTEMS

LITHIUM MAGNESIUM ANTIMONIDE

LITHIUM MAGNESIUM BISMUTHIDE

LITHIUM MANGANESE OXYGEN SYSTEMS

LITHIUM MERCURY BISMUTHIDE

Lithium Nickel Oxide
    See LITHIUM NICKEL OXYGEN SYSTEMS

LITHIUM NICKEL OXYGEN SYSTEMS

Lithium Oxygen Cobalt Systems
    See LITHIUM COBALT OXYGEN SYSTEMS

Lithium Oxygen Copper Systems
  See COPPER LITHIUM OXYGEN SYSTEMS

Lithium Oxygen Manganese Systems
  See LITHIUM MANGANESE OXYGEN SYSTEMS

Lithium Oxygen Nickel Systems
  See LITHIUM NICKEL OXYGEN SYSTEMS

MAGNESIUM ANTIMONIDE

Magnesium Cadmium Alloys
  See CADMIUM MAGNESIUM ALLOYS

MAGNESIUM GERMANIDE

Magnesium Lithium Antimonide
  See LITHIUM MAGNESIUM ANTIMONIDE

Magnesium Lithium Bismuthide
  See LITHIUM MAGNESIUM BISMUTHIDE

MAGNESIUM OXIDE

MAGNESIUM PLUMBIDE

MAGNESIUM SELENIDE

MAGNESIUM SILICIDE

MAGNESIUM STANNIDE

MAGNESIUM TITANATE

MANGANESE ARSENIDE

Manganese Lithium Oxygen Systems
  See LITHIUM MANGANESE OXYGEN SYSTEMS

MANGANESE OXIDE

Manganese Oxygen Lithium Systems
  See LITHIUM MANGANESE OXYGEN SYSTEMS

MANGANESE SELENIDE

MANGANESE SILICIDE

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MANGANESE STANNIDE

MANGANESE SULFIDE

MANGANESE TELLURIDE

Mercury Cadmium Tellurium Systems
    See CADMIUM MERCURY TELLURIUM SYSTEMS

MERCURY INDIUM SELENIDE

MERCURY INDIUM TELLURIDE

MERCURY IODIDE

Mercury Lithium Bismuthide
    See LITHIUM MERCURY BISMUTHIDE

MERCURY OXIDE

MERCURY SELENIDE

MERCURY SELENIUM TELLURIUM SYSTEMS

MERCURY SULFIDE

MERCURY TELLURIDE

Mercury Tellurium Cadmium Systems
    See CADMIUM MERCURY TELLURIUM SYSTEMS

MOLYBDENUM SILICIDE

MOLYBDENUM SULFIDE

Nickel Lithium Oxide
    See LITHIUM NICKEL OXIDE

Nickel Lithium Oxygen Systems
    See LITHIUM NICKEL OXYGEN SYSTEMS

NICKEL OXIDE

Nickel Oxygen Lithium Systems
    See LITHIUM NICKEL OXYGEN SYSTEMS

NICKEL SILICIDE

NICKEL TELLURIDE

NIOBIUM OXIDE

Oxygen Chromium Zinc Systems
    See ZINC CHROMIUM OXYGEN SYSTEMS

Oxygen Cobalt Lithium Systems
    See LITHIUM COBALT OXYGEN SYSTEMS

Oxygen Copper Lithium Systems
    See COPPER LITHIUM OXYGEN SYSTEMS

Oxygen Lithium Cobalt Systems
    See LITHIUM COBALT OXYGEN SYSTEMS

Oxygen Lithium Copper Systems
    See COPPER LITHIUM OXYGEN SYSTEMS

Oxygen Lithium Manganese Systems
    See LITHIUM MANGANESE OXYGEN SYSTEMS

Oxygen Lithium Nickel Systems
    See LITHIUM NICKEL OXYGEN SYSTEMS

Oxygen Manganese Lithium Systems
    See LITHIUM MANGANESE OXYGEN SYSTEMS

Oxygen Zinc Chromium Systems
    See ZINC CHROMIUM OXYGEN SYSTEMS

PHOSPHORUS

PHOSPHORUS OXIDE

POTASSIUM ANTIMONIDE

POTASSIUM BROMIDE

POTASSIUM CHLORIDE

POTASSIUM IODIDE

POTASSIUM OXIDE

Potassium Sodium Antimonide
    See SODIUM POTASSIUM ANTIMONIDE

RUBIDIUM ANTIMONIDE

RUBIDIUM BISMUTHIDE

RUBIDIUM IODIDE

RUBIDIUM TELLURIDE

SELENIUM

Selenium Aluminum Copper Systems
      See COPPER ALUMINUM SELENIUM SYSTEMS

Selenium Antimony Bismuth Tellurium Systems
      See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Selenium Arsenic Tellurium Systems
      See ARSENIC SELENIUM TELLURIUM SYSTEMS

Selenium Bismuth Antimony Tellurium Systems
      See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Selenium Bismuth Tellurium Systems
      See BISMUTH SELENIUM TELLURIUM SYSTEMS

Selenium Cadmium Copper Systems
      See COPPER CADMIUM SELENIUM SYSTEMS

Selenium Cadmium Sulfide
      See CADMIUM SELENIUM SULFIDE

Selenium Copper Aluminum Systems
      See COPPER ALUMINUM SELENIUM SYSTEMS

Selenium Copper Cadmium Systems
      See COPPER CADMIUM SELENIUM SYSTEMS

Selenium Indium Zinc Systems
      See ZINC INDIUM SELENIUM SYSTEMS

Selenium Lead Telluride
      See LEAD SELENIUM TELLURIDE

Selenium Silver Sulfide
      See SILVER SELENIUM SULFIDE

Selenium Sulfide — Cadmium Sulfide Systems
      See CADMIUM SULFIDE — SELENIUM SULFIDE SYSTEMS

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Selenium Tellurium Alloys
    See TELLURIUM SELENIUM ALLOYS

Selenium Tellurium Bismuth Systems
    See BISMUTH SELENIUM TELLURIUM SYSTEMS

Selenium Tellurium Bismuth Antimony Systems
    See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Selenium Tellurium Arsenic Systems
    See ARSENIC SELENIUM TELLURIUM SYSTEMS

Selenium Tin Sulfide
    See TIN SELENIUM SULFIDE

Selenium Zinc Indium Systems
    See ZINC INDIUM SELENIUM SYSTEMS

SILICON

SILICON CARBIDE

Silicon Copper Telluride
    See COPPER SILICON TELLURIDE

SILICON DIOXIDE

Silicon Germanium Alloys
    See GERMANIUM SILICON ALLOYS

SILICON IODIDE

Silicon Zinc Oxide
    See ZINC SILICON OXIDE

SILVER ALUMINUM SELENIUM SYSTEMS

SILVER ALUMINUM TELLURIUM SYSTEMS

Silver Antimony Lead Tellurium Systems
    See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

SILVER ANTIMONY SELENIDE

SILVER ANTIMONY SULFIDE

SILVER ANTIMONY TELLURIDE

SILVER ARSENIC SELENIDE

SILVER ARSENIC TELLURIDE

SILVER BISMUTH SELENIDE

SILVER BISMUTH TELLURIDE

SILVER BROMIDE

SILVER CESIUM OXIDE

SILVER CHLORIDE

Silver Copper Indium Tellurium Systems
See COPPER SILVER INDIUM TELLURIUM SYSTEMS

Silver Copper Telluride
See COPPER SILVER TELLURIDE

SILVER GALLIUM SELENIDE

SILVER GALLIUM TELLURIDE

Silver Indium Copper Tellurium Systems
See COPPER SILVER INDIUM TELLURIUM SYSTEMS

SILVER INDIUM SELENIDE

SILVER INDIUM SULFIDE

SILVER INDIUM TELLURIDE

SILVER IODIDE

SILVER IRON SELENIDE

SILVER IRON TELLURIDE

SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

SILVER PHOSPHIDE

SILVER SELENIDE

Silver Selenium Aluminum Systems
See SILVER ALUMINUM SELENIUM SYSTEMS

Silver Tellurium Aluminum Systems
See SILVER ALUMINUM TELLURIUM SYSTEMS

SILVER SELENIUM SULFIDE

SILVER SULFIDE

SILVER TELLURIDE

Silver Tellurium Copper Indium Systems
See COPPER SILVER INDIUM TELLURIUM SYSTEMS

Silver Tellurium Lead Antimony Systems
See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

SILVER TELLURIUM SELENIDE

SILVER THALLIUM TELLURIDE

SODIUM ANTIMONIDE

SODIUM CHLORIDE

SODIUM CYANIDE

SODIUM POTASSIUM ANTIMONIDE

STRONTIUM OXIDE

STRONTIUM OXIDE – BARIUM OXIDE SYSTEMS

STRONTIUM SELENIDE

STRONTIUM TELLURIDE

STRONTIUM TITANATE

STRONTIUM TITANATE – BARIUM TITANATE SYSTEMS

STRONTIUM TITANIUM OXIDE

Sulfur Arsenic Copper Lead Systems
See COPPER LEAD ARSENIC SULFUR SYSTEMS

Sulfur Bismuth Tellurium Systems
See BISMUTH SULFUR TELLURIUM SYSTEMS

Sulfur Copper Arsenic Lead Systems
See COPPER LEAD ARSENIC SULFUR SYSTEMS

Sulfur Lead Arsenic Copper Systems
See COPPER LEAD ARSENIC SULFUR SYSTEMS

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Sulfur Tellurium Alloys
    See TELLURIUM SULFUR ALLOYS

Sulfur Tellurium Bismuth Systems
    See BISMUTH SULFUR TELLURIUM SYSTEMS

TANTALUM OXIDE

TELLURIUM

Tellurium Aluminum Copper Systems
    See COPPER ALUMINUM TELLURIUM SYSTEMS

Tellurium Antimony Bismuth Systems
    See ANTIMONY BISMUTH TELLURIUM SYSTEMS

Tellurium Antimony Bismuth Selenium Systems
    See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Tellurium Arsenic Selenium Systems
    See ARSENIC SELENIUM TELLURIUM SYSTEMS

Tellurium Bismuth Selenide
    See BISMUTH TELLURIUM SELENIDE

Tellurium Bismuth Antimony Systems
    See ANTIMONY BISMUTH TELLURIUM SYSTEMS

Tellurium Bismuth Antimony Selenium Systems
    See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Tellurium Bismuth Selenium Systems
    See BISMUTH SELENIUM TELLURIUM SYSTEMS

Tellurium Bismuth Sulfur Systems
    See BISMUTH SULFUR TELLURIUM SYSTEMS

Tellurium Cadmium Mercury Systems
    See CADMIUM MERCURY TELLURIUM SYSTEMS

TELLURIUM CHLORIDE

Tellurium Copper Selenide
    See COPPER TELLURIUM SELENIDE

Tellurium Copper Aluminum Systems
    See COPPER ALUMINUM TELLURIUM SYSTEMS

Tellurium Mercury Cadmium Systems
    See CADMIUM MERCURY TELLURIUM SYSTEMS

Tellurium Mercury Selenium Systems
    See MERCURY SELENIUM TELLURIUM SYSTEMS

TELLURIUM SELENIDE

TELLURIUM SELENIUM ALLOYS

Tellurium Selenide — Bismuth Selenide Systems
    See BISMUTH SELENIDE — TELLURIUM SELENIDE SYSTEMS

Tellurium Selenium Antimony Bismuth Systems
    See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Tellurium Selenium Arsenic Systems
    See ARSENIC SELENIUM TELLURIUM SYSTEMS

Tellurium Selenium Bismuth Systems
    See BISMUTH SELENIUM TELLURIUM SYSTEMS

Tellurium Selenium Bismuth Antimony Systems
    See ANTIMONY BISMUTH SELENIUM TELLURIUM SYSTEMS

Tellurium Selenium Mercury Systems
    See MERCURY SELENIUM TELLURIUM SYSTEMS

Tellurium Silver Selenide
    See SILVER TELLURIUM SELENIDE

Tellurium Silver Antimony Lead Systems
    See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

Tellurium Silver Copper Indium Systems
    See COPPER SILVER INDIUM TELLURIUM SYSTEMS

Tellurium Silver Lead Antimony Systems
    See SILVER LEAD ANTIMONY TELLURIUM SYSTEMS

Tellurium Silver Indium Copper Systems
    See COPPER SILVER INDIUM TELLURIUM SYSTEMS

TELLURIUM SULFUR ALLOYS

Tellurium Sulfur Bismuth Systems
    See BISMUTH SULFUR TELLURIUM SYSTEMS

Tellurium Tin Systems
    See TIN TELLURIUM SYSTEMS

THALLIUM PHOSPHIDE

THALLIUM SELENIDE

Thallium Silver Telluride
    See SILVER THALLIUM TELLURIDE

THALLIUM SULFIDE

THORIUM OXIDE

TIN, GRAY

TIN ANTIMONIDE

TIN BISMUTH SELENIDE

TIN BISMUTH SYSTEMS

TIN BISMUTH TELLURIDE

Tin Cadmium Arsenide
    See CADMIUM TIN ARSENIDE

Tin Copper Alloys
    See COPPER TIN ALLOYS

Tin Copper Selenide
    See COPPER TIN SELENIDE

Tin Copper Sulfide
    See COPPER TIN SULFIDE

Tin Copper Telluride
    See COPPER TIN TELLURIDE

TIN OXIDE

TIN SELENIDE

TIN SELENIUM SULFIDE

TIN SULFIDE

TITANIUM CARBIDE

TITANIUM DIOXIDE

TITANIUM NITRIDE

Titanium Strontium Oxide
      See STRONTIUM TITANIUM OXIDE

TUNGSTEN OXIDE

TUNGSTEN SULFIDE

VANADIUM OXIDE

ZINC ANTIMONIDE

ZINC ARSENIDE

Zinc Cadmium Sulfide
      See CADMIUM ZINC SULFIDE

ZINC CHROMIUM OXYGEN SYSTEMS

ZINC FLUORIDE

ZINC GERMANIUM ARSENIDE

ZINC INDIUM SELENIUM SYSTEMS

ZINC OXIDE

Zinc Oxygen Chromium Systems
      See ZINC CHROMIUM OXYGEN SYSTEMS

ZINC PHOSPHIDE

ZINC SELENIDE

Zinc Selenium Indium Systems
      See ZINC INDIUM SELENIUM SYSTEMS

ZINC SILICON OXIDE

ZINC SULFIDE

Zinc Sulfide — Cadmium Sulfide Systems
      See CADMIUM SULFIDE — ZINC SULFIDE SYSTEMS

ZINC TELLURIDE

ZIRCONIUM DIOXIDE

BINARY ANTIMONIDES

ALUMINUM ANTIMONIDE
BISMUTH ANTIMONIDE
CADMIUM ANTIMONIDE
CESIUM ANTIMONIDE
COBALT ANTIMONIDE
COPPER ANTIMONIDE
GALLIUM ANTIMONIDE
INDIUM ANTIMONIDE
MAGNESIUM ANTIMONIDE
POTASSIUM ANTIMONIDE
RUBIDIUM ANTIMONIDE
SODIUM ANTIMONIDE
TIN ANTIMONIDE
ZINC ANTIMONIDE

BINARY ARSENIDES

ALUMINUM ARSENIDE
CADMIUM ARSENIDE
GALLIUM ARSENIDE
INDIUM ARSENIDE
MANGANESE ARSENIDE
ZINC ARSENIDE

BINARY BISMUTHIDES

ALUMINUM BISMUTHIDE
CESIUM BISMUTHIDE
GALLIUM BISMUTHIDE
INDIUM BISMUTHIDE
LITHIUM BISMUTHIDE
RUBIDIUM BISMUTHIDE

BINARY BROMIDES

CESIUM BROMIDE
COPPER BROMIDE
POTASSIUM BROMIDE
SILVER BROMIDE

BINARY CHLORIDES

CESIUM CHLORIDE
LANTHANUM CHLORIDE
POTASSIUM CHLORIDE
SILVER CHLORIDE
SODIUM CHLORIDE
TELLURIUM CHLORIDE

BINARY FLUORIDES

ZINC FLUORIDE

BINARY IODIDES

ANTIMONY IODIDE
BISMUTH IODIDE
CADMIUM IODIDE
CESIUM IODIDE
LEAD IODIDE
MERCURY IODIDE
POTASSIUM IODIDE
RUBIDIUM IODIDE
SILICON IODIDE
SILVER IODIDE

BINARY NITRIDES

BORON NITRIDE
TITANIUM NITRIDE

BINARY OXIDES

ALUMINUM OXIDE
BARIUM OXIDE
BISMUTH TRIOXIDE
CADMIUM OXIDE
CALCIUM OXIDE
COBALT OXIDE
COPPER OXIDE
GERMANIUM OXIDE
INDIUM OXIDE
IRON OXIDE
LEAD OXIDE
MAGNESIUM OXIDE
MANGANESE OXIDE
MERCURY OXIDE
NICKEL OXIDE
NIOBIUM OXIDE
PHOSPHORUS OXIDE

BINARY OXIDES (Cont.)

POTASSIUM OXIDE
SILICON DIOXIDE
STRONTIUM OXIDE
TANTALUM OXIDE
THORIUM OXIDE
TIN OXIDE
TITANIUM OXIDE
TUNGSTEN OXIDE
VANADIUM OXIDE
ZINC OXIDE
ZIRCONIUM DIOXIDE

BINARY PHOSPHIDES

ALUMINUM PHOSPHIDE
ARSENIC PHOSPHIDE
BORON PHOSPHIDE
CADMIUM PHOSPHIDE
COPPER PHOSPHIDE
GALLIUM PHOSPHIDE
INDIUM PHOSPHIDE
SILVER PHOSPHIDE
THALLIUM PHOSPHIDE
ZINC PHOSPHIDE

BINARY SILICIDES

CALCIUM SILICIDE
CHROMIUM SILICIDE
COBALT SILICIDE
COPPER SILICIDE
MAGNESIUM SILICIDE
MANGANESE SILICIDE
MOLYBDENUM SILICIDE
NICKEL SILICIDE

BINARY STANNIDES

CADMIUM STANNIDE
CALCIUM STANNIDE
GERMANIUM STANNIDE
MAGNESIUM STANNIDE
MANGANESE STANNIDE

BINARY SELENIDES

ALUMINUM SELENIDE
ANTIMONY SELENIDE
ARSENIC SELENIDE
BARIUM SELENIDE
BISMUTH SELENIDE
CADMIUM SELENIDE
ERBIUM SELENIDE
GALLIUM SELENIDE
GERMANIUM SELENIDE
INDIUM SELENIDE
LANTHANUM SELENIDE
LEAD SELENIDE
MAGNESIUM SELENIDE
MANGANESE SELENIDE
MERCURY SELENIDE
SILVER SELENIDE
STRONTHIUM SELENIDE
TELLURIUM SELENIDE
THALLIUM SELENIDE
TIN SELENIDE
ZINC SELENIDE

BINARY SULFIDES

ALUMINUM SULFIDE
ANTIMONY SULFIDE
ARSENIC SULFIDE
BARIUM SULFIDE
BISMUTH SULFIDE
CADMIUM SULFIDE
CALCIUM SULFIDE
CESIUM SULFIDE
CHROMIUM SULFIDE
COPPER SULFIDE
GALLIUM SULFIDE
GERMANIUM SULFIDE
INDIUM SULFIDE
IRON SULFIDE
LEAD SULFIDE
MANGANESE SULFIDE
MERCURY SULFIDE
MOLYBDENUM SULFIDE
SILVER SULFIDE
THALLIUM SULFIDE
TIN SULFIDE
TUNGSTEN SULFIDE
ZINC SULFIDE

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BINARY TELLURIDES

ALUMINUM TELLURIDE
ANTIMONY TELLURIDE
ARSENIC TELLURIDE
BARIUM TELLURIDE
BISMUTH TELLURIDE
CADMIUM TELLURIDE
CESIUM TELLURIDE
COPPER TELLURIDE
ERBIUM TELLURIDE
GADOLINIUM TELLURIDE
GALLIUM TELLURIDE
GERMANIUM TELLURIDE
INDIUM TELLURIDE
IRON TELLURIDE
LANTHANUM TELLURIDE
LEAD TELLURIDE
MANGANESE TELLURIDE
MERCURY TELLURIDE

NICKEL TELLURIDE
RUBIDIUM TELLURIDE
SILVER TELLURIDE
STRONTIUM TELLURIDE
ZINC TELLURIDE

ELEMENTS

ANTIMONY
BISMUTH
BORON
CARBON, DIAMOND
CARBON, GRAPHITE
GERMANIUM
IODINE
PHOSPHORUS
SELENIUM
SILICON
TELLURIUM
TIN, GRAY

OTHER BINARY COMPOUNDS, SYSTEMS, AND ALLOYS

Al - B
ALUMINUM BORIDE

Au - Ce
CESIUM AURIDE

Bi - Sn
TIN BISMUTH SYSTEMS

C - Si
SILICON CARBIDE

C - Ti
TITANIUM CARBIDE

Cu - Sn
COPPER TIN ALLOYS

Cd - Mg
CADMIUM MAGNESIUM ALLOYS

Ge - Si
GERMANIUM SILICON ALLOYS

Ge - Mg
MAGNESIUM GERMANIDE

Mg - Pb
MAGNESIUM PLUMBIDE

S - Te
TELLURIUM SULFUR ALLOYS

Se - Te
TELLURIUM SELENIUM ALLOYS

Sn - Te
TIN TELLURIUM SYSTEMS

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APPENDIX IV

INSULATION MATERIAL NAMES

ABR Rubber
    See RUBBER, NITRILE-BUTADIENE

ABS Plastics
    See ACRYLONITRILE-BUTADIENE-STYRENE PLASTICS

Acetal Copolymers
    See ACETAL PLASTICS

ACETAL PLASTICS

Acetate Cloth
    See RAYON

Acetate Fibers
    See RAYON

ACETATE FILM
    See also CELLOPHANE

Acetate, Rope
    See PAPER, ROPE (CELLULOSE ACETATE COVERED)

"Acrawax" (Trade Name, Glyco Products Co.)
    See WAXES, ACRAWAX

Acrylate Plastics
    See ACRYLIC PLASTICS

Acrylic Copolymers
    See ACRYLIC PLASTICS

Acrylic Esters
    See ACRYLIC PLASTICS

Acrylic Fiber
    (Any long chain synthetic polymer which contains 85% or more
    Acrylonitrile and which is formed into a filament).
    See ACRYLONITRILE PLASTICS

ACRYLIC PLASTICS

Acrylic Resins
    See ACRYLIC PLASTICS

"Acrylon" Rubber BA-12 and EA-12 (Trade Name, The Bordon Co.)
    See RUBBER, ACRYLIC ESTER-ACRYLONITRILE COPOLYMER

ACRYLONITRILE-BUTADIENE-STYRENE PLASTICS

ACRYLONITRILE PLASTICS

Acrylonitrile Rubber
    See RUBBER, NITRILE-BUTADIENE

AIR

Alkali Silicate Glass
    See GLASS, SODA-SILICA

"Alkathene" (Trade Name, Imperial Chemical Industries, Inc.)
    See POLYETHYLENE PLASTICS

ALKYD PLASTICS

ALKYD PLASTICS, GLASS FIBER FILLED

ALKYD PLASTICS, MINERAL FILLED

Alkyd-Vinyl Varnishes
    See FOSTERITE

Allyl Diglycol Carbonate
    See ALLYL PLASTICS

Allyl Plastics
    (A class of polyester resins derived from allyl alcohol and
    dibasic acids. The monomers, such as diallyl maleate and
    diallyl phthalate, form thermosetting resins).
    See also DIALLYL PHTHALATE PLASTICS
    See also TRIALLYL CYANURATE PLASTICS

Alpha Cellulose Filled Plastics
    See MELAMINE PLASTICS, ALPHA CELLULOSE FILLED
        UREA PLASTICS, ALPHA CELLULOSE FILLED

Alumina
    See ALUMINUM OXIDE

Alumina, Sintered
    See ALUMINUM OXIDE

Aluminosilicate Glass
    See GLASS, ALUMINOSILICATE

ALUMINUM OXIDE

ALUMINUM SILICATE
    See also MICA

AMBER

Ameriod (Trade Name, American Molding Powder & Chemical Corp.)
    See CASEIN PLASTICS

Anatase (Natural Titanium Dioxide)
    See TITANIUM DIOXIDE

ANILINE-FORMALDEHYDE LAMINATES, PAPER BASE

ANILINE-FORMALDEHYDE PLASTICS
    (Formed by controlled reaction of formaldehyde with an
    aqueous solution of aniline hydrochloride).

Aniline-Formaldehyde Resins
    See ANILINE-FORMALDEHYDE PLASTICS

Arcton O (Trade Name)
    See CARBON TETRAFLUORIDE

Arcton 1 (Trade Name)
    See TRIFLUOROMETHANE

Arcton 3 (Trade Name)
    See CHLOROTRIFLUOROMETHANE

Arcton 4 (Trade Name)
    See CHLORODIFLUOROMETHANE

Arcton 6 (Trade Name)
    See DICHLORODIFLUOROMETHANE

Arcton 7 (Trade Name)
    See DICHLOROFLUOROMETHANE

Arcton 9 (Trade Name)
    See TRICHLOROFLUOROMETHANE

Aroclors
    See CHLORINATED DIPHENYLS

ASBESTOS

ASBESTOS, ALUMINUM PHOSPHATE BONDED

Asbestos Board Base Laminates
    See SILICONE LAMINATES, ASBESTOS BOARD BASE

Asbestos Fabric Base Laminates
    See PHENOLIC LAMINATES, ASBESTOS FABRIC BASE
        SILICONE LAMINATES, ASBESTOS FABRIC BASE

Asbestos Filled Plastics
    See MELAMINE PLASTICS, ASBESTOS FILLED
        PHENOLIC PLASTICS, ASBESTOS FILLED
        POLYESTER PLASTICS, ASBESTOS FILLED
        UREA PLASTICS, ASBESTOS FILLED
        SILICONE PLASTICS, ASBESTOS FILLED
        POLYTETRAFLUOROETHYLENE PLASTICS, ASBESTOS FILLED

Asbestos Paper
    See PAPER, ASBESTOS

Asbestos Paper Base Laminates
    See PHENOLIC LAMINATES, ASBESTOS PAPER BASE
        SILICONE LAMINATES, ASBESTOS PAPER BASE

ASKARELS
    See also CHLORINATED BENZENE
           CHLORINATED DIPHENYLS
           TRANSFORMER FLUIDS

Baddeleyite
    See ZIRCITE

"Bakelite" Plastics (Trade Name, Union Carbide Corp)
        Grades: AYAA, AYAF, AYAT, AYAC, A-70, MA-28-18, T-24-9,
                and WC-130
        See POLYVINYL ACETATE PLASTICS
            POLYVINYL ALCOHOL PLASTICS

        Grades: QYNA, QYNV, QXSJ, QYSM, and QYSQ
        See POLYVINYL CHLORIDE PLASTICS

        Grades: VYHH, VYLF, VYNS, VYNW, VYDR, VYNV, VYCM, VMCH,
                and VAGH
        See POLYVINYL CHLORIDE-ACETATE PLASTICS

        Grades: XYSG, XYHL
        See POLYVINYL BUTYRAL PLASTICS

BARIUM CALCIUM ALUMINATE

Barium Glass
        See GLASS, BARIUM

BARIUM NIOBATE

BARIUM TANTALATE

BARIUM TITANATE

BARIUM ZIRCONATE

Beeswax
        See WAXES, BEESWAX

Beryllia, Sintered
        See BERYLLIUM OXIDES

BERYLLIUM OXIDE

Borate Glass
        See GLASS, BORATE

BORON NITRIDE

Borosilicate Glass
        See GLASS, BOROSILICATE

BR Rubber
        See RUBBER, BUTADIENE

Brazilite
        See ZIRCITE

BROMOTRIFLUOROMETHANE

Buna Rubber
    See RUBBER, BUTADIENE

Buna-N Rubber
    See RUBBER, NITRILE-BUTADIENE

Buna-S Rubber
    See RUBBER, STYRENE-BUTADIENE

Butadiene Acrylonitrile Rubber
    See RUBBER, NITRILE-BUTADIENE

Butadiene Rubber
    See RUBBER, BUTADIENE

Butadiene Styrene Rubber
    See RUBBER, STYRENE-BUTADIENE

BUTYL NAPHTHALATE

Butyl Octodecanoate
    See BUTYL STEARATE

Butyl Rubber
    See RUBBER, BUTYL

BUTYL SEBACATE

BUTYL STEARATE

Cable Paper
    See PAPER, KRAFT

CADMIUM NIOBATE

CALCIUM NIOBATE

Calcium Silicate (Natural)
    See WOLLASTONITE

CALCIUM STANNATE

CALCIUM TANTALATE

CALCIUM TITANATE

CAMBRIC, VARNISHED

Caoutchouc
 See RUBBER, NATURAL

Capacitor Tissue
 See PAPER, RAG
     PAPER, SULFATE

Caprolactam Nylons
 See POLYAMIDES, CAPROLACTUM PLASTICS
     POLYAMIDES, NYLON 6 PLASTICS

Caprolactam Plastics
 See POLYAMIDES, CAPROLACTUM PLASTICS
     POLYAMIDES, NYLON 6 PLASTICS

Carbamide-Formaldehyde Plastics
 See UREA PLASTICS

CARBON

CARBON TETRACHLORIDE

CARBON TETRAFLUORIDE

Carnauba Wax
 See WAXES, CARNAUBA

"Carnube Wax" (Trade Name, The Beacon Co.)
 See WAXES, CARNUBE

Casein Molding Compound
 See CASEIN PLASTICS

CASEIN PLASTICS

Cast Acrylic
 See ACRYLIC PLASTICS

CASTOR OIL

Celcon (Trade Name, Celanese Corporation of America)
 See ACETAL PLASTICS

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CELLOPHANE

CELLULOID PLASTICS

CELLULOSE ACETATE BUTYRATE PLASTICS

CELLULOSE ACETATE PLASTICS

Cellulose Acetate Plastics, Films
    See ACETATE FILMS

CELLULOSE ACETATE PLASTICS, HIGHLY ACETYL

CELLULOSE ACETATE PLASTICS, PAPER FILLED

CELLULOSE CYANOETHYL PLASTICS

CELLULOSE ESTER PLASTICS

CELLULOSE FIBERS
    See also COTTON
              LINEN
              RAYON

Cellulose Filled Plastics
    See MELAMINE PLASTICS, CELLULOSE FILLED
         UREA PLASTICS, CELLULOSE FILLED
         PHENOLIC PLASTICS, CELLULOSE FILLED

CELLULOSE NITRATE PLASTICS

CELLULOSE PROPIONATE PLASTICS

Cellulose Pulp
    See PAPER, WOODPULP
         CELLOPHANE

Cellulose, Regenerated
    See RAYON

Cellulose Triacetate
    See CELLULOSE ACETATE PLASTICS

Cellulosic Molding Compound
     See CELLULOSE ACETATE BUTYRATE PLASTICS
           CELLULOSE ACETATE PLASTICS
           CELLULOSE ACETATE, HIGHLY ACETYL PLASTICS
           CELLULOSE CYANOETHYL PLASTICS
           CELLULOSE ESTER PLASTICS
           CELLULOSE NITRATE PLASTICS
           CELLULOSE PROPIONATE PLASTICS

Ceramic Fiber Base Laminates
     See POLYTETRAFLUOROETHYLENE LAMINATES, CERAMIC FIBER
           BASE

Ceramic Fiber Filled Plastics
     See POLYTETRAFLUOROETHYLENE PLASTICS, CERAMIC FIBER
           FILLED

Ceramic Paper
     See MICA PAPER
           PAPER, CERAMIC

Ceramics
     See also ALUMINUM OXIDE
              BERYLLIUM OXIDE
              CERATE CERAMICS
              CORDIERITE
              MICA, SYNTHETIC
              MICA, SYNTHETIC, GLASS-BONDED
              NIOBATE CERAMICS
              PORCELAIN
              PYROCERAM
              QUARTZ, FUSED
              STANNATE CERAMICS
              STEATITE
              TANTALATE CERAMICS
              TITANATE CERAMICS
              ZIRCONATE CERAMICS
              ZIRCONIUM OXIDE

Ceramoplastics
     See MICA, SYNTHETIC, GLASS-BONDED
           MICA, GLASS-BONDED

CERATE CERAMICS

Cerese Wax
     See WAXES, CERESIN

Cerin
>> See WAXES, CERESIN

Cerosin
>> See WAXES, CERESIN

Cetylacetamide Wax
>> See WAXES, CETYLACETAMIDE

CFE Plastics
>> See POLYTRIFLUOROCHLOROETHYLENE PLASTICS

"Chemigum" (Trade Name, Goodyear Tire & Rubber Co.)
>> See RUBBER, NITRILE-BUTADIENE

CHLORENDIC ANHYDRIDE

CHLORINATED BENZENE

Chlorinated Biphenyls
>> See CHLORINATED DIPHENYLS

CHLORINATED DIPHENYLS
>> See also HEXACHLORODIPHENYL METHANE
>> PENTACHLORODIPHENYL
>> PENTACHLORODIPHENYL BENZOATE
>> PENTACHLORODIPHENYL KETONE
>> PENTACHLORODIPHENYL OXIDE
>> PENTACHLOROETHYL BENZENE
>> TRICHLOROBENZENE

Chlorinated Hydrocarbons
>> See HYDROCARBONS, CHLORINATED

Chlorinated Indans
>> See PHENYLINDAN DERIVATIVES

Chlorinated Naphthalenes
>> See WAXES, CHLORONAPHTHALENE

CHLORODIFLUOROMETHANE

Chloronaphthalene Wax
>> See WAXES, CHLORONAPHTHALENE

Chloroprene-Nitrile Rubber
        See RUBBER, NITRILE-CHLOROPRENE

CHLOROTRIFLUOROMETHANE

CMC Plastics
        See CASEIN PLASTICS

COATINGS, INSULATING

COATINGS, PORCELAIN ENAMEL

Cold Rubber
        See RUBBER, STYRENE-BUTADIENE

Condenser Paper
        See PAPER, RAG
             PAPER, SULFATE

"Coolant 45" (Trade Name, Monsanto Chemical)
        See SILICATE ESTER BASE FLUID

CORDIERITE

COTTON

Cotton Fabric Base Laminates
        See MELAMINE LAMINATES, COTTON FABRIC BASE
             PHENOLIC LAMINATES, COTTON FABRIC BASE
             DIALLYL PHTHALATE LAMINATES, COTTON FABRIC BASE

Cotton Flock Filled Plastics
        See MELAMINE PLASTICS, COTTON FLOCK-FILLED
             PHENOLIC PLASTICS, COTTON FLOCK FILLED

Crown Glass
        See GLASS, SODA-LIME

CRYOLITE

Cuprammonium Rayon
        See RAYON

Cyanoethylcellulose
        See CELLULOSE CYANOETHYL PLASTICS

"Dacron" (Trade Name, DuPont Co.)
(Product of Methyl Terephthalate and Ethylene Glycol.)
See POLYETHYLENE TEREPHTHALATE FIBER

DAP Plastics
See DIALLYL PHTHALATE PLASTICS

"Delrin" (Trade Name, DuPont Co.)
See ACETAL PLASTICS

DIALLYL PHTHALATE LAMINATES, COTTON FABRIC BASE

DIALLYL PHTHALATE LAMINATES, GLASS FABRIC BASE

DIALLYL PHTHALATE LAMINATES, ORLON BASE

DIALLYL PHTHALATE PLASTICS

DIALLYL PHTHALATE PLASTICS, GLASS FIBER FILLED

DIALLYL PHTHALATE PLASTICS, MINERAL FILLED

DIBUTYL SEBACATE

DICHLORODIFLUOROMETHANE

DICHLOROFLUOROMETHANE

Dichlorostyrene Polymers
See POLYDICHLOROSTYRENE PLASTICS

DICHLOROTETRAFLUORETHANE

Dichlorotrimethylphenylindan
See PHENYLINDAN DERIVATIVES

Dichroite
See CORDIERITE

DIETHYLENE GLYCOL

Difluorodichloromethane
See DICHLORODIFLUOROMETHANE

Difluoromonochloromethane
See CHLORODIFLUOROMETHANE

"Distrene" (Trade Name, BX Plastics, Ltd.)
See POLYSTYRENE PLASTICS

"Dow Corning 3, 4, and 5 Compounds" (Trade Name, Dow-Corning Co.)
See SILICONE DIELECTRIC GEL

"Dow Corning 33, 41, and 44 Greases" (Trade Name, Dow-Corning Co.)
See SILICONE GREASES

"Dow Corning 200 Fluids" (Trade Name, Dow-Corning Co.)
See SILICONE FLUIDS

"Dow Corning 550 and 710 Fluids" (Trade Name, Dow-Corning Co.)
See SILICONE FLUIDS

"Dow Corning 935, 994, 996 and 997 Varnishes"
(Trade Name, Dow-Corning Co.)
See VARNISHES, SILICONE

"Dow Corning 2103, 2104, 2105, 2106 Resins"
(Trade Name, Dow-Corning Co.)
See SILICONE LAMINATES, GLASS BASE

"Durez 791 (Trade Name, Hooker Chemical Corp.)
See PHENOLIC PLASTICS, WOOD FLOUR FILLED

Earth Wax
See WAXES, CERESIN

Elastomers (Synthetic polymers with rubber-like characteristics).
See RUBBER, SYNTHETIC

Electrical Insulating Fluids
See ASKARELS
ETHYLENE GLYCOL
HYDROCARBONS, FLUORINATED
MINERAL OILS
ORGANIC ESTERS
SILICATE ESTER BASE FLUID
SILICONE FLUIDS
TRANSFORMER OILS

Electrical Porcelain
See PORCELAIN

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Enamel, Vitreous
    See COATINGS, PORCELAIN ENAMEL

"Enjay Butyl" (Trade Name, Enjay Co., N. Y.)
    See RUBBER, BUTYL

"Enjay EPR" (Trade Name, Enjay Co., N. Y.)
    See RUBBER, ETHYLENE-PROPYLENE

EPOXY LAMINATES

EPOXY LAMINATES, CERAMIC FIBER BASE

EPOXY LAMINATES, GLASS FABRIC BASE

EPOXY LAMINATES, GLASS MAT BASE

EPOXY LAMINATES, MICA PAPER BASE

EPOXY LAMINATES, PAPER BASE

EPOXY-PHENOLIC LAMINATES, GLASS FABRIC BASE

EPOXY-PHENOLIC PLASTICS

EPOXY PLASTICS

EPOXY PLASTICS, CERAMIC FILLED

EPOXY PLASTICS, GLASS FABRIC FILLED

EPOXY PLASTICS, GLASS FIBER FILLED

EPOXY PLASTICS, GLASS MAT FILLED

EPOXY PLASTICS, METAL POWDER FILLED

EPOXY PLASTICS, MINERAL FILLED

EPOXY PLASTICS, SILICA FILLED

EPOXY-POLYESTER PLASTICS

EPOXY-POLYSULFIDE LAMINATES, GLASS FABRIC BASE

Epoxy-Polytrifluorochloroethylene Laminates, Glass Fiber Base
    See POLYTRIFLUOROCHLOROETHYLENE LAMINATES, GLASS
       FIBER BASE

Epoxy Resins
    See EPOXY PLASTICS

Ethenoid Plastics (Thermosetting)
    See POLYESTER PLASTICS

Ethenoid Polymers (Thermoplastic)
    (Polymers formed from monomer molecules containing the
    reactive ethenoid link, $-C = C-$)
    For plastics containing one ethenoid linkage, and one
    polymerization see:
       ACRYLIC PLASTICS
       POLYETHYLENE PLASTICS
       POLYSTYRENE PLASTICS
       POLYTETRAFLUOROETHYLENE PLASTICS
       POLYVINYL ACETATE PLASTICS
       POLYVINYL CHLORIDE PLASTICS
       POLYVINYLIDENE CHLORIDE PLASTICS

Ethyl Cellulose Plastics
    See CELLULOSE ESTER PLASTICS

ETHYLENE GLYCOL

Ethylene-Propylene Copolymer
    See RUBBER, ETHYLENE-PROPYLENE

Fabrics
    See also ASBESTOS
       COTTON
       GLASS CLOTH
       LINEN
       RAYON
       SILK
       QUARTZ FABRICS

Fatty Acid Plastics
    See ALKYD PLASTICS

"FEP" Plastics (Tradename, DuPont Co.)
    See POLYFLUOROETHYLENE PROPYLENE PLASTICS

FIBER BOARD

Fiber, Vulcanized
    See VULCANIZED FIBER

Fibrous Silica Fabrics
    See QUARTZ FABRICS

Flatback Paper
    See PAPER, FLATBACK

Flint Glass
    See GLASS, LEAD, ALKALI

Fluorinated Ethylene Propylene Copolymers
    See POLYFLUOROETHYLENE PROPYLENE PLASTICS

Fluorinated Hydrocarbons
    See HYDROCARBONS, FLUORINATED

Fluorocarbons, Gaseous
    See FREONS
         HYDROCARBONS, FLUORINATED

Fluorocarbons (Plastics)
    See POLYFLUOROETHYLENE PROPYLENE PLASTICS
         POLYTETRAFLUOROETHYLENE PLASTICS
         POLYTRIFLUOROCHLOROETHYLENE PLASTICS

Fluorodichloromethane
    See DICHLOROFLUOROMETHANE

Fluorophlogopite
    See MICA, SYNTHETIC

"Fluoroplast" (Trade Name, Russian)
    See POLYTETRAFLUOROETHYLENE PLASTICS

Fluoroply-E Laminate
    See POLYTRIFLUOROCHLOROETHYLENE-EPOXY
         LAMINATES, GLASS FIBER BASE

Fluoroply-P Laminate
    See POLYTRIFLUOROCHLOROETHYLENE-PHENOLIC
         LAMINATES, PAPER BASE

Fluorothene
  (A plastic polymer of trifluorochloroethylene.)
  See POLYTRIFLUOROCHLOROETHYLENE PLASTICS

Fluorotrichloromethane
  See TRICHLOROFLUOROMETHANE

Fluxed Alumina
  See ALUMINUM OXIDE

Formaldehyde-Aniline Plastics
  See ANILINE-FORMALDEHYDE PLASTICS

Formaldehyde-Urea Plastics
  See UREA PLASTICS

"Forticel" (Trade Name, Celanese Chemical Co.)
  See CELLULOSE PROPIONATE PLASTICS

Fossil Resin
  See AMBER

"FOSTERITE" (Trade Name, Westinghouse)
  (A family of resins used as a solventless varnish, alkyd-vinyl
  formulation.)

Freon-11
  See TRICHLOROFLUOROMETHANE

Freon-12
  See DICHLORODIFLUOROMETHANE

Freon-13
  See CHLOROTRIFLUOROMETHANE

Freon-13B1
  See BROMOTRIFLUOROMETHANE

Freon-22
  See CHLORODIFLUOROMETHANE

Freon-113
  See TRICHLOROTRIFLUOROETHANE

Freon-114
   See DICHLOROTETRAFLUOROETHANE

"Freon" C-318
   See OCTAFLUOROCYCLOBUTANE

FREONS (Trade Name, DuPont)
   (Use only for mixtures)
   See also CHLORODIFLUOROMETHANE, $CHCl\,F_2$ (Freon-22)
            CHLOROTRIFLUOROMETHANE, $CClF_3$ (Freon-13)
            DICHLORODIFLUOROMETHANE, CCl_2F_2 (Freon-12)
            DICHLOROTETRAFLUOROETHANE, $CClF_2CClF_2$ (Freon-114)
            TRICHLOROTRIFLUOROETHANE (Freon-113)

Fuller Board
   See PAPER, PRESSBOARD

FURAN PLASTICS

Furan Resins
   See FURAN PLASTICS

Furniture Varnish
   See VARNISHES, OIL

Fused Silica
   See QUARTZ, FUSED

GADOLINIUM OXIDE

'Galom' (Trade Name, Morrell Corp.)
   See CASEIN PLASTICS

"GE Mycalex" (Trade Name, General Electric Co.)
   See MICA, GLASS-BONDED

"Genetrons" (Trade Names, Allied Chemical Corp.)
   (A line of fluorinated hydrocarbons)
   They include:
   "Genetron" 21, Dichlorofluoromethane, $CHCl_2F$
   "Genetron" 23, Fluoroform, CHF_3
   "Genetron" 142B, 1, 1-Difluoro-1-Chloroethane, CH_3CClF_2
   "Genetron" 152A, 1, 1-Difluoroethane CH_3CHF_2
   "Genetron" 1132A, 1, 1-Difluoroethylene, $CH_2:CF_2$

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"Geon" Plastics (Trade Name, B. F. Goodrich)
      See   POLYVINYL CHLORIDE PLASTICS

Glass
      See also   GLASS, ALUMINOSILICATE
                 GLASS, BISMUTH-CADMIUM
                 GLASS, BORATE
                 GLASS, BOROSILICATE
                 GLASS, FLAKE
                 GLASS, LEAD
                 GLASS, LEAD, ALKALI
                 GLASS, LITHIA
                 GLASS, NICKEL
                 GLASS, PHOSPHATE
                 GLASS, SILICA
                 GLASS, SODA-LIME
                 GLASS, SODA-SILICA
                 GLASS, TITANIA

GLASS, ALUMINOSILICATE

GLASS, BARIUM

Glass Base Laminates
      See   SILICONE LAMINATES, GLASS BASE

GLASS, BISMUTH-CADMIUM

Glass-Bonded Mica
      See   MICA, GLASS-BONDED
            MICA, SYNTHETIC, GLASS-BONDED

GLASS, BORATE

GLASS, BOROSILICATE

GLASS CLOTH

Glass Coatings
      See   COATINGS, PORCELAIN ENAMEL

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Glass Fabric Base Laminates
>See DIALLYL PHTHALATE LAMINATES, GLASS FABRIC BASE
>EPOXY-PHENOLIC LAMINATES, GLASS FABRIC BASE
>EPOXY-POLYSULFIDE LAMINATES, GLASS FABRIC BASE
>MELAMINE LAMINATES, GLASS FABRIC BASE
>PHENOLIC LAMINATES, GLASS FABRIC BASE
>POLYESTER LAMINATES, GLASS FABRIC BASE
>POLYTETRAFLUOROETHYLENE LAMINATES, GLASS FABRIC BASE
>POLYSTYRENE LAMINATES, GLASS FABRIC BASE
>SILICONE LAMINATES, GLASS FABRIC BASE

Glass Fabric, Silicone Varnished
>See VARNISHES, SILICONE, GLASS FABRIC FILLED

Glass Fabrics
>See GLASS CLOTH

Glass Fiber Filled Plastics
>See ALKYD PLASTICS, GLASS FIBER FILLED
>DIALLYL PHTHALATE PLASTICS, GLASS FIBER FILLED
>MELAMINE PLASTICS, GLASS FIBER FILLED
>PHENOLIC PLASTICS, GLASS FIBER FILLED
>POLYESTER PLASTICS, GLASS FIBER FILLED
>POLYSTYRENE PLASTICS, GLASS FIBER FILLED
>POLYTETRAFLUOROETHYLENE PLASTICS, GLASS FIBER FILLED
>SILICONE PLASTICS, GLASS FIBER FILLED

Glass Fiber Paper
>See PAPER, GLASS FIBER

GLASS FLAKE

Glass-Flake Paper
>See PAPER, GLASS FLAKE

Glass Flake Paper Base Laminates
>See PHENOLIC LAMINATES, GLASS FLAKE PAPER BASE

GLASS, LEAD

GLASS, LEAD, ALKALI

GLASS, LITHIA

Glass Mat Base Laminates
    See MELAMINE LAMINATES, GLASS MAT BASE
         POLYESTER LAMINATES, GLASS MAT BASE
         POLYTETRAFLUOROETHYLENE LAMINATES, GLASS MAT BASE
         SILICONE LAMINATES, GLASS MAT BASE
         TRIALLYL CYANURATE LAMINATES, GLASS MAT BASE

GLASS, NICKEL

GLASS, PHOSPHATE

GLASS, RIBBON

GLASS, SILICA

GLASS, SODA-LIME

GLASS, SODA-SILICA

GLASS, TITANIA

Glycol Terephthalate
    See POLYETHYLENE TEREPHTHALATE PLASTICS

Government Rubber-Styrene
    See RUBBER, STYRENE-BUTADIENE

GR-A Rubber
    See RUBBER, NITRILE-BUTADIENE

GR-I Rubber
    See RUBBER, BUTYL

GR-N Rubber
    See RUBBER, NITRILE-BUTADIENE

GR-S Rubber
    See RUBBER, STYRENE-BUTADIENE

GUTTA-PERCHA

Halowaxes
    See WAXES, CHLORONAPHTHALENE

Hard Glass
 See GLASS, SODA-LIME

"Havalex" (Trade Name, Haveg Industries, Inc.)
 See MICA, SYNTHETHIC, GLASS-BONDED

HELIUM

HEPTAETHYLENE GLYCOL

HEXACHLORODIPHENYL METHANE

HEXAETHYLENE GLYCOL

HEXAFLUOROETHANE

Hexamethylene Adipamide Polymer
 See POLYAMIDES, NYLON 6/6 PLASTICS

Hexamethylene Sebacamide Polymer
 See POLYAMIDES, NYLON 6/10 PLASTICS

Hexane
 See HYDROCARBONS, LIQUID

"Hycar" Nitrile Rubbers (Trade Name, B. F. Goodrich Chemical Co.)
 See RUBBER, NITRILE-BUTADIENE

"Hycar" Styrene Rubbers (Trade Name, B. F. Goodrich Chemical Co.)
 See RUBBER, STYRENE-BUTADIENE

HYDROCARBONS, BROMINATED

HYDROCARBONS, CHLORINATED
 See also ASKARELS
     CHLORINATED BENZENE
     CHLORINATED DIPHENYLS
     FREONS
     PHENYLINDAN DERIVATIVES

HYDROCARBONS, FLUORINATED
 See also FREONS

Hydrocarbons, Halogenated
 See HYDROCARBONS, BROMINATED
 HYDROCARBONS, CHLORINATED
 HYDROCARBONS, FLUORINATED

HYDROCARBONS, LIQUID

HYDROGEN

Hydroxystearin Wax
 See WAXES, HYDROXYSTEARIN

IN-420 (Trade Name, International Telephone & Telegraph Co.)
 (Dichloro-1,3,3-Trimethyl-1-Phenylindan)
 See PHENYLINDAN DERIVATIVES

India Rubber
 See RUBBER, NATURAL

Inorganic Plastics
 See MICA, GLASS-BONDED
 MICA, SYNTHETIC, GLASS-BONDED

Iolite
 See CORDIERITE

IR Rubber
 See RUBBER, BUTYL

Irrathene (Trade Name, General Electric Co.)
 See POLYETHYLENE PLASTICS

"Isomica" (Trade Name, Mica Insulator Co.)
 See MICA PAPER

"Isoprene"
 (The molecular unit of rubber)
 (3-Methyl-1,3-Butadiene; 2-Methyl-1, 3-Butadiene).
 See RUBBER, BUTYL

Isoprene Rubber
 See RUBBER, BUTYL

Japanese Paper
 See PAPER, JAPANESE

"Kel-F" Plastic (Trade Name, Minnesota Mining & Manufacturing Co.)
    See POLYTRIFLUOROCHLORETHYLENE PLASTICS

Laminates
    See DIALLYL PHTHALATE LAMINATES
           EPOXY LAMINATES
           MELAMINE LAMINATES
           PHENOLIC LAMINATES
           POLYESTER LAMINATES
           POLYSTYRENE LAMINATES
           POLYTETRAFLUOROETHYLENE LAMINATES
           SILICONE LAMINATES

Lead Glass
    See GLASS, LEAD

LEAD TITANATE

LEAD ZIRCONATE

LEATHER

Lepidolite Mica
    See MICA, LEPIDOLITE

"Lexan" (Trade Name, General Electric Co.)
    See POLYCARBONATE PLASTICS

LIGNIN

Lignite Wax
    See WAXES, MONTAN

LINEN

Linen Fabric Base Laminates
    See PHENOLIC LAMINATES, LINEN FABRIC BASE

Liquid Dielectrics
    See ASKARELS
           ETHYLENE GLYCOL
           HYDROCARBONS, FLUORINATED
           MINERAL OILS
           ORGANIC ESTERS
           SILICATE ESTER BASE FLUID
           SILICONE FLUIDS

Lithia Mica
>   See   MICA, LEPIDOLITE

Lithia Porcelain
>   See   PROCELAIN, LITHIA

LITHIUM NIOBATE

LITHIUM TANTALATE

" Lucite"(Trade Name, DuPont Co.)
>   See   ACRYLIC PLASTICS

Macerated Fabric Filled Plastics
>   See   MELAMINE PLASTICS, MACERATED FABRIC FILLED
>   MELAMINE PLASTICS, MACERATED FABRIC FILLED (PHENOLIC
>   MODIFIED)

Magnesia
>   See   MAGNESIUM OXIDE

Magnesium Aluminum Silicate (Mineral)
>   See   CORDIERITE

MAGNESIUM FLUORIDE FILMS

MAGNESIUM NIOBATE

MAGNESIUM OXIDE

MAGNESIUM SILICATES
>   See also   MICA
>   SPINEL
>   STEATITE
>   TALC

MAGNESIUM TANTALATE

MAGNESIUM TITANATE

Manila Paper
>   See   PAPER, ROPE

Melamine-Formaldehyde Molding Compounds
>   See   MELAMINE LAMINATES
>   MELAMINE PLASTICS

Melamine-Formaldehyde Plastics
See MELAMINE PLASTICS

MELAMINE LAMINATES

MELAMINE LAMINATES, ASBESTOS FABRIC BASE

MELAMINE LAMINATES, COTTON FABRIC BASE

MELAMINE LAMINATES, GLASS FABRIC BASE

MELAMINE LAMINATES, GLASS MAT BASE

MELAMINE LAMINATES, PAPER BASE

MELAMINE PLASTICS
See also MELAMINE LAMINATES

MELAMINE PLASTICS, ALPHA CELLULOSE FILLED

MELAMINE PLASTICS, ASBESTOS FILLED

MELAMINE PLASTICS, CELLULOSE FILLED

MELAMINE PLASTICS, COTTON FLOCK-FILLED

MELAMINE PLASTICS, GLASS FIBER FILLED

MELAMINE PLASTICS, MACERATED FABRIC FILLED

MELAMINE PLASTICS, MACERATED FABRIC FILLED (PHENOLIC MODIFIED)

MELAMINE PLASTICS, MINERAL FILLED

MELAMINE PLASTICS, WOODFLOUR FILLED

Melamine Resins
See MELAMINE PLASTICS

"Merlon" (Trade Name, Mobay Chemical Co.)
See POLYCARBONATE PLASTICS

Metal Powder Filled Plastics
See EPOXY PLASTICS, METAL POWDER FILLED

Methacrylate
>   See ACRYLIC PLASTICS

Methyl Methacrylate (MMA)
>   See ACRYLIC PLASTICS

Methyl Polysiloxanes
>   See SILICONE FLUIDS

MICA
>   See also MICA, MUSCOVITE.
>   MICA, PHLOGOPITE

Mica, Amber
>   See MICA, PHLOGOPITE

MICA, FLAKE

MICA, GLASS-BONDED

MICA, LEPIDOLITE
>   See also MICA

MICA, MUSCOVITE

Mica, Paper
>   (Plain or impregnated and/or bonded with Epoxy, Shellac, etc.)
>   See also MICA, GLASS BONDED

Mica Paper Base Laminates
>   See EPOXY LAMINATES, MICA PAPER BASE

MICA, PHLOGOPITE

Mica, Phlogopite (Fluorinated)
>   See MICA, SYNTHETIC

MICA SPLITTINGS
>   (Mica sheets, 1 mil thick and more than 2 sq. in. in area).

MICA, SYNTHETIC
>   (Fluorine derivative of phlogopite)
>   See also MICA, SYNTHETIC, GLASS-BONDED

MICA SYNTHETIC, GLASS-BONDED

Mineral Fiber Base Laminates
See POLYTETRAFLUOROETHYLENE LAMINATES, MINERAL FIBER
BASE

Mineral Filled Plastics
See ALKYD PLASTICS, MINERAL FILLED
DIALLYL PHTHALATE PLASTICS, MINERAL FILLED
MELAMINE PLASTICS, MINERAL FILLED
PHENOLIC PLASTICS, MINERAL FILLED
POLYESTER PLASTICS, MINERAL FILLED
POLYSTYRENE PLASTICS, MINERAL FILLED
SILICONE PLASTICS, MINERAL FILLED

Mineral Graphite
See TALC

MINERAL OIL
See also TRANSFORMER OIL

Mineral Wax
See WAXES, CERESIN

MMA Plastics
See ACRYLIC PLASTICS

Modified Acrylic Molding Compound
See ACRYLIC PLASTICS

Monobromotrifluoromethane
See BROMOTRIFLUOROMETHANE

Monochlorodifluoromethane
See CHLORODIFLUOROMETHANE

Monochlorotrifluoromethane
See CHLOROTRIFLUOROMETHANE

Monofluorodichloromethane
See DICHLOROFLUOROMETHANE

Monofluorotrichloromethane
See TRICHLOROFLUOROMETHANE

Montan Wax
    See WAXES, MONTAN

"Moplen" (Trade Name, Chemore Corp.)
    See POLYPROPYLENE PLASTICS

Muscovite Mica
    See MICA, MUSCOVITE

"Mycalex" (Trade Name, Mycalex Corp. of America)
    See MICA, GLASS-BONDED

"Mycroy" (Trade Name, Electronic Mechanics, Inc.)
    See MICA, SYNTHETIC, GLASS-BONDED

"Mylar" (Trade Name, DuPont Co.)
    (A film of polyethylene terephthalate resin.)
    See POLYETHYLENE TEREPHTHALATE FILM

NADIC METHYL ANHYDRIDE

NBR Rubber
    See RUBBER, NITRILE-BUTADIENE

NCR Rubber
    See RUBBER, NITRILE-CHLOROPRENE

NEODYMIUM OXIDE

Neoprene
    (A series of elastomers based on polymers of chloroprene).
    See RUBBER, CHLOROPRENE

Niobate Ceramics
    See also BARIUM NIOBATE
              CADMIUM NIOBATE
              CALCIUM NIOBATE
              CERAMICS
              LITHIUM NIOBATE
              MAGNESIUM NIOBATE
              POTASSIUM NIOBATE
              SODIUM NIOBATE
              STRONTIUM NIOBATE
              ZINC NIOBATE

Nitrile-Butadiene Rubber
See RUBBER, NITRILE-BUTADIENE

Nitrile Rubber
See RUBBER, NITRILE-BUTADIENE

Nitrile-Vinyl Rubber
See RUBBER, VINYL-NITRILE

Nitrocellulose
See CELLULOSE NITRATE

NITROGEN

Nonane
See HYDROCARBONS, LIQUID

Novolaks
See PHENOLIC PLASTICS

NR Rubber
See RUBBER, NATURAL

Nylon Fabric Base Laminates
See PHENOLIC LAMINATES, NYLON FABRIC BASE

Nylon 61 Plastic (Zytel)
See POLYAMIDES, NYLON 6/10 or 610 PLASTICS

Nylons
See POLYAMIDE PLASTICS

OCTAFLUOROCYCLOBUTANE

Octafluoropropane
See PERFLUOROPROPANE

Oil Varnishes
See VARNISHES, OIL

Oils
See CASTOR OIL
MINERAL OIL
SILICONE FLUIDS
TRANSFORMER OIL

"Opalon" (Trade Name, Monsanto Chemical)
See POLYVINYL CHLORIDE PLASTICS

ORGANIC ESTERS
See also BUTYL NAPHTHALATE
BUTYL SEBACATE
BUTYL STEARATE
TETRAHYDROFURFURYLOXALATE

Organosiloxane Polymers
See SILICONE FLUIDS

Ouricury Wax
See WAXES, OURICURY

OXYGEN

PAPER

See also PAPER, INORGANIC
PAPER, ORGANIC

PAPER, ASBESTOS

Paper Base Laminates
See ANILINE-FORMALDEHYDE LAMINATES, PAPER BASE
MELAMINE LAMINATES, PAPER BASE
PHENOLIC LAMINATES, PAPER BASE
POLYESTER LAMINATES, PAPER BASE

PAPER, CERAMIC

PAPER, CREPE

PAPER, FISH
(A special electrical grade of vulcanized fiber).

PAPER, FLATBACK

PAPER, GLASS FIBER

PAPER, GLASS-FLAKE

PAPER, INORGANIC
See also MICA PAPER
PAPER, ASBESTOS
PAPER, CERAMIC
PAPER, GLASS FIBER
PAPER, GLASS FLAKE

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PAPER, JAPANESE
>   (Made from mulberry wood pulp. In 1-mil thicknesses, used as a backing for mica flake).

PAPER, KRAFT
>   (A tan sulfate paper easily impregnated with varnish. Used as cable and wire wrapping and insulation, backing for composites, and base for laminates).

Paper, Mica
>   See MICA PAPER

PAPER, ORGANIC
>   See also PAPER, CREPE
>   PAPER, FISH
>   PAPER, FLATBACK
>   PAPER, JAPANESE
>   PAPER, KRAFT
>   PAPER, PRESSBOARD
>   PAPER, RAG
>   PAPER, ROPE
>   PAPER, SULFATE
>   PAPER, WOODPULP

PAPER, PRESSBOARD
>   (Made from rag, or rag plus pulp, and is readily impregnated with oil.)

PAPER, RAG
>   (Good abrasion resistance, slot insulation, spacers. Very thin condenser papers either all rag or rag plus pulp.)

PAPER, ROPE
>   (A paper made from Manila hemp or old rope.)

PAPER, ROPE, CELLULOSE ACETATE COVERED

PAPER, SULFATE

PAPER, WOODPULP

Paraffin
>   See WAXES, PARAFFIN

PENTACHLORODIPHENYL

PENTACHLORODIPHENYL KETONE

PENTACHLORODIPHENYL OXIDE

PENTACHLOROETHYL BENZENE

PENTACHLOROPHENYL BENZOATE

PENTAETHYLENE GLYCOL

Perchloromethane
    See CARBON TETRACHLORIDE

PERFLUOROBUTANE

PERFLUOROPROPANE

Periclase
    (Natural Magnesium Oxide)
    See MAGNESIUM OXIDE

"Perspex" (Trade Name, Imperial Chemical Industries, Ltd.)
    See ACRYLIC PLASTICS

PF Resins
    See PHENOLIC PLASTICS

Phenol-Formaldehyde Plastics
    See PHENOLIC PLASTICS

Phenolic-Epoxy Plastics
    See EPOXY-PHENOLIC PLASTICS

Phenolic Impregnated Wood
    See WOOD, PHENOLIC IMPREGNATED

PHENOLIC LAMINATES

PHENOLIC LAMINATES, ASBESTOS FABRIC BASE

PHENOLIC LAMINATES, ASBESTOS PAPER BASE

PHENOLIC LAMINATES, COTTON FABRIC BASE

PHENOLIC LAMINATES, GLASS FABRIC BASE

PHENOLIC LAMINATES, GLASS FLAKE PAPER BASE

PHENOLIC LAMINATES, LINEN FABRIC BASE

PHENOLIC LAMINATES, NYLON FABRIC BASE

PHENOLIC LAMINATES, PAPER BASE

PHENOLIC PLASTICS

PHENOLIC PLASTICS, ASBESTOS FILLED

PHENOLIC PLASTICS, CELLULOSE FILLED

PHENOLIC PLASTICS, COTTON FLOCK FILLED

PHENOLIC PLASTICS, GLASS FIBER FILLED

PHENOLIC PLASTICS, MINERAL FILLED
    (Includes Mica fillings)

PHENOLIC PLASTICS, WOOD FLOUR FILLED

Phenolic-Polytrifluorochloroethylene Laminates, Paper Base
    See POLYTRIFLUOROCHLOROETHYLENE-PHENOLIC LAMINATES,
    PAPER BASE

Phenolic Resins
    See PHENOLIC PLASTICS

Phenyl Polysiloxanes
    See SILICONE FLUIDS

PHENYLINDAN DERIVATIVES

Phlogopite Mica
    See MICA, PHLOGOPITE

Phosphate Esters
    See ORGANIC ESTERS

Phosphate Glass
        See GLASS, PHOSPHATE

PLASTICS
        See also   ACETAL PLASTICS
                   ACRYLIC PLASTICS
                   ACRYLONITRILE PLASTICS
                   ALLYL PLASTICS
                   CASEIN PLASTICS
                   CELLULOID PLASTICS
                   CELLULOSE ACETATE BUTYRATE PLASTICS
                   CELLULOSE ACETATE PLASTICS

Plate Glass
        See GLASS

Plexiglas (Trade Name, Rohm & Haas)
        See ACRYLIC PLASTICS

"Pliofilm" (Trade Name, Goodyear Tire & Rubber Co.)
        See RUBBER, HYDROCHLORIDE

"Polectron" (Trade Name, General Aniline & Film Corp.)
        See POLYVINYL CARBAZOLE PLASTICS

POLYAMIDE LAMINATES

POLYAMIDE PLASTICS
        See also   POLYAMIDES, CAPROLACTUM PLASTICS
                   POLYAMIDES, NYLON 6 PLASTICS
                   POLYAMIDES, NYLON 66 PLASTICS
                   POLYAMIDES, NYLON 610 PLASTICS
                   POLYAMIDES, NYLON FM-300 PLASTICS
                   POLYAMIDES, NYLON SINTERED PLASTICS

Polyamide Resins
        (Compounds formed by the polymerization of amino acids or by
        the condensation of polyamines with polycarboxylic acids.)
        See POLYAMIDE PLASTICS
            POLYAMIDES, VERSAMIDES

POLYAMIDES, CAPROLACTUM PLASTICS

POLYAMIDES, NYLON FM-300 PLASTICS

POLYAMIDES, NYLON SINTERED PLASTICS

POLYAMIDES, NYLON 6 PLASTICS
     (Obtained by polycondensation of caprolactum).

POLYAMIDES, NYLON 6/6 OR 66 PLASTICS
     (Obtained by condensation of hexamethylene diamine with
     adipic acid.)

POLYAMIDES, NYLON 6/10 OR 610 PLASTICS
     (Obtained by condensation of hexamethylene diamine with
     sebacic acid.)

POLYAMIDES, VERSAMIDES

POLYAMIDES, ZYTEL 101

Polybutadiene Acrylonitrile Rubber
     See RUBBER, NITRILE-BUTADIENE

Polybutadiene Rubber
     See RUBBER, BUTADIENE

Polybutadiene Styrene Rubber
     See RUBBER, STYRENE-BUTADIENE

POLYBUTENES
     (General term for polymers of isobutene).
     See also RUBBER, BUTYL (71000 isobutene units)
                WAXES, POLYBUTENE

Polybutylenes
     See POLYBUTENES

Polycaprolactum Plastics
     See POLYAMIDES, CAPROLACTUM PLASTICS

POLYCARBONATE PLASTICS

Polychloroprene Nitrile Rubber
     See RUBBER, NITRILE-CHLOROPRENE

Polychloroprene Rubber
    See RUBBER, CHLOROPRENE

Polychlorotrifluoroethylene Plastics
    See POLYTRIFLUOROCHLOROETHYLENE PLASTICS

POLYDICHLOROSTYRENE PLASTICS

POLYESTER COPOLYMER PLASTICS

Polyester-Epoxy Plastics
    See EPOXY-POLYESTER PLASTICS

POLYESTER LAMINATES

POLYESTER LAMINATES, GLASS FABRIC BASE

POLYESTER LAMINATES, GLASS MAT BASE

POLYESTER LAMINATES, PAPER BASE

Polyester Plastics
    (A class of thermosetting resins produced by the esterification
    of polybasic organic acids with polyhydric alcohols.)
    See also POLYETHYLENE TEREPHTHALATE
    (The term alkyd resin is usually reserved for the saturated
    esters, which polymerize by the esterification reaction,
    while the term polyester resin is applied more specifically
    to the unsaturated esters of maleic acid, copolymers of
    unsaturated esters with monomers like styrene and the
    allyl resins.
    See also ALKYD PLASTICS
             ALLYL PLASTICS
             DIALLYL PHTHALATE PLASTICS
             POLYESTER COPOLYMER PLASTICS
             TRIALLYL CYANURATE PLASTICS

POLYESTER PLASTICS, ASBESTOS FILLED

POLYESTER PLASTICS, GLASS FIBER FILLED

POLYESTER PLASTICS, MINERAL FILLED

Polyester Rubber
>   See RUBBER, URETHANE

Polyesters, Fatty Acid Plastics
>   See ALKYD PLASTICS

Polyethylene Glycol Terephthalate
>   See POLYETHYLENE TEREPHTHALATE PLASTICS

POLYETHYLENE GLYCOLS
>   See also DIETHYLENE GLYCOL
>   ETHYLENE GLYCOL
>   HEPTAETHYLENE GLYCOL
>   HEXAETHYLENE GLYCOL
>   PENTAETHYLENE GLYCOL
>   TETRAETHYLENE GLYCOL
>   TRIETHYLENE GLYCOL

POLYETHYLENE PLASTICS
>   (Includes, High, Medium, & Low density types)

POLYETHYLENE PLASTICS, CARBON FILLED

POLYETHYLENE TEREPHTHALATE FIBER

POLYETHYLENE TEREPHTHALATE FILM

POLYETHYLENE TEREPHTHALATE PLASTICS
>   (A polyester resin formed from ethylene glycol and terephthalic acid).
>   See also POLYETHYLENE TEREPHTHALATE FIBER
>   POLYETHYLENE TEREPHTHALATE FILM

Polyglycol Terephthate
>   See POLYETHYLENE TEREPHTHALATE PLASTIC

Poly-(Hexamethylene Adipamide)
>   See POLYAMIDES, NYLON 6/6 PLASTICS

Poly-(Hexamethylene Sebacamide)
>   See POLYAMIDES, NYLON 6/10 PLASTICS

Polyisobutylenes
> See POLYBUTENES

Polymethyl Methacrylate
> See ACRYLIC PLASTICS

Polymonochlorotrifluoroethylene polymer
> See POLYTRIFLUOROCHLOROETHYLENE PLASTICS

"Polypenco"(Trade Name, Polymer Corp. of Pennsylvania; Polypenco, Inc.)
> See POLYCARBONATE PLASTICS

POLYPROPYLENE PLASTICS

POLYSTYRENE-ACRYLONITRILE COPOLYMER

POLYSTYRENE COPOLYMERS
> See also POLYSTYRENE-ACRYLONITRILE COPOLYMER

POLYSTYRENE LAMINATES, GLASS FABRIC BASE

POLYSTYRENE PLASTICS
> (Made by polymerization of the hydrocarbon styrene).
> See also POLYSTYRENE COPOLYMERS

POLYSTYRENE PLASTICS, GLASS FIBER FILLED

POLYSTYRENE PLASTICS, MINERAL FILLED

Polystyrene Rubber
> See RUBBER, POLYSTYRENE

Polysulfide-Epoxy Laminates, Glass Fabric Base
> See EPOXY-POLYSULFIDE LAMINATES, GLASS FABRIC BASE

Polytetrafluoroethylene Hexafluoropropylene Copolymer
> See POLYFLUOROETHYLENE PROPYLENE PLASTICS

POLYTETRAFLUOROETHYLENE LAMINATES

POLYTETRAFLUOROETHYLENE LAMINATES, CERAMIC FIBER BASE

POLYTETRAFLUOROETHYLENE LAMINATES, GLASS FABRIC BASE

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POLYTETRAFLUOROETHYLENE LAMINATES, GLASS MAT BASE

POLYTETRAFLUOROETHYLENE LAMINATES, MINERAL FIBER BASE

POLYTETRAFLUOROETHYLENE PLASTICS
    (High polymer of tetrafluoroethylene, $CF_2 = CF_2$).

POLYTETRAFLUOROETHYLENE PLASTICS, ASBESTOS FILLED

POLYTETRAFLUOROETHYLENE PLASTICS, CERAMIC FIBER FILLED

POLYTETRAFLUOROETHYLENE PLASTICS, GLASS FIBER FILLED

POLYTETRAFLUOROETHYLENE PLASTICS, PROPYLENE

POLYTETRAFLUOROETHYLENE PLASTICS, QUARTZ FILLED

POLYTETRAFLUOROETHYLENE PLASTICS, SILICA FILLED

Polythene Plastics
    See POLYETHYLENE PLASTICS

POLYTRIFLUOROCHLOROETHYLENE-EPOXY LAMINATES, GLASS FIBER BASE

POLYTRIFLUOROCHLOROETHYLENE-PHENOLIC LAMINATES, PAPER BASE

POLYTRIFLUOROCHLOROETHYLENE PLASTICS

POLYURETHANE PLASTICS
    (A class or resins obtained by the reaction od diisocyanates
    with phenols, amines, hydroxylic, and carboxylic compounds
    to form polymers having free isocyanate groups).

POLYVINYL ACETAL PLASTICS

Polyvinyl Acetals
    (General name for condensation products of acetaldehyde or
    any other aldehyde with polyvinyl alcohol. The aldehydes
    commonly used are formaldehyde, acetaldehyde, butyraldehyde).
    See POLYVINYL ACETAL PLASTICS
          POLYVINYL BUTRAL PLASTICS
          POLYVINYL FORMAL PLASTICS

POLYVINYL ACETATE PLASTICS
    (Derived from polymerization of vinyl acetate with peroxide
    catalysts).

POLYVINYL ALCOHOL PLASTICS
(Derived from acidic or basic hydrolysis of a polyvinyl ester, usually the acetate).

Polyvinyl Butyral Acetal
See POLYVINYL BUTYRAL PLASTICS

POLYVINYL BUTYRAL PLASTICS
(General name for product of condensation of acetaldehyde or other aldehyde with polyvinyl alcohol, obtained in turn by partial hydrolysis of polyvinyl acetate).

POLYVINYL CARBAZOLE PLASTICS
(Polymerization of N-vinyl carbazole, $C_{12}H_8NCH: CH_2$; similar to mica in dielectric properties).

Polyvinyl Chloride-Acetate Copolymers
See POLYVINYL CHLORIDE-ACETATE PLASTICS

POLYVINYL CHLORIDE-ACETATE PLASTICS

POLYVINYL CHLORIDE PLASTICS

POLYVINYL FLUORIDE PLASTICS

POLYVINYL FORMAL PLASTICS

POLYVINYL METHYL ETHER PLASTICS
(Polymerization of vinyl methyl ether).

POLYVINYL STEARATE PLASTICS

POLYVINYLIDENE CHLORIDE PLASTICS

POLYVINYLIDENE FLUORIDE PLASTICS

PORCELAIN
See also COATINGS, PORCELAIN ENAMEL
PORCELAIN, LITHIA
PORCELAIN, ZIRCON

Porcelain Enamel
See COATINGS, PORCELAIN ENAMEL

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PORCELAIN, LITHIA

PORCELAIN, ZIRCON

POTASSIUM NIOBATE

POTASSIUM TANTALATE

POTASSIUM TITANATE

Pressboard
>   See PAPER, PRESSBOARD

"Pro-fax" (Trade Name, Hercules Powder)
>   See POLYPROPYLENE PLASTICS

PTFE Plastics
>   See POLYTETRAFLUOROETHYLENE PLASTICS

PVA
>   See POLYVINYL ACETATE PLASTICS
>   POLYVINYL ALCOHOL PLASTICS

PVC Plastics
>   See POLYVINYL CHLORIDE PLASTICS

PVF Plastics
>   See POLYVINYL FLUORIDE PLASTICS

PVM Plastics
>   See POLYVINYL METHYL ETHER PLASTICS

PVS Plastics
>   See POLYVINYL STEARATE PLASTICS

"Pyrex" Glass (Trade Name, Corning Glass Co.)
>   See GLASS, BOROSILICATE

"PYROCERAM" (Trade Name, Corning Glass Co.)

Pyroxylin
>   See CELLULOSE NITRATE PLASTICS

QUARTZ

QUARTZ FABRICS

Quartz Filled Plastics
    See POLYTETRAFLUOROETHYLENE PLASTICS, QUARTZ FILLED

QUARTZ, FUSED

"Quinterra" (Trade Name, Johns-Manville Co.)
    See PAPER, ASBESTOS

RAYON

Reconstituted Mica (Inorganic Bonded)
    See MICA PAPER

Ribbon, Glass
    See GLASS RIBBON

Rigid PVC
    See POLYVINYL CHLORIDE ACETATE PLASTICS
        POLYVINYL CHLORIDE COPOLYMERS

Rope, Acetate
    See PAPER, ROPE (CELLULOSE ACETATE COVERED)

Rope, Paper
    See PAPER, ROPE

ROSIN

RUBBER
    See also   RUBBER, NATURAL
               RUBBER, SYNTHETIC

RUBBER, ACRYLIC ESTER-ACRYLONITRILE COPOLYMER

RUBBER, BUTADIENE

Rubber, Butadiene Acrylonitrile
    See RUBBER, NITRILE-BUTADIENE

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RUBBER, BUTYL
     (Synthetic rubber produced by copolymerization of isobutene
     (about 98%) with small proportion (2%) of isoprene or
     butadiene.)

RUBBER, CHLOROPRENE

Rubber, Chloroprene-Nitrile
     See RUBBER, NITRILE-CHLOROPRENE

RUBBER, ETHYLENE-PROPYLENE

RUBBER, HYDROCHLORIDE

RUBBER, NATURAL

RUBBER, NITRILE-BUTADIENE
     (A synthetic rubber made by the polymerization of acrylonitrile
     with butadiene).

RUBBER, NITRILE-CHLOROPRENE

RUBBER, POLYSTYRENE

RUBBER, POLYSULFIDE

RUBBER, SILICONE

RUBBER, STYRENE-BUTADIENE

RUBBER, SYNTHETIC
     See also   RUBBER, ACRYLIC ESTER-ACRYLONTRILE COPOLYMER
                  RUBBER, BUTADIENE
                  RUBBER, BUTYL
                  RUBBER, CHLOROPRENE
                  RUBBER, ETHYLENE-PROPYLENE
                  RUBBER, NITRILE-BUTADIENE
                  RUBBER, NITRILE-CHLOROPRENE
                  RUBBER, POLYSTYRENE
                  RUBBER, POLYSULFIDE
                  RUBBER, SILICONE
                  RUBBER, STYRENE-BUTADIENE
                  RUBBER, URETHANE

RUBBER, URETHANE

RUBBER, VINYL-NITRILE

Rutile (Natural Titaniam Dioxide)
See TITANIUM DIOXIDE

Saphir d'Eau
See CORDIERITE

Saponified Acetate Fiber
See RAYON

Sapphire
See ALUMINUM OXIDE

Saran

(Generic name for thermoplastic resin obtained by the
polymerization of vinylidene chloride or copolymerization
of vinylidene chloride with lesser amounts of other
unsaturated compounds).
See POLYVINYLIDENE CHLORIDE PLASTICS
VINYLIDENE CHLORIDE - VINYLCHLORIDE COPOLMER*

*Preferred

SBR Rubber
See RUBBER, STYRENE-BUTADIENE

"Silastic" Rubber (Trade Name, W. A. Cleary Corp.)
See RUBBER, SILICONE

Silica
See SILICON DIOXIDE
QUARTZ

Silica, Fibrous (Fabric)
See QUARTZ FABRICS

Silica Filled Plastics
See SILICONE PLASTICS, SILICA FILLED
POLYTETRAFLUOROETHYLENE PLASTICS, SILICA FILLED

Silica, Fused
    See QUARTZ, FUSED

Silica Glass
    See GLASS, SILICA

Silica, Vitreous
    See QUARTZ, FUSED

SILICATE ESTER BASE FLUID

Silicate Glass
    See GLASS, SODA-SILICA

SILICON CARBIDE

SILICON DIOXIDE

Silicon Dioxide (Natural crystals)
    See QUARTZ

SILICONE
    See also   RUBBER, SILICONE
                 SILICONE DIELECTRIC GEL
                 SILICONE FLUIDS
                 SILICONE GREASES
                 SILICONE PLASTICS
                 VARNISHES, SILICONE

SILICONE DIELECTRIC GEL

Silicone Elastomers
    See RUBBER, SILICONE

SILICONE FLUIDS

SILICONE GREASES

SILICONE LAMINATES

SILICONE LAMINATES, ASBESTOS BOARD BASE

SILICONE LAMINATES, ASBESTOS FABRIC BASE

SILICONE LAMINATES, ASBESTOS PAPER BASE

SILICONE LAMINATES, GLASS BASE

SILICONE LAMINATES, GLASS FABRIC BASE

SILICONE LAMINATES, GLASS MAT BASE

SILICONE MONOXIDE FILMS

SILICONE PLASTICS

SILICONE PLASTICS, ASBESTOS FILLED

SILICONE PLASTICS, GLASS FIBER FILLED

SILICONE PLASTICS, MINERAL FILLED

SILICONE PLASTICS, SILICA FILLED

Silicone Resins
   See SILICONE PLASTICS

Silicone Rubber
   See RUBBER, SILICONE

Silicone Varnished Glass Fabric
   See VARNISHES, SILICONE, GLASS FABRIC FILLED

Silicone Varnishes
   See VARNISHES, SILICONE

SILK

Soapstone (Impure Steatite)
   See STEATITE

Sodium Aluminum Fluoride
   See CRYOLITE

Sodium Fluoaluminate
   See CRYOLITE

SODIUM NIOBATE

SODIUM TANTALATE

Soft Glass
 See GLASS, LEAD/POTASSIUM

Spar Varnish
 See VARNISHES, OIL

SPINEL

Spirit Varnishes
 See VARNISHES, SPIRIT

STANNATE CERAMICS

Stearin and Fatty Acid Waxes
 See WAXES, STEARIN AND FATTY ACID

STEATITE (Compact massive variety of TALC)

STRONTIUM NIOBATE

STRONTIUM OXIDE

STRONTIUM TANTALATE

STRONTIUM TITANATE

Styrene-Butadiene Rubber
 See RUBBER, STYRENE-BUTADIENE

Styrene Plastics
 See POLYSTYRENE PLASTICS

Succinate
 See AMBER

SULFUR

SULFUR HEXAFLUORIDE

"Supramica" (Trade Name, Mycalex Corp. of America)
 See MICA, SYNTHETIC, GLASS-BONDED

TAC Plastics
 See TRIALLYL CYANURATE PLASTICS

TAC Polyester
 See TRIALLYL CYANURATE PLASTICS

TALC (Foliated variety of natural hydrous magnesium silicate).
 See also STEATITE

Talcum
 See TALC

TANTALATE CERAMICS
 See also BARIUM TANTALATE
      CALCIUM TANTALATE
      CERAMICS
      LITHIUM TANTALATE
      MAGNESIUM TANTALATE
      POTASSIUM TANTALATE
      SODIUM TANTALATE
      STRONTIUM TANTALATE
      TANTALUM OXIDE

TANTALUM OXIDE

"Tedlar" (Trade Name, DuPont)
 See POLYVINYL FLUORIDE PLASTICS

Teflon FEP
 See POLYFLUOROETHYLENE PROPYLENE PLASTICS

"Teflon 100" (Trade Name, DuPont Co.)
 See POLYFLUOROETHYLENE PROPYLENE PLASTICS

Teflon TFE
 See POLYTETRAFLUOROETHYLENE PLASTICS

Teflons
 See POLYTETRAFLUOROETHYLENE PLASTICS
   POLYFLUOROETHYLENE PROPYLENE PLASTICS

"Tenite" Acetate (Trade Name, Eastman Chemical Products)
"Tenite I"
      See CELLULOSE ACETATE PLASTICS

"Tenite" Butyrate (Trade Name, Eastman Chemical Products)
"Tenite II"
      See CELLULOSE ACETATE BUTYRATE PLASTICS

"Tenite" Polyethylene (Trade Name, Eastman Chemical Products)
      See POLYETHYLENE PLASTICS

"Terylene" (Trade Name, Imperial Chemicals, London).
      See POLYETHYLENE TEREPHTHALATE FIBER

"Teslar" (Trade Name, Du Pont)
      See POLYVINYL FLUORIDE PLASTICS

Tetrachloromethane
      See CARBON TETRACHLORIDE

TETRAETHYLENE GLYCOL

Tetrafluorodichloroethane
      See DICHLOROTETRAFLUOROETHANE

Tetrafluoromethane
      See CARBON TETRAFLUORIDE

TETRAHYDROFURFURYLOXALATE

TFE Plastics
      See POLYTETRAFLUOROETHYLENE PLASTICS

TFE Teflon
      See POLYTETRAFLUOROETHYLENE PLASTICS

"Thiokol" Organic Polysulfide Rubbers: A, FA, ST.
      See RUBBER, POLYSULFIDE

"Thiokol RD" (Trade Name, Thiokol Chemical Corp.)
      See RUBBER, NITRILE-BUTADIENE

Titanate Ceramics
    See also   BARIUM TITANATE
              CALCIUM TITANATE
              LEAD TITANATE
              MAGNESIUM TITANATE
              STRONTIUM TITANATE
              TITANIUM DIOXIDE
              ZIRCONIUM TITANATE

Titania
    See   TITANIUM DIOXIDE

Titanic Acid Anhydride
    See   TITANIUM DIOXIDE

Titanic Anhydride
    See   TITANIUM DIOXIDE

Titanic Oxide
    See   TITANIUM DIOXIDE

TITANIUM DIOXIDE

Titanium White
    See   TITANIUM DIOXIDE

TRANSFORMER OIL
    See also ASKARELS

TRIALLYL CYANURATE LAMINATES

TRIALLYL CYANURATE LAMINATES, GLASS MAT BASE

TRIALLYL CYANURATE PLASTICS

Triallyl Cyanurate Resins
    See   TRIALLYL CYANURATE PLASTICS

TRICHLOROBENZENE

TRICHLOROFLUOROMETHANE

Trichloromonofluoromethane
    See   TRICHLOROFLUOROMETHANE

TRICHLOROTRIFLUOROETHANE

TRIETHYLENE GLYCOL

Trifluorochloromethane
    See CHLOROTRIFLUOROMETHANE

TRIFLUOROMETHANE

Trifluoromonobromomethane
    See BROMOTRIFLUOROMETHANE

Trifluorotrichloroethane
    See TRICHLOROTRIFLUOROETHANE

Urea-Formaldehyde Plastics
    See UREA PLASTICS

UREA PLASTICS
    (Synthetic resin derived from reaction of urea (carbamide)
    with formaldehyde).

UREA PLASTICS, ALPHA CELLULOSE FILLED

UREA PLASTICS, ASBESTOS FILLED

Urethane Plastics
    See POLYURETHANE PLASTICS

Urethane Rubber
    See RUBBER, URETHANE

Varnishes
    See VARNISHES, OIL
         VARNISHES, SPIRIT

VARNISHES, OIL
    (Film-forming by oxidation or polymerization of binder alone
    or in combination with natural or synthetic resins,
    chlorinated rubber, etc.) (Includes "solventless" varnishes)
    See also FOSTERITE

VARNISHES, OIL, GLASS FABRIC FILLED

VARNISHES, OIL, GLASS FIBER FILLED

VARNISHES, SILICONE

VARNISHES, SILICONE, GLASS FABRIC FILLED

VARNISHES, SILICONE, GLASS FIBER FILLED

VARNISHES, SPIRIT
      (Film-forming by <u>evaporation</u> of the solvent, such as shellac, cellulose ester or ether, alkyd or phenolic resin varnishes). (Solvents such as methanol, methyl isobutyl ketone, butyl acetate, toluene, etc.)
      <u>See also</u> VARNISHES, SILICONE

"Versamides" (Trade Name, General Mills)
      (Condensation of polycarboxylic acids with polyamines).
      <u>See</u> POLYAMIDES, VERSAMIDES

N-Vinylcarbozole Polymers
      <u>See</u> POLYVINYL CARBAZOLE PLASTICS

Vinyl Chloride Copolymers
      <u>See</u> VINYLIDENE CHLORIDE-VINYLCHLORIDE COPOLYMER

Vinyl Chloride-Vinyl Acetate Copolymers
      <u>See</u> POLYVINYL CHLORIDE-ACETATE PLASTICS

Vinyl-Nitrile Rubber
      <u>See</u> RUBBER, VINYL-NITRILE

VINYL PLASTICS
      <u>See also</u>   POLYVINYL ACETATE PLASTICS
                  POLYVINYL ALCOHOL PLASTICS
                  POLYVINYL BUTRYAL PLASTICS
                  POLYVINYL CHLORIDE-ACETATE PLASTICS
                  POLYVINYL CHLORIDE PLASTICS
                  POLYVINYL FLUORIDE PLASTICS
                  POLYVINYL METHYL ETHER PLASTICS
                  POLYVINYL STEARATE PLASTICS
                  POLYVINYLIDENE CHLORIDE PLASTICS

Vinyl Resins
      <u>See</u> VINYL PLASTICS

VINYLIDIENE CHLORIDE-VINYLCHLORIDE COPOLYMER

VINYLIDENE FLUORIDE-HEXAFLUOROPROPYLENE COPOLYMER

VINYLIDENE FLUORIDE-TRIFLUOROCHLOROETHYLENE COPOLYMER

Vinylidene Polymers
      See POLYVINYLIDENE CHLORIDE PLASTICS
           POLYVINYLIDENE FLUORIDE PLASTICS
           VINYLIDENE FLUORIDE-HEXAFLUOROPROPYLENE COPOLYMER

"Vinylite" (Trade Name, Union Carbide)
      (Available in four series, A, Q, V, and X)
      Series A (Polymerized vinyl acetate, vinyl alcohol-acetate)
      See POLYVINYL ACETATE PLASTICS
           POLYVINYL ALCOHOL PLASTICS

      Series Q (Polymerized vinyl chloride)
      See POLYVINYL CHLORIDE PLASTICS

Viscose Film
      See CELLOPHANE

Viscose Rayon
      See RAYON

"Viton A" (Trade Name, DuPont Co.)
      See VINYLIDENE FLUORIDE-HEXAFLUOROPROPYLENE COPOLYMER

Vitreous Enamel
      See COATINGS, PORCELAIN ENAMEL

Vitreous Porcelain Enamel
      See COATINGS, PORCELAIN ENAMEL

VULCANIZED FIBER
      See also PAPER, FISH

"Vulkene" (Trade Name, General Electric Co.)
      See POLYETHYLENE PLASTICS, CARBON FILLED

"Vycor" Glass (Trade Name, Corning Glass)
      See GLASS, SILICA

WAXES, ACRAWAX

WAXES, BEESWAX

WAXES, CARNAUBA

WAXES, CARNUBE

WAXES, CERESIN

WAXES, CETYLACETAMIDE

WAXES, CHLORONAPHTHALENE

WAXES, HYDROXYSTEARIN

WAXES, MONTAN

WAXES, OURICURY

WAXES, PARAFFIN

WAXES, POLYBUTENE

WAXES, STEARIN AND FATTY ACID

Waxes, Wool
> See WAXES, STEARIN AND FATTY ACID

WOLLASTONITE
> (Natural calcium silicate, $CaSiO_3$)

WOOD, PHENOLIC IMPREGNATED

Woodflour Filled Plastics
> See MELAMINE PLASTICS, WOODFLOUR FILLED
> PHENOLIC PLASTICS, WOOD FLOUR FILLED

Wool Wax
> See WAXES, STEARIN AND FATTY ACID

Woven Asbestos
> See ASBESTOS

XENON

ZINC NIOBATE

ZINC SULFIDE FILMS

ZIRCITE (Natural zirconium oxide)
        See also ZIRCONIUM OXIDE

ZIRCON

Zircon Porcelain
        See PORCELAIN, ZIRCON

ZIRCONATE CERAMICS
        See also BARIUM ZIRCONATE
                       LEAD ZIRCONATE

Zirconia
        See ZIRCONIUM OXIDE

Zirconia, Sintered
        See ZIRCONIUM OXIDE

Zirconic Anhydride
        See ZIRCONIUM OXIDE

Zirconium Anhydride
        See ZIRCONIUM OXIDE

Zirconium Dioxide
        See ZIRCONIUM OXIDE

ZIRCONIUM OXIDE

ZIRCONIUM TITANATE

Zirkite
        See ZIRCITE

"Zytel" (Trade Name, DuPont Co.)
        (Nylon resin molding powders and Nylon soluble resin).
        See POLYAMIDES, ZYTEL 101

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GLOSSARY OF SELECTED PROPERTIES AND EFFECTS

The following preliminary glossary of selected properties and effects has been assembled to assist all personnel involved in the Electronic Properties of Materials Program. An attempt has been made to give simple explanations and descriptions of those properties and effects most relevant to the scope of the Project. In addition, supplementary background information in the form of notes, diagrams, equations, and related terminology is included. Typical graphs are included to aid in the standardization of compilation, evaluation, and presentation of the data.

ABSORPTION COEFFICIENT

Symbol: α (alpha)

Units: cm^{-1}

When light or other electromagnetic radiation enters matter it experiences attenuation. This attenuation is of two types: scattering and absorption. The scattered radiation is reflected in all directions without essential change of character, while the absorbed radiation, by being converted into other forms of energy, either ceases to exist as radiation or is re-emitted as secondary radiation. The rate at which this occurs is termed the absorption or scattering coefficient. Strictly speaking, therefore, the true absorption coefficient should be distinguished from the scattering coefficient, but for practical purposes it is sometimes convenient to add them together as the total attenuation or extinction coefficient.

The decrease in flux density (intensity of light), dI is proportional to the original intensity, I_o, times the distance traversed, dx,

$$dI = -\alpha I_o dx \qquad (1)$$

which may be integrated to:

$$I = I_o e^{-\alpha x} \qquad , \qquad (2)$$

where α is the absorption coefficient. (It may be noticed that this equation is typical of other physical phenomena where there is an exponential decay or decrease.) For scattering, in which the same law

is obeyed, α is the scattering coefficient. And for the total attenuation α is the extinction coefficient (the sum of the absorption and scattering coefficients).

The coefficient characterizing true absorption is a function of the incident radiation; a plot of the absorption coefficient versus wavelength or photon energy constitutes the ABSORPTION SPECTRUM of the material. Such spectra usually display certain distinctive features characteristic of the various mechanisms responsible for the absorption. For example, free carriers give rise to a spectrum in which α increases
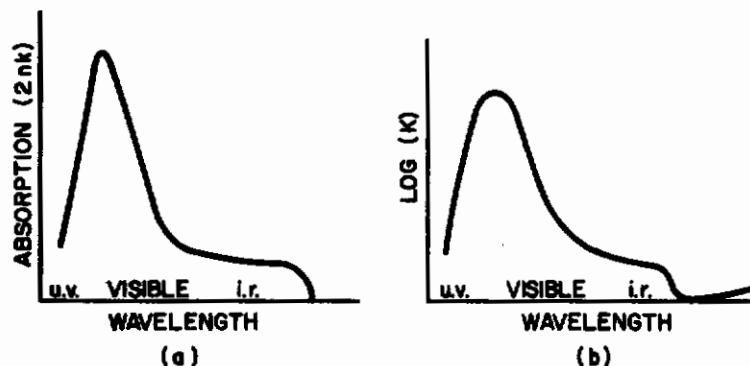
Typical absorption spectra

with some low power of the wavelength, e.g., α λ^2 or $\lambda^{3/2}$. The absorption spectrum due to impurities is usually characterized by a number of sharp bands followed by a broad band. The absorption due to transitions of electrons between the valance and conduction bands gives a broad band with a very steep long wavelength edge, usually referred to as the intrinsic ABSORPTION EDGE. Absorption bands are also produced as a result of the interaction of radiation with lattice vibrations.

Both the reflectance R and the transmittance T must be measured in order to determine the absorption constant (α). The relation between these three quantities is expressed by the equation:

$$T = \frac{(1-R)^2 e^{-\alpha d}}{1-R^2 e^{-2\alpha d}} \qquad (3)$$

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where $T = I/I_i$. (I_i is the intensity of radiation incident on the sample and I is the transmitted intensity, R is the reflectance of only one surface, i.e., of an infinitely thick sample, and d is the thickness of the sample.)

It is also possible to determine the absorption spectrum from the reflectance spectrum, provided that measurements have been made over wavelengths including all principal absorption bands. The results of such a determination are usually presented in terms of the extinction coefficient, k, which is related to α by

$$\alpha = \frac{4\pi k}{\lambda} \qquad (4)$$

ABSORPTION EDGE

Symbol: E_g, E_o, ΔE, $\tilde{\nu}_o$, λ_o

Units: Photon energy (ev.),
          Wavelength (Microns, angstroms)
          Wavenumber (cm^{-1})

Experimentally, the absorption edge appears as a sharp rise in the absorption coefficient in a very narrow range of wavelength. Where the mechanism of the absorption process is not understood, the actual location of the edge is defined by some arbitrary criteria. For example, it might be taken as the wavelength or photon energy at which the transmittance falls to $1/2$ or $1/10$ of its peak value.

The characteristic feature of all semiconductors, in the pure state, is that at a certain wavelength, generally in the near or intermediate infra-red, the absorption coefficient drops rapidly and the material becomes fairly transparent at longer wavelengths. This marked drop in absorption is called the fundamental absorption edge; it is sometimes referred to in the literature as the 'lattice absorption edge', but this terminology is unfortunate, as 'lattice absorption' implies absorption by exciting the lattice vibrations, and the fundamental edge is due to an electronic transition.

In semiconductors, the transitions responsible for the intrinsic absorption edge may be classed as either direct or indirect. In the former case the absorption constant varies with the photon energy according to the relation

$$\alpha = \text{constant} \cdot (h\nu - E_i)^{1/2} \qquad (5)$$

and in the latter case

$$\alpha = \text{constant} \cdot (h\nu - E_i)^2 \qquad (6)$$

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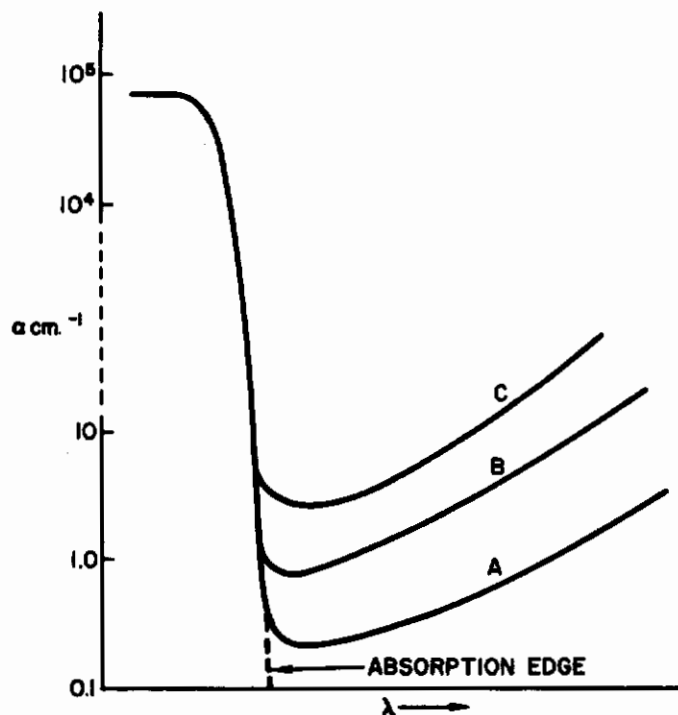
Variation of absorption with
wavelength near the fundamental absorption
edge for specimens of different purity.
(Curve A represents the purest sample.)

The analysis of the data is simplified in the former case by plotting α^2 vs. $h\nu$ and in the latter by plotting $\alpha^{1/2}$ vs. $h\nu$. The straight line portions of the resulting curves can be extrapolated to intersect the photon energy axis. The intersection point is the required absorption edge.

ABSORPTION SPECTRUM

The spectral dependance of the absorption coefficient. See ABSORPTION EDGE and ABSORPTION COEFFICIENT for discussion.

ACTIVATION ENERGY

Symbol: E_g, E_i, Q

(7)

Units: ev (electron volt)

Activation energy is defined as the increase in energy required by an atomic system to raise it from the ground state to a state capable of serving a particular function. Examples in solid state physics are the energy required to break a valence bond, to remove an electron

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from a donor, or to remove a hole from an acceptor. It is also defined as the excess energy over the ground state which must be acquired by an atomic or molecular system in order that a particular process may occur, such as the energy needed by an electron to reach the conduction band in a semiconductor. Where the process results in the generation of free carriers, the activation energy is frequently referred to as an ionization energy.

Activation energy is included as a term in a number of basic equations:

1) Conductivity: $\sigma(T) = \sigma_i e^{-\frac{E_g}{2kT}}$ (8)

where σ_i is the intrinsic conductivity, and E_g is the activation energy, or the intrinsic energy gap in this instance.

2) Diffusion: $D = D_o e^{-Q/kT}$, (9)

where Q is the activation energy in ev.

ARC RESISTANCE

Symbol: None

Units: Seconds

Arc resistance is a measure of the resistance of the surface of an electrically insulating material to breakdown under electrical stress. ASTM standard test D-495 measures the total elapsed time until failure occurs when an arc of high voltage and low current is passed between two electrodes in contact with an insulation surface. The time to failure is measured in seconds. The insulation is said to "track" when a conducting path, usually the result of carbonization under the action of the arc, forms between the electrodes.

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ATOMIC POLARIZATION

Symbol: α (Alpha)

Units: susceptability per atom

The atomic polarization is the susceptability per atom. If P is the dipole moment per unit volume induced by an electric field E, the polarization χ is given by $P = \chi e_o E$, where e_o is the permittivity of free space, and the polarizability per atom is $a = \chi/n$, where n is the number of atoms per unit volume. (See also, POLARIZATION.)

BREAKDOWN

A disruptive discharge (puncture) through an insulation. See BREAKDOWN VOLTAGE and DIELECTRIC STRENGTH.

BREAKDOWN VOLTAGE

Symbol: None

Units: V (voltage)

A disruptive discharge through an insulating medium is termed a breakdown of that insulation; if through a solid, a breakdown puncture. The voltage at which it occurs is the breakdown voltage. The breakdown voltage is a function of the other electrode voltages or currents and of the environment. In gaseous environments the breakdown voltages are sometimes termed "pickup voltage," "starting voltage," etc.

CAPACITANCE

Symbol: cm. or F

Units: Centimeters in the esu system of units; Fareds in the mksa system.

The capacity or capacitance of a system refers to the ratio of the charge on either of a pair of conductors to the potential difference between them. It therefore has the units of charge divided by potential. (See above.) The capacitance depends on the sizes of the pair of conductors, their shape, separation, and on the dielectric constant of the medium separating them; it increases with area of the conductors and is inversely proportional to the distance between them.

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ELECTRODES OF AREA A

DISTANCE BETWEEN
ELECTRODES

SEPARATING MEDIUM OF
DIELECTRIC CONSTANT e'
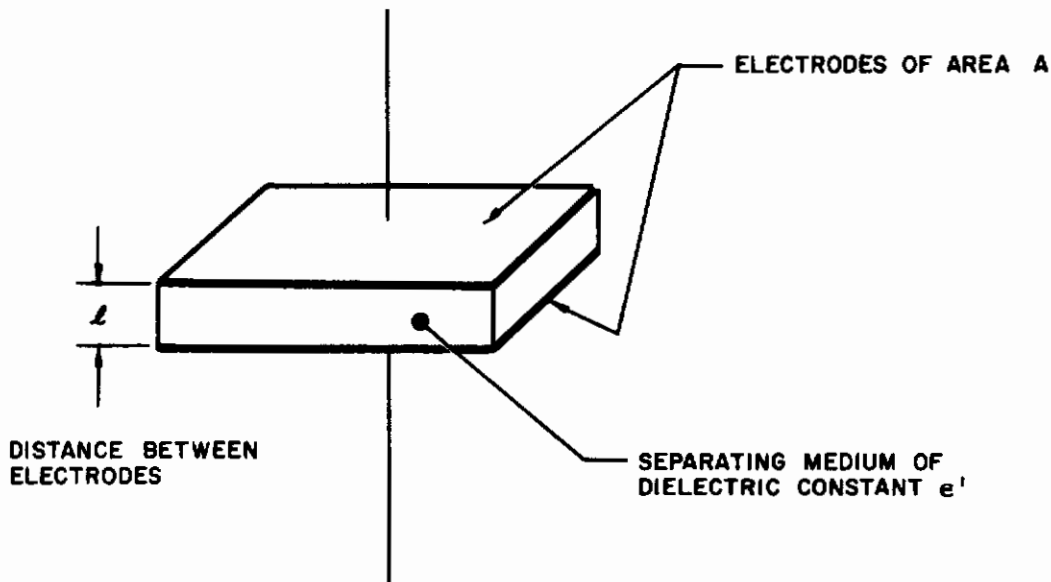
Capacitance $= C = \dfrac{e'A}{l} = \dfrac{Q}{V}$ (where electrostatic units are used) (10)

CAPACITY, SPECIFIC

A variant term for the DIELECTRIC CONSTANT.

CORONA DISCHARGE

This is a luminous discharge due to the ionization of a gas surrounding a conductor around which there exists a potential gradient which exceeds a certain value but is not sufficient to cause sparking.

CROSS SECTION

Symbol: σ (Sigma); S

Units: An area, usually cm^2

Cross section is a parameter which expresses the probability of interaction between a scattering or absorbing center and an incident particle. If there is a flux density of Φ particles/cm^2 moving with an average velocity $\bar{v}$ incident on matter with N interacting centers per cubic centimeter, each interacting center may be regarded as the center of a circular area σ with regard to the incident particles. An incident particle passing through this area will experience an interaction, scattering or absorption. The number of such collisions per

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second in a square centimeter of the matter is proportional to the flux Φ , the velocity $\bar{v}$, and the concentration of interacting centers N ; i.e., is equal to $\sigma N\bar{v}\Phi$, where the constant of proportionality is the cross section for interaction.

> Note: Other terminology related to cross section:
>
> > Equivalent cross sectional area
> > Collision cross section
> > Recombination cross section
> > Impurity cross section

CYCLOTRON RESONANCE

Symbol: None

Units: None

In ideal crystals, electrons and holes move respectively under the influence of applied fields, like free particles with negative and positive charges with the appropriate effective masses. In general, the effective mass of the hole will not be the same as that for an electron, since they arise from different bands.

Cyclotron resonance is a method for determing $m*$, the effective mass, one of the most important quantities for any semiconductor. It was shown in 1951 that, in general, the effective mass of neither holes nor electrons could be represented by a single scalar quantity $m*$. From the form of the effective mass tensor a great deal may be deduced about the general form of the energy bands.

The method is based upon the fact that the path of a charged particle moving with a velocity v is bent into a circular orbit of radius r when a magnetic field of induction B is applied,

$$\frac{m*v^2}{r} = Bev, \quad (e = \text{charge of an electron}) \quad (11)$$

or

$$v = Ber/m* \quad (12)$$

The electron describes the circle with frequency ν_c given by

$$\nu_c = \frac{Be}{2\pi m*} \quad (13)$$

This frequency is known as the cyclotron frequency; it is independent of the radius of the circle. If now, a small radio frequency field is also applied, the electron will absorb energy provided the frequency is equal to ν_c, and the radius of the circle will grow. This resonant condition may be observed and ν_c determined experimentally. Knowing ν_c, m* may be readily calculated.

Cyclotron resonance measurements are usually made at a fixed frequency and the magnetic field is varied in a search for the resonance absorption. The data are presented as a plot of relative absorption as
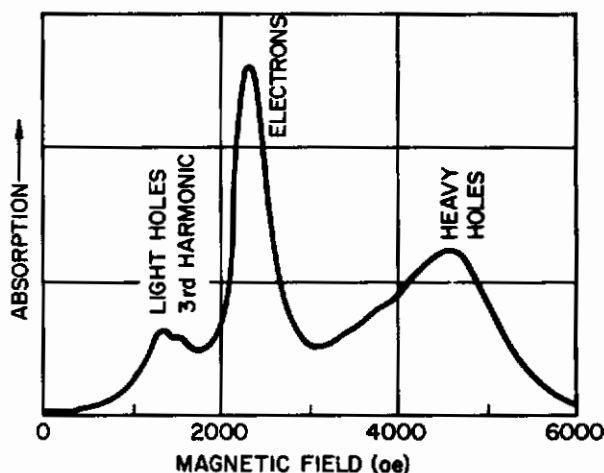
Cyclotron resonance trace in silicon near 4°K and 23,000 Mc/sec; external magnetic field was nearly parallel to the [111] axis after R.N. Dexter, H.J. Zeiger, and B. Lax, Phys, Rev. 104, 637 (1956) .

a function of magnetic field for various crystal orientations relative to the direction of the field. Frequently, only the effective masses and energy band parameters, determined from the measurements, will be given, or the results are given in terms of effective mass, $m*/m_o$, although other parameters characterizing band structures are used when necessary.

In a quantum mechanical treatment of the problem of a free carrier in a magnetic field, it is found that the continuum of energy levels

characteristic of a band breaks up into a series of highly degenerate
discrete energy levels, termed Landau levels, which have a spacing

$$h\nu_c = \frac{Beh}{2\pi m^*} \tag{14}$$

so that the system exhibits absorption of radiation at the frequency
ν_c, in agreement with the cyclotron results above.

DEBYE TEMPERATURE

Symbol: θ_D (Theta), or T_D

Units: °K

Instead of assuming a fixed frequency for all oscillations in the
solid, Debye supposed that the spectrum of the thermal vibrations of a
crystal lattice was similar to that of a continuum, except that it is cut
off at a maximum frequency in such a way that the total number of vibra-
tional modes is equal to the total number of degrees of freedom of the
lattice. This assumption leads to the equation for the molar specific
heat at constant volume:

$$C_v = 3Nk \left[4D - \frac{3\theta_D/T}{e^{\theta_D/T} - 1} \right] \tag{15}$$

where θ_D is the Debye temperature, N is the Avogadro number, k the
Boltzmann constant, T the absolute temperature, and D the Debye
function:

$$D(x) = \frac{3}{x^3} \int_0^x \frac{x^3 dx}{e^x - 1} \tag{16}$$

Here $x = \theta_D/T$ and the Debye temperature is

$$\theta_D = h\nu_D/k \tag{17}$$

where ν_D is the cut-off frequency,

$$\nu_D = \left[9N/4\pi \ V\left(2c_t^{-3} + c_\ell^{-3} \right) \right]^{1/3} \quad , \qquad (18)$$

V being the specific volume, c_t the speed of transverse waves in the crystal, and c_ℓ the speed of longitudinal waves.

The Debye temperature is important for characterizing the phonon spectrum of a crystal and is determined from measurements of the temperature dependance of specific heat, or from elastic constant measurements.

When $T \ll \theta_D$, it is found that

$$C_v \approx \frac{12Nk}{5\pi} \left(\frac{T}{\theta_D} \right)^3 \quad , \qquad (19)$$

that is, the specific heat varies as the cube of the absolute temperature. This conclusion is known as the Debye T^3 approximation and is in reasonable agreement with experiment except for metals, in which the electronic specific heat becomes important at low temperatures.

DIELECTRIC

A medium having the property that the energy required to establish an electrical field is recoverable, in whole or in part, as electrical energy. It is also defined as a material of low d-c electric conductivity and hence a good insulator. (See also DIELECTRIC CONSTANT and POLARIZATION).

DIELECTRIC ABSORPTION

In some dielectrics there is a persistance of electric polarization after removal of the polarizing electric field; i.e., there exists a residual polarization. For example, a capacitor may be discharged repeatedly with series of diminishing discharge currents. In some materials it is possible to establish a permanently polarized body, analogous to a permanent magnet. Such bodies are called "electrets" and are usually composed of certain waxes which are allowed to harden within a strong electric field. In these materials the polarization may last for years. (See also DIELECTRIC LOSS)

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DIELECTRIC CONSTANT

In the presence of an electric field, a free atom will acquire a dipole moment because the center of charge of the electron cloud is displaced from the positive nucleus. A similar effect occurs for all the atoms in a solid, resulting in a net polarization per unit volume. Because of this polarization, the electric field strength (E) induced in the medium by an external system of free charges (e.g., charged capacitor plates) is less than the field (D), the electric displacement, induced in free space by the same distribution of charges. The ratio $D/E = \epsilon$ in the c.g.s., e.m.u., and e.s.u. systems is defined as the absolute dielectric constant or permittivity of the medium. For isotropic media, ϵ is a scalar so that the vectors D and E have the same direction and differ only in magnitude. In anisotropic media, ϵ is a tensor. In the MKS practical system of units, $D/E = \epsilon \epsilon_o$ where ϵ has the same value as before and ϵ_o is the dielectric permittivity of free space. A medium of dielectric constant ϵ included between the plates of a capacitor will increase the capacitance by a factor ϵ.

The dielectric constant may be defined in terms of this effect, since for a parallel plate capacitor of area A and separation d

$$C = A/d \qquad (C = \text{capacitance}) \qquad (20)$$

in vacuum, and

$$C = \epsilon A/d \qquad (21)$$

if a material of dielectric constant ϵ is placed between the plates.

The dielectric constant is a function of the frequency of the applied electric field and can vary with temperature. Free carriers can make a contribution to the dielectric constant of a medium, as well as the electrons bound to the atomic sites. At optical frequencies the dielectric constant is the square of the index of refraction in transparent material $\epsilon = n^2$, (Maxwell's relation).

The dielectric constant, ϵ, of an ensemble of molecules, whether they constitute a gas, liquid, or solid, depends on the polarizabilities and the dipole moments of the individual molecules. In the absence of permanent dipoles, it is given by the Clausius - Mosotti equation,

$$\frac{\epsilon - 1}{\epsilon + 2} = \frac{4\pi}{3} N \alpha = \frac{\epsilon}{M} P_M \qquad (22)$$

where ϵ is the dielectric constant, α is the polarizability of the individual molecules of an assembly containing N such molecules per

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unit volume, where ρ/M is the ratio of density to molecular weight, and P_M is the molar polarization of the substance.

For dipoles of moment μ , the dielectric constant is given by

$$e = 1 + \frac{4\pi N\mu^2}{3k(T - T_c)} \tag{23}$$

where $T_c = 4\pi N\mu^2/9k$, the temperature of the polarization catastrope and k is the Boltzmann constant.

The dielectric constant is sometimes also known as the specific inductive capacity, the specific capacity, and the relative permittivity. It is also considered as a measure of the capacity of a material to store electrical energy. The dielectric constant is sometimes written in the literature as e'.

DIELECTRIC CONSTANT, COMPLEX

The ratio of the static capacitance C of a capacitor filled with a dielectric medium to its geometrical or vacuum capacitance is $C/C_o = e/e_o = K$, where e and e_o are the permittivities of the medium and of free space, respectively, and K is the relative dielectric constant. If the medium is dissipative (either because it is not a perfect insulator, so that real currents can flow through it, or because there is frictional resistance to induced polarization currents), the a-c behavior of the capacitance is equivalent to that of a resistance in parallel with a capacitance. The effect of this resistance can be incorporated into the dielectric constant, which then becomes a complex quantity denoted by $k^* = e^*/e_o$, which can be written as $k^* = k' - jk''$. The imaginary coefficient (k'' or e'') is called the LOSS FACTOR, $\tan\delta = k''/k'$ or $\frac{e''}{e'}$ is called the LOSS TANGENT, and δ is called the LOSS ANGLE.

DIELECTRIC LOSS

The power loss in a dielectric due to dielectric heating caused by molecular friction in it as a result of the application of a high-frequency, alternating electric field. (See DIELECTRIC CONSTANT, COMPLEX.)

DIELECTRIC LOSS ANGLE

See LOSS ANGLE.

DIELECTRIC LOSS FACTOR

See LOSS FACTOR.

DIELECTRIC PHASE ANGLE

See PHASE ANGLE

DIELECTRIC POWER FACTOR

See POWER FACTOR

DIELECTRIC STRENGTH

Symbol: None

Units: V (volts per unit thickness)

The maximum potential gradient (electric field strength) that a material can withstand without rupturing is termed its dielectric strength. It is usually expressed in volts per mil; sometimes in volts per micron. (See also BREAKDOWN VOLTAGE.) The ASTM uses four basic tests: Short-time, Step-by-Step, Slow Rate of Rise (generally an alternate to Step-byStep), and Long-Time. The relation between dielectric strength and thickness is not usually linear, having higher "volts per mil" values for the thinner cross-sections. The dielectric strength decreases with time of exposure to the electrical stress.

DISSIPATION FACTOR

Symbol: D, $\tan\delta$

The DISSIPATION FACTOR IS defined as the ratio of the parallel reactance (X_C) to the parallel resistance (R_C), or the ratio of the conductance (G) of the dielectric (capacitor), to the susceptance (B). It is also known as the Loss Tangent, since it may be defined as the tangent of the LOSS ANGLE, δ, or the cotangent of the PHASE ANGLE, θ.

The reciprocal of the DISSIPATION FACTOR, D, is known as the Storage Factor, Q, sometimes called the Quality Factor.

$$D = \cot\theta = \tan\delta \frac{R_C}{X_C} = \frac{G}{B} = \frac{1}{Q} \tag{24}$$

As a measure of the energy dissipated to the energy stored per cycle, it is an indication of the relative "lossiness" of a dielectric for normally "good" capacitors and is a convenient term easily integrated by "bridge" measurements. When the cotangent of the phase angle is smaller than 0.1 (10%), the cosine and cotangent differ by less than 0.0005 and the dissipation factor D may be considered to be identical with the power factor, P.F.

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EFFECTIVE MASS

Symbol: $m*$, $m*/m_o$

Units: Usually expressed in terms of fraction of the free electron mass.

   The effective mass is a parameter used in the band theory of solids which states, in effect, that electrons and holes, at the top or bottom of a band respectively, behave in many respects as if they were free particles with masses different from the mass of a free electron. It is a measure of the inertia of a charge carrier in a solid just as true mass is a measure of the inertia of a free particle. However, because of interactions of the carrier with the periodic potential of the host lattice, its effective mass may be different from the free electron mass and, in addition, may be anisotropic. If the energy band structure, if the material is sufficiently well known so that the carrier energy $E(\underline{k})$ is known as a function of the wave vector $\underline{k}$, then the effective mass is determined at any $\underline{k}$ by the tensor relation:

$$\frac{1}{m*} = \frac{1}{h^2} \nabla_k \nabla_k E(\underline{k}) \tag{25}$$

For an isotropic band, this reduces to:

$$\frac{1}{m} = \frac{1}{h^2} \frac{d^2 E}{dk^2} \tag{26}$$

which is identical with the classical relation:

$$\frac{1}{m} = \frac{d^2 E}{dp^2} \tag{27}$$

if it is recalled that in a crystal, momentum $p = hk$.

   In cases where the band structure is complex, such as the semiconductors, the effective masses, as determined from conductivity or thermoelectric measurements, may differ since they represent

different ways of averaging over the distribution of carriers among the states in the band. CYCLOTRON RESONANCE experiments permit a direct determination of portions of the curve $E(k)$ and thus give a more detailed knowledge of effective mass.

ELECTRICAL CONDUCTIVITY

Symbol: σ (Sigma)

Units: $(ohm\text{-}cm)^{-1}$ or mho/cm

The concept of electrical conductivity is strictly defined only for a material which obeys Ohm's law and is equal to the ratio $\sigma = J/E$, where J is the current density and E is the electrical field vector. The most commonly used unit is the mho per cm. In anisotropic media, the conductivity is a tensor, rather than a scaler. Electrical conductivity is also the reciprocal of the electrical resistivity.

For semiconductors, the conductivity is given in terms of the concentration of free charge carriers n and their mobility μ by the relation:

$$\sigma = ne\mu \tag{28}$$

In semiconductors, it is necessary to consider the possibility that there may be several different types of charge carriers contributing to the current (e.g., holes and electrons, or both light and heavy holes). When this is the case, the conductivity is the sum of the conductivity due to each component:

$$\sigma = \sum_i n_i e \mu_i \tag{29}$$

$$= e\left(n_h \mu_h + n_e \mu_e\right)$$

in the intrinsic region.

In a semiconductor both the carrier concentration and the mobility can be functions of temperature. At low temperatures where kT is comparable to the ionization energies of impurities, there exist only carriers of one type (n or p, depending on the character of the impurity) and the carrier concentration increases with T approximately as $\exp(-E_I/kT)$. At higher temperatures such that kT is comparable with the intrinsic ionization energy (the energy necessary to create

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hole electron pairs), both holes and electrons contribute to the conductivity and the conductivity in this intrinsic region is proportional to $T^{3/2} (\mu_\epsilon + \mu_h) \exp(-E_g/2kT)$. Mobility also varies with the temperature but uusually only with some low power such as $T^{-3/2}$ or $T^{-2.4}$. Other factors which may produce conductivity variations are stress (piezoresistance), magentic fields (magnetoresistance), electric field (hot carrier effects), and illumination (photoconductivity).
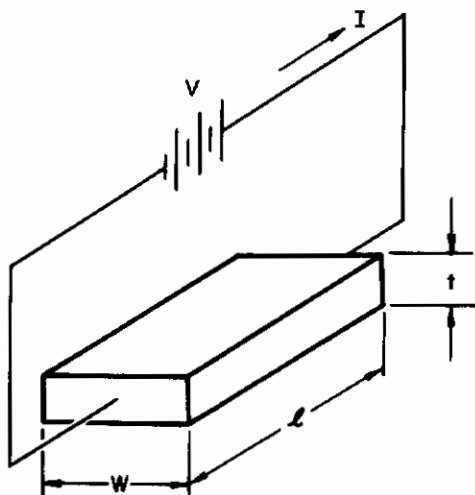
I = current flowing in sample

V = voltage applied to sample

$$\sigma = \frac{J}{E} = \frac{I/wt}{V/\ell} = \frac{\ell I}{wtV} \qquad (30)$$

$$= \frac{cm}{cm^2} \frac{amp}{volts} = \frac{1}{ohm\ cm}$$

ELECTRICAL RESISTIVITY

Symbol: ρ (Rho)

Units: ohm-cm

The electrical resistivity is the reciprocal of the electrical conductivity and so is the ratio of the electric field intensity in a material to the current density induced by that field:

$$E = \rho J \qquad (31)$$

where E is the electric field in volts/cm and J is the current density in ampere/cm^2. See ELECTRICAL CONDUCTIVITY for detailed discussion.

ELECTRONIC POLARIZATION

That part of the polarization of an atom which arises from the displacement or deformation of the electrons in the outer electronic shells. The electrons are attracted to the anode, the positively charged nucleus by the cathode. In its deformed or polarized state each ion represents a "dipole", i.e., a unit the positive and negative centers of gravity of which do not coincide. It is given by

$$\alpha = \frac{e^2}{m} \sum \frac{f_{ij}}{\omega_{ij}^2 - \omega^2} \tag{32}$$

where f_{ij} and ω_{ij} are the oscillator strength and frequency for the transition from the ground state i to the excited state j, and ω is the frequency of the external measuring field. (See also POLARIZA TION.)

ENERGY BAND (LEVEL) STRUCTURE

Symbol: Generally presented as a graphical plot of energy (E) vs. crystal momentum (k) for various principal directions in the crystal.

Units:

In classical mechanics the state of motion of a free particle is specified by giving its momentum p, a vector quantity. Its energy is then determined by the relationship, $E = p^2/2m$. In a quantum mechanical treatment of the motion of a free particle, it is again found that the state of the particle can be specified by its momentum p, and that the particle in this state is characterized by a wave function periodic in space with a wavelength $\lambda = h/p$. It has become customary to use, not p, but a wavenumber k, defined by the relation $k = 2\pi/\lambda = 2\pi p/h$ to specify the state of a free particle. The energy of the particle is given in terms of the wavenumber as $E = \hbar^2 k^2/2m$, where $p = \hbar k$, $\hbar = h/2\pi$, h is Planck's constant, and m is the mass of the particle.

For a charge in a crystal, the wave number k is also found to be a good parameter with which to characterize the state of the particle. However, the periodic structure of the crystal introduces two differences from the situation that obtains in free space in that first, k is restricted to a finite range of values, usually $-\pi/a$ to $+\pi/a$ (a is related to the lattice spacing), rather than the infinite range available

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to the free particle, and second, the simple parabolic relationship $E = \hbar^2 k^2 / 2m$ no longer holds and one finds the available energy levels distributed among a number of "bands", each of which characterized by a different relation in the form $E = E(k)$. The simple parabolic law usually holds over restricted ranges of k about points where $E(k)$ curves have maxima or minima. The relation between E and k may also vary with the direction along which k varies. Therefore, these ENERGY BANDS are represented in a graphical plot such as the one shown below which is characteristic of silicon:
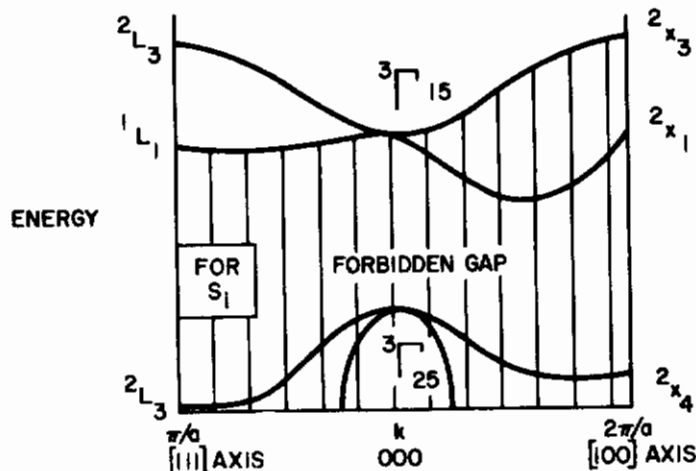
k is also expressed from

$$0, \ \frac{\pi}{4}, \ \frac{\pi}{2}, \ \frac{3\pi}{4}$$

In this diagram, Γ (gamma) represents centers of the Brillouin zone; L represents intersections of [111] axis with Brillouin zone boundary; and, x represents intersection of 1,1,1 axis with Brillouin zone boundary.

ENERGY GAP

Symbol: E_o , E_g

Units: ev (electron volts)

The energy gap (sometimes referred to as the intrinsic energy gap) is the difference in energy between the highest state in the valence band and the lowest state in the conduction band. It is the minimum energy necessary to create a hole-electron pair. It is determined from measurements of the temperature dependence of the conductivity and Hall coefficient, optical absorption spectrum, and from photoconductive and photovoltaic response of the material. At room temperature, the

gap is found to decrease with temperature according to the relation $E_g = E_o - \alpha T$. The energy gap can vary with pressure, electric field and magnetic field. See the discussion under ENERGY BAND STRUCTURE.

ETTINGHAUSEN EFFECT

See discussion under GALVANOMAGNETIC EFFECTS.

ETTINGHAUSEN - NERNST EFFECT

See discussion under THERMOMAGNETIC EFFECTS.

EXCITON

The exciton is generally assumed to consist of an electron and a hole coupled together electrostatically. Two limiting cases of this concept are well known:

a) The electron and hole are situated at the same lattice cell and jump simultaneously from one cell to the next one.

b) The electron and the hole are separated by a distance which is large compared with the lattice constant. In this case, the electron and the hole may be treated approximately as point charges having an effective mass and interacting through a Coulomb potential.

Excitons have an effective mass ($\mu*$), diameter, are dimagnetic in character.

An exciton is a combination of an electron and a hole in a semiconductor or insulator in an excited state. The hole behaves as a positive charge and it is supposed that the electron is attracted to it to form a state akin to that of a hydrogen atom (hydrogen-like excitons).

The exciton is in some ways like a hydrogen atom and is capable of transmitting energy through the lattice. It has no net charge and does not react to electric fields. The exciton is described not only by its internal structure, the hydrogen-like atom, but also by a wave number vector, linear and angular momentum, etc. Thus, it must be distinguished from an impurity center, which has a localized energy level. The exciton is an excited state of the lattice as a whole, since the excitation can pass from atom to atom.

The exciton has been brought into the theory of crystals in relatively few places. Some places where excitons may be of importance are:

1. In the absorption spectra of many insulating crystals and possibly also some semiconductors, there are absorption "lines" close to the expected absorption band. These lines may be caused by the excitation of electrons to exciton states.
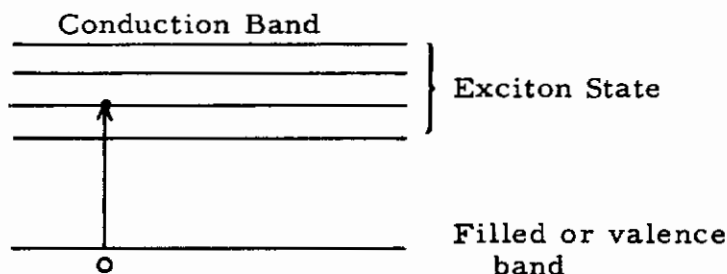
2. In the theory of secondary emission, in order to account for the number of secondary electrons emitted, it has been assumed that some of the energy of the primary was transmitted to excitons, which diffused to the surface and there broke up, yielding electrons with sufficient energy to leave the surface. Similar effects have been observed with photoelectric emission from alkali halides, and there also the exciton has been brought into the picture.

Exciton phenomena are related to absorption and other optical properties wherein energy transfer processes take place.

GALVANOMAGNETIC EFFECTS (ETTINGSHAUSEN EFFECT AND NERNST EFFECT)

Symbols: Ettinghausen: A_E, P. Nernst: A_N

Units: Ettinghausen: $°K$-meter^3/ampere-weber (mks system)
$°K$-cm/gauss-ampere (cgs system)

Nernst: $°K$-meter/ampere (mks system)
$°K$-cm/ampere (cgs system)

When a sample carrying a current is placed in a magnetic field, there are a number of effects which occur which are generically termed 'galvanomagnetic effects.' Besides the two effects discussed below, the Hall effect and the Magnetoresistance are very extensively exploited in investigations of semiconductors and are discussed separately in this glossary.

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The **ETTINGSHOUSEN EFFECT** is a transverse effect similar to the Hall Effect and is the appearance of a thermal gradient mutually perpendicular to the direction of a longitudinal electrical current and a transverse magnetic field. That is, if an electric current were flowing in the x-direction, a thermal gradient would appear in the y-direction, when a magnetic field were applied in the z-direction. The Ettingshausen Coefficient, A_E or P, is defined as:
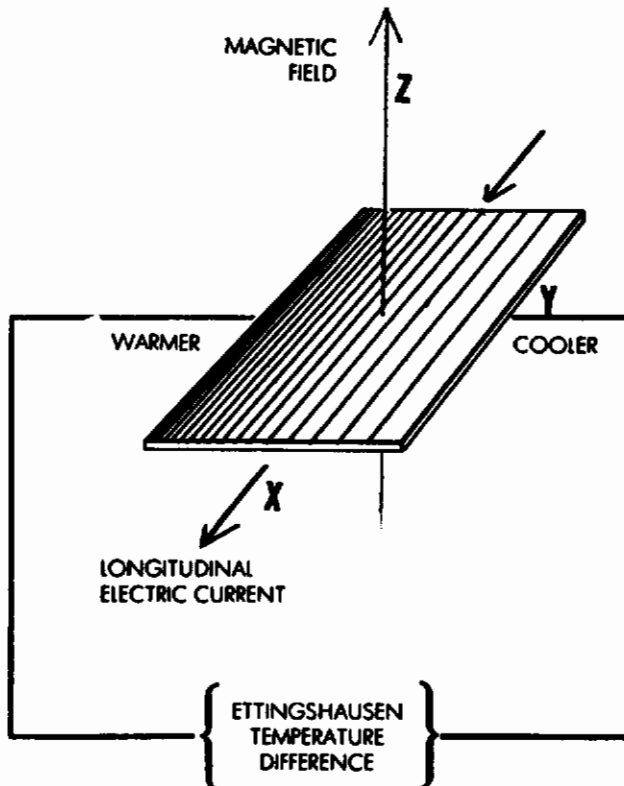
$$\frac{\partial T}{\partial y} = - A_E B_z J_x \qquad (33)$$

where

$\frac{\partial T}{\partial y}$ is the thermal gradient in the y-direction in °K/meter,

B_z is the magnetic induction in the z-direction in webers/meter^2,

J_x is the electrical current density in the x-direction in amperes/meter^2.

For metals in which the free electron theory is valid and for small magnetic fields,

$$A_E = \frac{T}{n\tau} \frac{\partial \tau}{\partial e_F} \qquad (34)$$

in which

n   is the number of charge carriers per cubic meter,

τ is the relaxation time in seconds,

e_F is the Fermi energy level in joules.

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The Ettingshausen coefficient is related to the isothermal Ettingshausen-Nernst coefficient by the relationship $A_E = T A^i_{EN}$ and the relation among the four coefficients is given by

$$\frac{R_H A^i_{EN}}{A_E A_{RL}} = \text{constant} \qquad (35)$$

in which R_H is the Hall coefficient and A_{RL} is the Righi-Leduc coefficient. The thermoelectric voltage generated by the Ettingshousen Effect is in the same direction as the Hall voltage. The magnetic field interacts with the charge carriers resulting in a transverse motion of the particles, which momentum, when exchanged with the lattice, results in a transverse temperature gradient.

The NERNST EFFECT is a longitudinal effect in a transverse magnetic field. It is the change in the thermal gradient in the direction of an electric current when a transverse magnetic field is applied. If, for example, an electric current is flowing in the x-direction, and a magnetic field is applied in the z-direction, there will occur a change in the thermal gradient in the x-direction. The Nernst coefficient is defined as

$$\frac{\partial T}{\partial x} = A_N J_x$$

in which

$\frac{\partial T}{\partial x}$ is the thermal gradient in the x-direction in °K/meter

J_x is the electric current density in amperes/ meter^2.

A_N is the Nernst coefficient in °K-meter/ampere.

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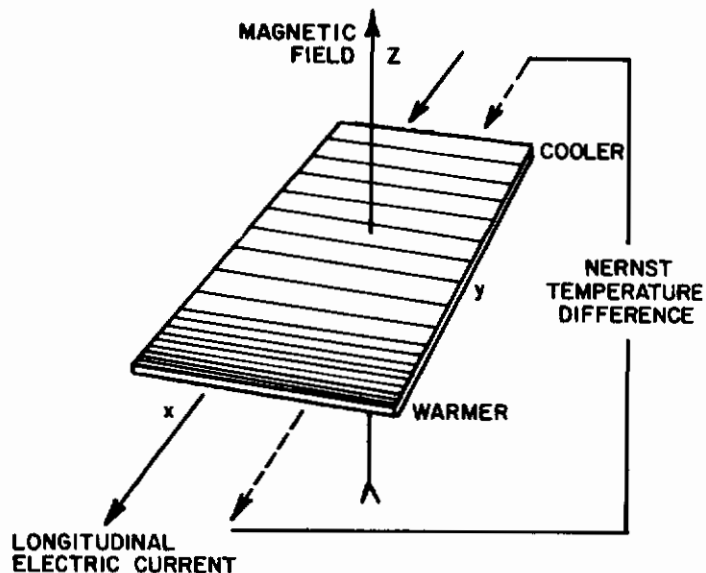
The Nernst coefficient depends on the thermal conditions perpendicular to the magnetic field and the electric current. If isothermal conditions are satisfied the Nernst coefficient can be written as the ratio of the Peltier coefficient to the thermal conductivity. If adiabatic conditions are satisfied, the expression for A_N depends on the tensor character of the Peltier coefficient and the thermal conductivity. As both the Peltier coefficient and thermal conductivity depend on the magnetic induction, the value of A_N is a function of the magnetic induction.

From the theoretical point of view, both the ETTINGSHAUSEN and NERNST effects depend on the nature of the carrier scattering mechanism and the energy distribution of the free carriers. The temperature and dependence of these coefficients can thus furnish additional information on the distribution function and scattering mechanisms.

If a Hall Effect measurement is performed without sufficient precaution to insure isothermal conditions, the temperature gradient due to the Ettingshausen effect can give rise to thermoelectric voltages which will add to the Hall voltage and lead to spurious readings.

HALL COEFFICIENT

Symbol: R_H

Units: volt-meter^3/ampere-weber (mks system); volt-cm/amp-gauss (cgs) cm^3/coulomb

The Hall Coefficient is defined as $E_y = R_H B_z J_x$ where E_y is the electric field in the y-direction in volts/meter; B_z is the magnetic induction in the z-direction in webers/meter^2; and J_x is the electric current density in the x-direction in amperes/meter^2. R_H is the Hall Coefficient in volt-meter^3/ampere-weber. Its usefullness in semi-conductor measurements lies in the fact that it is related to the carrier concentration n by the relation

$$R_H = \pm \frac{r}{ne} \qquad (36)$$

where the quantity r is a number whose value lies between 1 and 2, depending on the nature of the predominant carrier scattering processes, and e is the electron charge, in coulombs. The sign of R_H corresponds to that of the charge carrier. For cases where several types of charge carriers are present, the contributions of each to the Hall effect must be considered, with regard for the sign of each. The Hall

coefficient varies with temperature, character, and concentration of the doping, and may also change with the magnitude of the applied electric or magnetic fields.

In particular case where scattering is predominantly by acoustic lattice vibration modes, the coefficient $r = 3\pi/8$.

In ferromagnetic materials a complication arises due to the magnetization of the material. An additional Hall coefficient, related to the magnetization, is defined as the extraordinary Hall coefficient.

HALL EFFECT

The Hall Effect is the appearance of an electric field mutually perpendicular to the direction of a longitudinal electric current and a transverse magnetic field. Thus, if an electric current is flowing in the x-direction, an electric field will appear in the y-direction when a magnetic field is applied in the z-direction. The effect is termed a 'galvanomagnetic' effect. (See also HALL COEFFICIENT.)

The equation below gives the relationship between the Righi-Leduc coefficient, A_{RL}, the electrical conductivity, σ, and the Hall coefficient:

$$A_{RL} = R_H \sigma \qquad (37)$$

The Corbino effect is a special case of the Hall effect which occurs when a disk carrying a radial current is placed in a magnetic field which is perpendicular to the plane of the disc. If the Hall effect is measured by a d.c. method, the Ettinghausen effect will cause a temperature gradient between the potential probes. If the probes are not of the same material as the sample a Seeback emf will appear in addition to the Hall emf. A thermal current will be present in the same direction as the electric

MAGNETIC FIELD

Z

LONGITUDINAL ELECTRIC CURRENT

HALL VOLTAGE
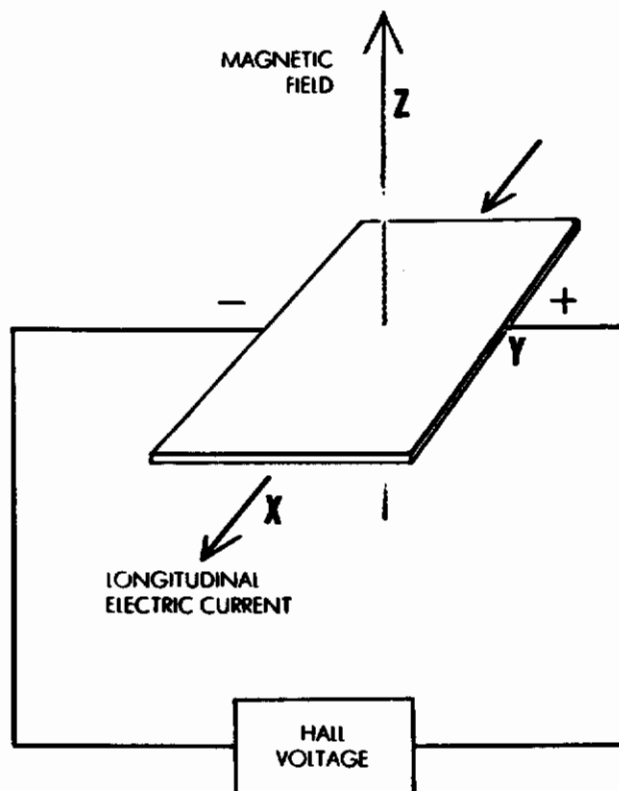
current in most d.c. measurements due to a Peltier effect at the junctions between the sample and the current leads. This thermal current can also be the result of the Nernst effect. If this heat current is taken into account an additional Seebeck emf will appear due to the Righi-Leduc effect. The heat current will also result in an Ettinghausen-Nernst emf. If the magnetic induction and sample current are reversed in all possible combinations these effects can be separated from the Hall effect except for the Ettinghausen effect. The Ettinghausen effect can be minimized if a.c. techniques are used because of the time delay required to establish a thermal gradient by the Ettinghausen effect.

INSULATION RESISTANCE

Units: megohms

The insulation resistance between two electrodes which are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to the total current between them. It is dependent upon both the volume and surface resistances. It is desirable to have the insulation resistance as high as possible, consistant with acceptable mechanical, chemical, and heat-resisting properties, although in many cases it need only be high enough to have no appreciable effect on the operation of the network. Since insulation resistance combines both volume and surface resistance, its measured value is strictly applicable only when the test specimen has the same form as is required in actual use.

IONIZATION ENERGY

Symbol: E_i , E , ϕ_T , $\phi_{h\nu}$

Units: ev. (electron volts)

Ionization is the process of generating free charge carriers. The energy required to produce a single carrier is the ionization energy. If the carrier was initially bound to an impurity center, the energy required to free it is the impurity ionization energy (sometimes called the extrinsic ionization energy.) The ionization energy required to produce a free electron-hole pair is equal to the intrinsic band gap (intrinsic ionization energy).

IRRADIATION (ELECTROMAGNETIC)

Electromagnetic radiation comprises the entire spectrum of electromagnetic waves characterized by variations of electric and magnetic fields. Depending on the frequency, they are known as radio waves, heat rays, light rays, gamma, and x-rays. The interactions of electromagnetic radiations with matter are quite complex and include

effects such as particle/photon absorption, scattering, and emission, energy exchange, photoemission, luminescence, etc. The particular process involved is determined primarily by the energy (frequency) of the radiation.

IRRADIATION (PARTICULATE)

Particulate radiation is defined here as comprising particles having the properties of mass. The particles may carry negative, positive, or zero charge. Those of particular interest here may have an effect on the electronic properties of bulk matter; e. g. , electrons alpha particles, and neutrons. Bulk matter in a space environment may be subject to bombardment by heavy ions, mesons, etc. Interactions among particles may produce new particles of different energies and may also produce types of electromagnetic radiation.

LIFETIME

Symbol: τ (Tau)

Units: microseconds (μ sec.)

The carrier concentration in a semiconductor is the result of a balance between generation and recombination processes which are continually taking place. Since these processes occur at random (but at average rates that vary with temperature and are determined by sample characteristics) the times between "birth and death" of a carrier will have a wide distribution. The mean value of this time for all carriers of interest is the LIFETIME of these carriers. If a small excess concentration of carriers is created by some external agent (such as by injection or photoexitation) the mean lifetime is the time required for this increment to decrease to 1/e of its initial value.

Lifetimes can be defined for particular groups of carriers, such as minority carrier lifetime. It is, in general, a function of temperature and doping concentration.

Near the surface of a semiconductor there are frequently agents (such as dislocations, surface states) which enhance carrier recombination and so shorten lifetime. A surface recombination velocity is used to characterize these effects.

Lifetimes can be obtained from photo-electromagnetic, photo-conductivity, and from diffusion length measurements.

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LOSS ANGLE

Symbol: δ

The Loss Angle (sometimes called the Phase Defect Angle), of a dielectric material is the difference between 90 degrees and the Phase Angle, θ, or the complement of the Phase Angle. (See diagram under PHASE ANGLE.) A perfect insulator would have a loss angle of zero degrees.

LOSS FACTOR

Symbol: e''

The Loss Factor, e'', of a dielectric or insulating material is defined as equal to the product of its Dissipation Factor, D, and its Dielectric Constant, and is the rate at which heat is generated in the dielectric. Since both the dielectric constant and the power factor are usually functions of frequency, the loss factor also changes with changing frequency. (It is also proportional to the energy loss per cycle per squared potential gradient per unit volume.) It is expressed in the same units as Dissipation Factor. A low Loss Factor is desirable for high frequencies. Sometimes Loss Factor is deliberately increased in an insulating material, usually by increasing the electrical conductivity to reduce the voltage gradient.

$$e'' = \frac{J_{loss}}{2\pi f E} \qquad (38)$$

LOSS TANGENT

See DISSIPATION FACTOR

MAGNETIC SUSCEPTIBILITY

Symbol: χ (Chi)

Units: cgs units (+ or -) or emu/gram

Magnetic susceptibility is defined as the proportionality constant between the magnetization M and the magnetizing field, H. Thus,

M = χH (in rationalized units) or

M = $4\pi\chi$ H (in non-rationalized units)

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or

$$\chi = \frac{M}{H} = \frac{\mu M}{B} = \frac{k_m \mu_o M}{B} = k_m - 1 = \frac{\mu - \mu_o}{\mu_o} \tag{39}$$

where B is the magnetic induction; k_m is the relative permeability, equal to μ/μ_o, where μ is the permeability of the medium; and μ_o is the permeability of free space; χ is dimensionless. χ is negative for diamagnetic materials and positive for paramagnetic materials.

For isotropic media M is a scaler; for anisotropic media, it is a tensor. The susceptibility is related to the relative permeability μ_r by the expression:

$$\mu_r = \left(1 + 4 \pi \chi\right) \mu_o \tag{40}$$

and again the factor 4π is dropped in rationalized units. Note that the magnitude of the susceptibility differs by the factor of 4π in rationalized units, but that μ_r is unaffected by rationalization.

MAGNETORESISTANCE

Symbol: $\frac{\Delta \rho}{\rho_o}$

Units: Dimensionless

Magnetoresistance refers to the change in resistivity of a material when it is placed in a magnetic field. The simplest effect is the transverse magnetoresistance, in which the magnetic field is applied perpendicular to the direction of current flow. For the complicated band structures of the semiconductors the effect will be different for current flow along different axes and, in addition, for some directions of current, there exists a longitudinal effect, i.e., the resistance changes when the magnetic field is parallel to the current. For cubic crystals, measurements at three independent relative orientations of current and field are sufficient to specify magnetoresistance completely.

The relative change in resistance $\frac{\Delta \rho}{\rho_o} = -\frac{\Delta \sigma}{\sigma_o}$ is generally proportional to $R_o^2 \sigma_o^2 B^2$, where $R_o \sigma_o = \mu_H$ is the low field Hall mobility and B is the magnetic field. The magnetoresistance coefficients are defined as the constants of proportionality.

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$$\frac{\Delta \rho}{\rho_o} = \zeta_{001}^{100} \; R_o^2 \, \sigma_o^2 \; B^2 . \quad (41)$$

The upper indices give the direction of the magnetic field and the lower indices give the current direction in the crystal lattice. Magnetoresistance data give valuable insight into the electronic band structure of semiconductors. The figure right illustrates $\dfrac{\Delta \rho}{\rho_o}$ as a function of the magnetic field, and the figure below illustrates $\dfrac{\Delta \rho}{\rho_o}$ as a function of the relative orientation of current and magnetic field.
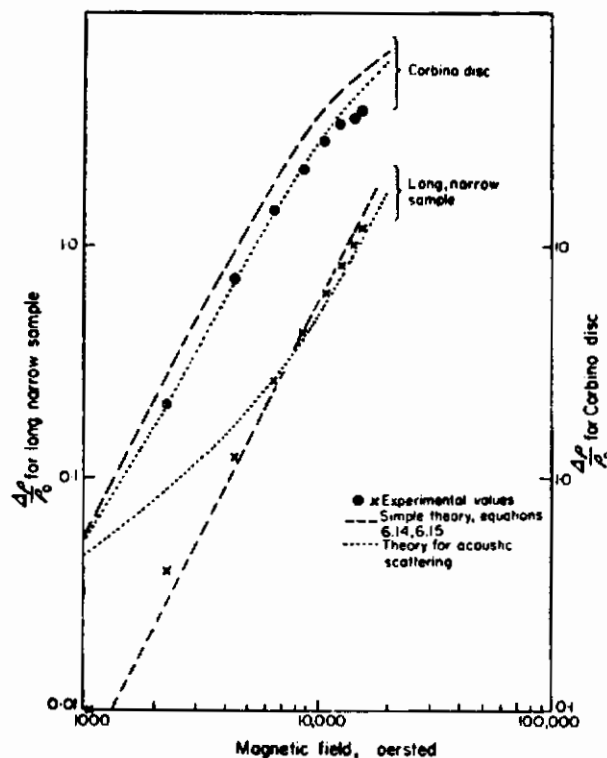
Magnetoresistance and Corbino resistance for a pure specimen of InSb at room temperature (R_{Ho} = 76,000 $cm^2/Vsec$, b = 104.
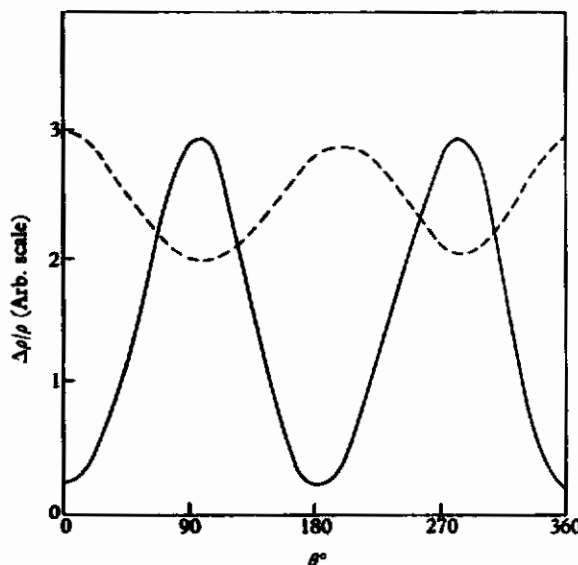
Variation of magneto-resistance of n-type Ge and Si and angle θ between the current i and magnetic induction B. (i is along the direction (100) and B is perpendicular to the direction (010)).

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MEAN FREE PATH

Symbol: l, m.f.p.

Units: cm (centimeters)

Mean free path is defined as the average distance traversed by a particle (such as a molecule in a gass or a free carrier in a semi-conductor lattice) between collisions. The computation of the magnitude of the mean free path depends upon the types of collisions postulated. If the particle moves at high velocity relative to the velocities of an ensemble of identical particles that have random positions, the relationship $l = 1/n$ applies, where l is the mean free path, n is the number of particles per unit volume, and σ is the effective cross sectional area for collision. If, on the other hand, the velocities of the identical particles have a Maxwell distribution of velocities, the relationship

$$l = 1/\sqrt{2}\ n\sigma \quad \text{applies.}$$

The mean free path may be extended to cover other particle encounters than collisions, such as absorption, inelastic collision, etc., by using the relationship: $l = 1/n\sigma$, where σ is the cross section for the process under consideration. Thus, σ can represent a cross section for interaction with phonons, or with impurity centers and the corresponding m.f.p. is then defined for collisions with phonons or impurity centers.

MOBILITY

Symbol: μ (mu)

Units: cm^2/volt-sec; cm/sec / volt/cm

Under the influence of an electric field, the free carriers in a conductor acquire a mean drift velocity in the direction of the field. The current density observed will be proportional to the concentration of carriers and their mean drift velocity, $J = ne\bar{v}$. It is generally found that this drift velocity v is proportional to the field, i.e., $\bar{v} = \mu E$, and the constant of proportionality μ is the MOBILITY. From this it follows that $J = ne\mu E$ (Ohm's Law) and, therefore, conductivity is related to mobility as $\sigma = ne\mu$. If τ is the mean time between collisions for a free carrier, the mobility is given in the simplest model as $e\tau/m*$, where m* is the effective mass, and e is the electronic charge. In terms of the mean free path between collisions $\tau = l/v_T$, where v_T is the mean thermal velocity (usually much greater than the mean drift velocity) of the carrier, and $\mu = \dfrac{el}{m*v_T}$.

The mobility is determined by the scattering processes affecting carrier motion. The various possible scattering interactions are with phonons (both acoustic and optical), neutral and ionized impurities, and dislocations. Each of these processes has a characteristic

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temperature dependence. Carriers in different bands (different effective masses) will have different mobilities. In high electric fields the mobility can change and thus lead to non-ohmic behavior.

Mobility determined from conductivity measurements coupled with carrier concentration determined by other means than Hall effect is referred to as conductivity mobility; i.e., $\mu_c = \sigma/ne$. The mobility $\mu_H = R\sigma$ calculated from the Hall effect and conductivity is equal to $r\mu_c$ (see HALL COEFFICIENT for discussion of r). The mobility determined from direct observations of the drift of a pulse of injected minority carriers is referred to as the drift mobility. If the minority carrier concentration is small compared to that of the majority carriers, the drift mobility equals the conductivity mobility.
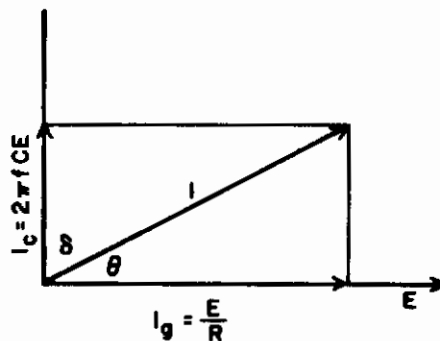
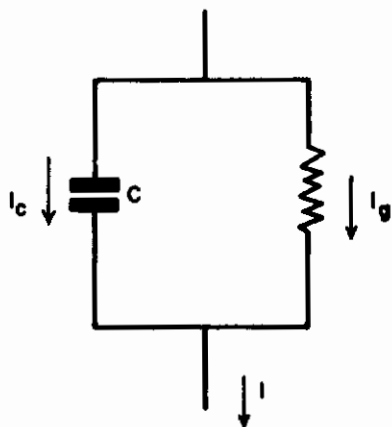## PERMITTIVITY

See DIELECTRIC CONSTANT

PHASE ANGLE

Symbol: θ
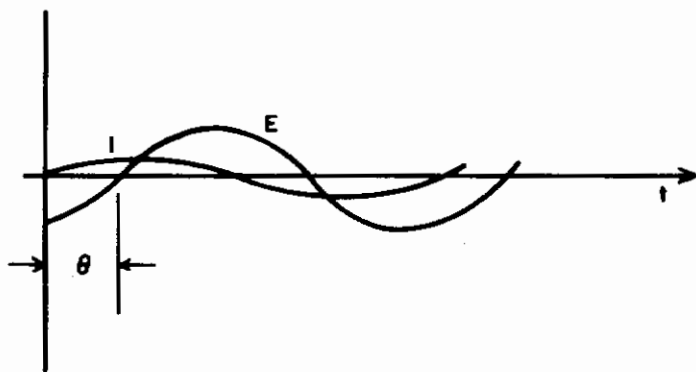
Phase relations in a capacitative
current

Phase diagram

Equivalent circuit diagram

θ = Phase angle

δ = Loss angle

f = frequency, cps

I_g = loss current

I_c = charging current

In a dielectric (capacitor), charge and voltage cannot be acquired until after a current has been established for a period of time, i.e., the current leads the voltage. It is, then, the angular difference in phase between the sinusoidal alternating emf applied to a dielectric and the component of the resulting alternating current having the same period of the emf. It is also the complement of the material's LOSS ANGLE.

POLARIZATION

The process by which a partial separation of electric charges of opposite sign in a body are brought about by the superposition of an external electric field. If one knows the properties of the ions of a crystal, namely, their charge, size, and polarization properties (the latter being determined by their electronic configurations), it becomes possible, for example, to predict the influence of a change in composition on the properties of crystals and glasses. These three factors can be considered as chiefly responsible for the properties and structure of a crystal.

It is also defined as a vector quantity (P) representing the dipole moment per unit volume of a dielectric medium.

The response of a structure is conditioned by the electronic polarizability, the atomic polarizability, and the molecular or orientational polarizability; these three determine the dielectric constant. Temperature, frequency of the field, composition, determine the relative contribution of these three types of polarization to the value of the dielectric constant. A certain time is required for an assembly of dipoles to come into equilibruim with the applied field. This is termed the dielectric relaxation and is a measure of that part of the dielectric constant which depends on the orientation of the dipole moments of the molecules. As the frequency of the applied electric field increases, the contribution to the dielectric constant made by the molecular polarization is taken over by the atomic polarization. At still higher frequencies, the electronic polarization is predominant. The time for dielectric relaxation becomes smaller, and at very high frequencies (light waves or microwaves) the response is almost instantaneous.

PHONON

Symbol:

Units: Phonon energies are usually given in equivalent frequencies or temperatures (see discussion).

The atoms in a crystalline solid can vibrate about their equilibrium positions and as in the simpler mechanical system of spring-coupled masses, there are particular or "normal" modes of vibration characteristic of the system. The unique feature of these normal modes is that a complex vibrational motion can be resolved into a simple linear sum of the normal modes (each with a different amplitude) and the total energy of the vibrational system can be written as a sum over the square of the mode amplitues with no cross product terms between modes. Classically, the

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amplitude and energy of a vibrational mode can have any value, but in quantum mechanics the energy of a mode can change only by multiples of a discrete amount $h\nu$, where ν is the vibrational frequency. A single quantum ($h\nu$) of energy of a particular mode is called a phonon and can be treated as a "particle" that can be created, absorbed, or scattered in interacting with free carriers in the material.

A phonon may be visualized as either a progressive or standing wave in the crystal and is characterized by its wave number (reciprocal of wave-length) and its energy. The various possible phonons (modes of vibrational motion) in any given crystal can be grouped into bands, each characterized by particular energy - wave number relations (analogous to the electronic energy bands). Thus arises the classification into longitudinal, transverse, acoustic, and optical and recurs frequently in the literature.

The phonon properties most frequently referred to are the energy wave-number relations. Where detailed data concerning these relations is unavailable, the energies of phonons of various types at particular wave-number points in the Brillouin zone are given. The phonon energy E is given in a number of different ways: as a frequency, $\nu = E/h$ (sec^{-1}), an angular frequency $\omega = 2\pi\nu = E/\hbar$ (sec^{-1}), or an equivalent temperature $T = E/k$ ($^{\circ}K$). Note: $h = 2\pi\hbar$ is Planck's constant, k is Boltzmann's constant.

PHOTOCONDUCTIVITY

Symbol: None

Units: See discussion below.

Photoconductivity is the increase (or sometimes decrease) in the conductivity of a substance when it is irradiated with electromagnetic radiation. The most frequently encountered cause of such an effect is a change in carrier concentration due to some photoionization process. In intrinsic photoconducitvity, free hole electron pairs are produced by absorption of photons with energies greater than the band gap. At low temperatures an extrinsic photoconductive effect occurs in which additional carriers are produced by photoionization of impurity centers.

A photoconductive effect can also be observed as a result of a mobility change, as when a free carrier is excited to a band where it has a different mobility.

The photoconductivity displayed by thin polycrystalline films (e. g. , PbS) has been attributed by some authors to a barrier effect; e. g. , incident radiation effects the height of the energy barrier a carrier must overcome to move between elements of the films. The usual unit of photoconductivity is relative change in conductance $(\Delta\sigma/\sigma)$ per unit radiant energy or per photon.

PHOTOELECTROMAGNETIC EFFECT

Symbol: P. E. M.

Units:

When a slab of semiconducting material is illuminated on one side with radiation of wavelength somewhat shorter than that corresponding to the fundamental absorption edge, electron-hole pairs are formed near the surface, owing to the high value of the absorption coefficient. These charge carriers diffuse into the sample, and if a magnetic field is applied parallel to the illuminated surface, negative and positive carriers will tend to drift to opposite ends of the sample (in analogy with the Hall effect), creating a photovoltage, which, for not too large fields, is proportional to the field. If the sample is short circuited a photocurrent, again proportional to the magnetic field, will flow in the external circuit.

The PEM effect is useful in determining lifetime in materials where γ is too short to be measured by direct methods. For this purpose, it is used in combination with photoconductive measurements and in the case where the product of absorption constant and diffusion length is very large ($\alpha L \gg 1$) the ratio of PEM to photoconductive current is

$$\frac{i_{pem}/B}{i_p/E} = \left(\frac{D}{\tau}\right)^{1/2} \tag{42}$$

where D is the ambipolar diffusion coefficient, given in terms of the carrier mobilities as

$$D = \frac{\mu_e \mu_h}{\mu_e + \mu_h} \tag{43}$$

If the sample thickness is reduced to a value small compared to the diffusion length, ($t \ll L$) then the ratio of the currents gives the surface recombination velocity:

$$\frac{i_{pEM}/B}{i_r/E} = S \tag{44}$$

B is the magnetic field applied in the PEM measurement and E the electric field used in the photoconductive measurement.

The magnitude of the short circuit PEM current is proportional to the intensity of illumination; it is independent of wavelength if $\alpha L \gg 1$ and varies as does the absorption constant when this condition is not fulfilled. At very large magnetic fields ($\mu B \gg 1$) the effect tends to saturate. Apparently, a P.E.M. coefficient has not been defined, since the effect is generally used in combination with photoconductive measurements to determine carrier lifetime.

PHOTON

The electromagnetic field is the mechanism whereby charged particles interact with each other and whereby systems composed of charged particles transfer energy. In the quantum mechanical theory of the electromagnetic field, it is found that the energy of the field is carried in discrete units, such that the total energy of a wave of frequency ν is an integral multiple of the quantity $h\nu$, where h is Planck's constant. The electromagnetic field can transfer energy only in units of $h\nu$ and so it is convenient to consider the wave as composed of "particles", called PHOTONS, each of which carries just $h\nu$ of energy.

A more detailed analysis reveals that a photon corresponds to the quantum of energy of the normal modes of the electromagnetic field, in a manner analogous to the way in which the phonon is the quantum of energy of the normal modes of vibration of a crystal lattice.

A photon of sufficient energy can be absorbed by a crystal and generate a free electron hole pair. Photons of small ere energy can photoionize neutral impurity centers. If the energy of an incident photon is smaller than the activation energy of the various absorption processes characteristic of the crystal, the photon cannot be absorbed and the crystal is transparent to such photons. The energy of a photon is related to the wavelength of the electromagnetic wave by the equation

$$E = \frac{hc}{\lambda}$$

(c = velocity of light).

PIEZORESISTANCE

Symbol: Π

Units: $cm^2/dyne$

The change of resistivity of a solid as a result of the application of a stress is the piezoresistance effect.   Alternatively, it is called elastoresistance is the change in resistivity is regarded as being caused by the introduction of an elastic strain. Since the elastic constant tensor defines the relationship between the stress and the strain, a knowledge of one effect implies a knowledge of the other in a material with known elastic constants.

Since in the general case resistivity is a function of direction in a material, it is characterized by tensor; i.e., the relationship between applied field and current density is

$$E_k = \sum_{\ell} \rho_{k\ell} \, j_\ell \tag{45}$$

The resistivity tensor is symmetric and therefore can have at most six independent components. Crystal symmetry reduces the number of independent components and in a cubic srystal there is only one: $\rho_{ij} = \rho$ for $i = j$ and $\rho_{ij} = 0$ for $i \neq j$; the diagonal components are all equal and the off diagonal components are zero. The stress is also representable by a symmetric tensor with, in general, six independent components, $K_{k\ell}$. The piezoresistance must therefore be characterized by a fourth rank tensor $\Pi_{ijk\ell}$ expressing the linear relationship between the change in the resistivity components and the components of stress.

$$\frac{\delta \rho_{ii}}{\rho_{ij}} = \sum_{k\ell} \Pi_{ijk\ell} \, K_{k\ell} \tag{46}$$

An alternative representation frequently used is that analogous to the shorthand notation common in treatments of the elastic constants. The six independent components of the resistivity tensor are written $\rho_{xx} = \rho_1$, $\rho_{yy} = \rho_2$, $\rho_{zz} = \rho_3$, $\rho_{yz} = \rho_4$, $\rho_{xz} = \rho_5$ and $\rho_{xy} = \rho_6$ and similarly with the components of the stress tensor. The piezoresistance tensor is then defined by the relations:

$$\frac{\delta \rho_s}{\rho_s} = \sum_{st} \Pi_{st} \, K_t \tag{47}$$

For cubic crystals there are only three independent piezoresistance constants, and at least three independent measurements are therefore necessary to specify the tensor completely.

Piezoresistivity is most frequently measured as a function of temperature and doping level, and provides information concerning the energy band structure of solids.

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POWER FACTOR

Symbol: P. F.

The POWER FACTOR or as it is sometimes known, dielectric power factor, is taken as the cosine of the phase angle or the sine of the loss angle. (See diagram under PHASE ANGLE). In practice, it is the percentage rating obtained by dividing the parallel resistance of the capacitor (R_C) by its impedance (Z_C) at the operating frequency.

$$P.F. = \cos\theta = \sin\delta = \frac{R_C}{Z_C} \qquad (48)$$

Since the DISSIPATION FACTOR is defined as cotangent θ or tangent δ, the power factor is smaller than the dissipation factor by less than 0.5% when the dissipation factor is less than 0.1. A low power factor is essential in materials to be used at high frequencies, since energy loss is directly proportional to frequency.

The power factor is a measure of the electrical power loss in a dielectric subjected to an alternating emf and is the ratio of the energy lost in the form of heat to the energy required to charge the dielectric (e. g., capacitor).

QUALITY FACTOR

Symbol: Q

This is the reciprocal of the DISSIPATION FACTOR.

REFLECTANCE

Symbol: R (Reflection coefficient)

Units: Expressed usually in % or as a ratio between 0 and 1.

The reflectance is the proportion of incident radiation reflected from the surface of a sample. The wavelength dependence of the reflectance in the infrared and optical regions of the spectrum is determined by the energy band structure of the material and the distribution of the carriers among the bands. It will accordingly vary with temperature, and doping level. In polar crystals, such as the III-V compounds, the interaction of the lattice vibrations with electromagnetic radiation results in very prominent reflection peaks in the far infrared referred to as the reststrahlen peaks.

SEMICONDUCTOR

A semiconductor is often defined as an electrical conductor that has a conductivity intermediate between that of an insulator and that of a metal.

A distinctive hallmark of semiconductors is that they possess negative temperature coefficient of resistance in some range of temperature. The negative coefficient is connected with the excitation of electrons from a source.

In terms of the possible energy band structures that solid may have, a semiconductor is characterized as a material in which, at absolute zero, all the electrons are in a valence band which they completely fill, and the next higher available states are in a conduction band separated from the valence band by a finite energy gap. As the temperature is increased, electrons are excited across the gap providing some electrons in the conduction band and leaving holes in the valence band. The increasing concentration of these free carriers with temperature leads to the large negative temperature coefficient of resistance of these materials. Carriers may also arise from impurities with which the semiconductor is intentionally doped. Since less energy is required to ionize such an impurity than to produce an electron-hole pair, free carriers appear at lower temperatures in doped material and the rate of change of conductivity is characteristic of the impurity ionization energy.
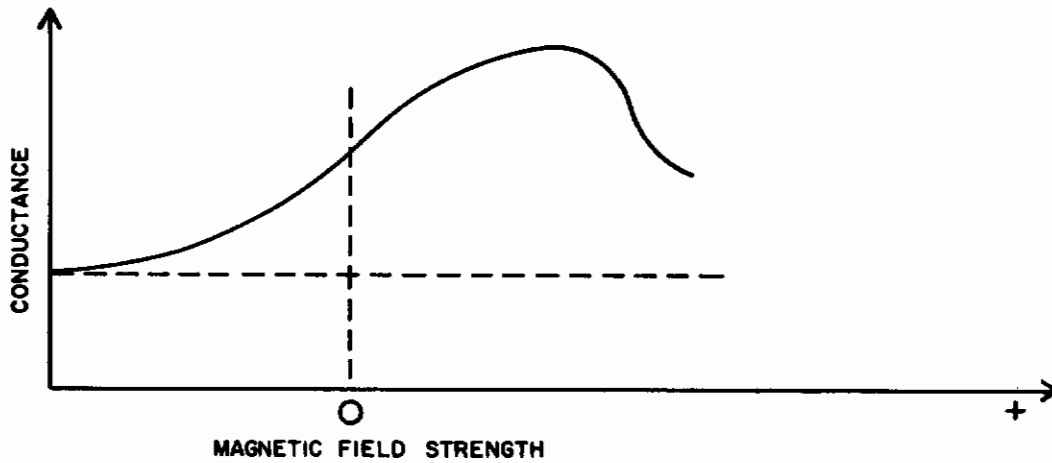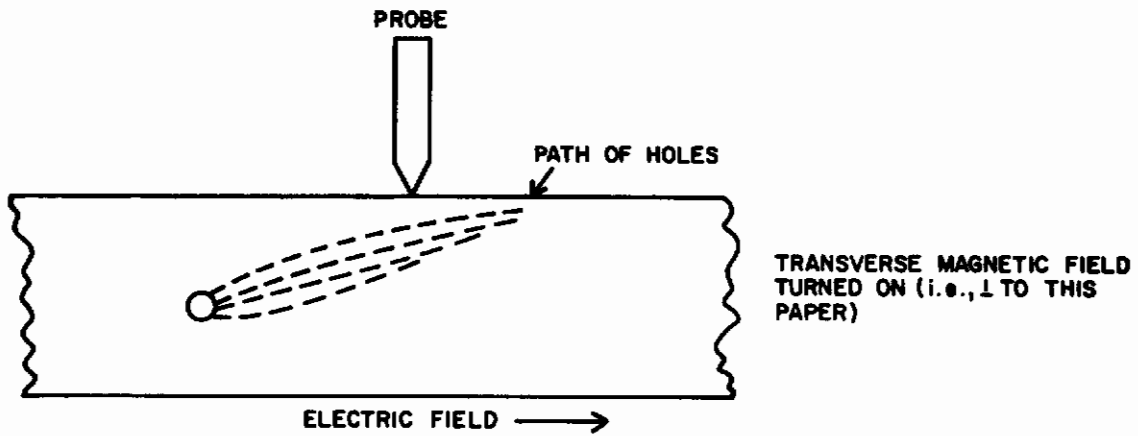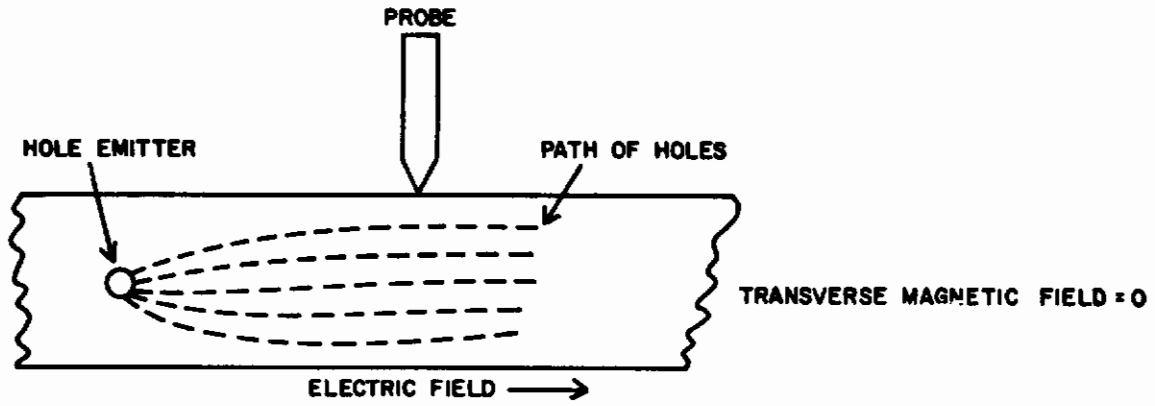
SUHL EFFECT

The change in conductivity of a surface region in a semiconductor due to the magnetic concentration of the minority charge carriers in the presence of the Hall effect is termed the Suhl effect.

When minority carriers are present in a semiconductor with a transverse electric and magnetic field, the minority carriers will be concentrated on the same surface as the majority carriers by bending in the magnetic field. The concentration of minority carriers on the surface will tend to be increased by an increased magnetic field but as the surface concentration increases the rate of recombination of holes and electrons will increase. The conductivity of a surface region should increase with increasing magnetic field due to this magnetic concentration. When the increase in the rate of recombination begins to exceed the increase in concentration of the minority carriers, the conductivity of the surface region will begin to decrease with further increases in the magnetic field.

PROBE

HOLE EMITTER

PATH OF HOLES

TRANSVERSE MAGNETIC FIELD = 0

ELECTRIC FIELD ⟶

PROBE

PATH OF HOLES

TRANSVERSE MAGNETIC FIELD
TURNED ON (i.e., ⊥ TO THIS
PAPER)

ELECTRIC FIELD ⟶

CONDUCTANCE

O   +

MAGNETIC FIELD STRENGTH

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THERMAL CONDUCTIVITY

Symbol: k

Units:
(1) Btu/hr/sq. ft/$^\circ$F/ft
(2) Cal/cm^2/cm$^\circ$C/sec
(3) Btu/hr/sq. ft/$^\circ$F/in.
(4) Watts/cm/$^\circ$C/ or Watts-cm^{-1}$^\circ$C^{-1}
(5) BTU-in/sq. ft/sec/$^\circ$F (This is equivalent to No. 3 above.)

The thermal conductivity, k , of a substance may be defined as the quantity of heat transmitted, due to unit temperature gradient, in unit time under steady conditions in a direction normal to a surface of unit area, when the heat transfer is dependent on the temperature gradient.

The ratio (k) of the time rate of heat flow per unit area to the negative gradient of the temperature:

$$k = \frac{-dQ/dt}{A\,(dT/dx)} \qquad \text{or} \qquad k = -\frac{\dfrac{dQ}{dt}}{\dfrac{A}{dT/dx}} \tag{49}$$

where dQ/dt is the energy flow per unit time through an area, A , taken perpendicularly to the direction along which the temperature changes most rapidly (x) and dT/dx is the rate of change of temperature with distance, this is equivalent to:

$$k = \frac{(dQ/dt)\,(x_2 - x_1)}{A\,(T_1 - T_2)} \tag{50}$$

where T_1 is the temperature at position x_1, and T_2 at x_2 .
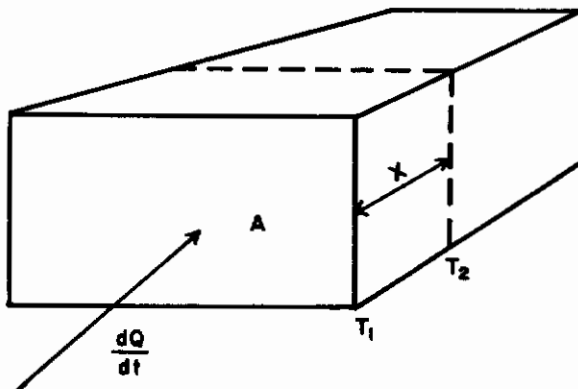
In metals and semiconductors, heat is transported by both the charge carriers and the lattice. The total thermal conductivity, is therefore, composed of two parts:

$$k_{total} = k_{electron} + k_{lattice} \quad . \qquad (51)$$

THERMOELECTRIC EFFECTS

SEEBECK EFFECT:

Symbol: S

Units: volts/degree

PELTIER EFFECT:

Symbol: π

Units: watts/ampere

THOMSON EFFECT:

Symbol: o_π

Units: watts/ampere-degree

     In the presence of both electric fields and temperature gradients, circuits containing conductors of two or more different materials display a set of phenomena referred to collectively as thermoelectric effects. If Joule heating and thermal conduction are neglected, then the remaining effects are reversible in the thermodynamic sense and all of the thermo-electric phenomena can be described in terms of two effects, the Peltier effect and the Thomson effect. In actual practice it is much easier to measure the Seebeck effect, and from the temperature dependence of the Seebeck voltage, the parameters characterizing the other two effects can be deduced.
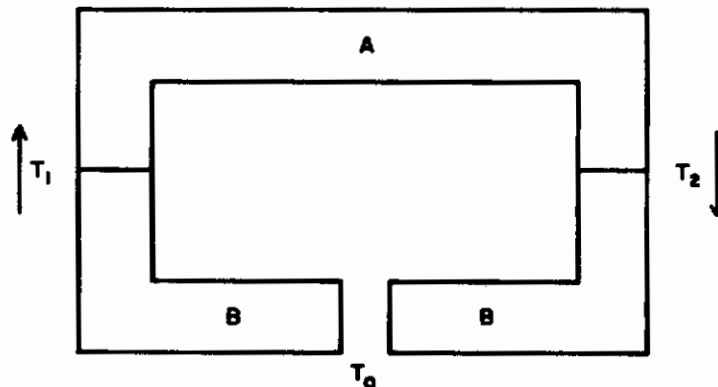
In order to describe these effects consider the circuit shown in the figure, which consists of two different materials, A and B, connected together at junctions maintained at temperatures T_1 and T_2. If an infinite impedance voltmeter (so that the current is zero) is inserted in arm B at some temperature T_o a voltage E_s appears whenever $T_2 \neq T_1$. This is the Seebeck voltage, and if T_1 is kept constant then the Seebeck coefficient is defined as the rate of change of the Seebeck voltage with temperature.

$$S_{AB}(T_2) = \frac{dE_s}{dT} \tag{52}$$

α, Q, and P are sometimes used to represent the Seebeck coefficient whose units are volts/degree. S is also referred to as the thermoelectric power. S is independent of the reference temperature T_1 and depends only on the nature of the materials of the thermocouple and the temperature T_2. The Seebeck voltage that is observed is given by

$$E_s = \int_{T_1}^{T_2} S_{AB}(T) \, dT \tag{53}$$

Empirically, it is found that the Seebeck voltage can be represented by the relation

$$E_s = at + 1/2 \, bt^2 + (1/3) \, ct^3 \tag{54}$$

where $t = (T_2 - T_1)$; b and c are generally small compared to a.

The Peltier effect can be observed if the high impedance voltmeter is replaced with a battery that sends a current, I, through the thermocouple circuit in the same direction as it would flow under the influence of the Seebeck voltage. The warmer junction (T_2) will then cool and heat will have to be supplied to it in order to maintain its temperature. The rate Q at which it is necessary to supply heat to keep the junction temperature constant is proportional to the current and the constant of proportionality is the Peltier coefficient.

$$Q = \Pi_{AB} \, I$$

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Its units are volts and it is a function of the materials of the junction and of the temperature of the junction. It does not depend on the temperature of the cooler junction. A similar effect occurs at the cooler junction but since the current passes through it in the opposite direction compared to the hotter junction heat is liberated and the junction heats up.

Both the Seebeck and Peltier effects are properties of junctions of dissimilar materials. There is a third effect which occurs in a single homogeneous material in a temperature gradient and through which a current is flowing. If dT is the temperature difference across an infinitesimal region of the wire through which a current I flows then the heat input necessary to maintain this temperature difference is given by

$$dQ = \sigma I \, dT \tag{55}$$

and the power required to maintain a temperature difference $T_2 - T_1$ across a finite length of wire is

$$Q = I \int_{T_1}^{T_2} \sigma \, dT \tag{56}$$

The Thomson coefficient σ has units of volts/degree and may be either positive or negative. Its magnitude depends on the nature of the material and the temperature.

As noted before, the three thermoelectric coefficients are not all independent and the relationship between them is given by the expression

$$E_s = \int_{T_1}^{T_2} S_{AB} \, dT = \Pi_{AB}(T_1) - \Pi_{AB}(T_2) + \int_{T_1}^{T_2} \left(\sigma_B - \sigma_A \right) dT \tag{57}$$

or in differential form

$$\frac{dE_s}{dT} = S_{AB} = \frac{d\Pi_{AB}}{dT} + \sigma_A - \sigma_B \quad . \tag{58}$$

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In practical applications of thermoelectric materials, the effects of Joule heating and thermal conduction must be taken into consideration as well as its thermoelectric power. The usefulness of a particular material is characterized by a Figure of Merit defined as

$$Z = \frac{S^2 \sigma}{k} \qquad (59)$$

where S is the Seebeck coefficient of the material k is the thermal conductivity and σ is the electrical conductivity. Z is sometimes written $S^2/k\rho$ where the electrical resistivity $\rho = 1/\sigma$ has been used. The units of Z are $(^\circ K)^{-1}$ (reciprocal degrees, or per degree) and it is a function of temperature.

THERMOMAGNETIC EFFECTS (RIGHI-LEDUC AND ETTINGSHAUSEN-NERNST EFFECTS)

Symbols: Righi-Leduc: A_{RL}

Ettingshausen-Nernst: A_{EN}

Units: Righi-Leduc: $^\circ$K-cm-sec/gauss-joule (cgs)

meter^3-$^\circ$K-sec/joule-weber (mks)

Ettingshausen-Nernst: volt-cm-sec/gauss-joule (cgs)

volt-meter^3-sec/joule-weber (mks)

When a sample carrying a heat current is placed in a magnetic field, there are a number of effects which are generically termed 'thermomagnetic' effects. Besides the two transverse effects discussed below, the thermal conductivity and thermoelectric power are extensively exploited in investigations of semiconductors and are discussed separately in this glossary.

The RIGHI-LEDUC EFFECT is the appearance of a thermal gradient perpendicular to the direction of a longitudinal heat current and a transverse magnetic field. Thus, if a heat current is flowing in the x-direction, a thermal gradient will appear in the y-direction when a magnetic field is applied in the z-direction. This effect is observed whenever a principal mechanism for heat conduction is the motion of charged particles as in metals. The Lorentz force acting on the charge carriers taking part in the energy transport will produce a transverse motion of the particles. The momentum exchange between the particles and the lattice will result in a transverse temperature gradient.

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The Righi-Leduc coefficient is defined by the equation

$$\frac{\partial T}{\partial y} = A_{RL} \, B_z \, W_x \, k \qquad (60)$$

where

$\dfrac{\partial T}{\partial y}$ is the thermal gradient in the y-direction in $^{\circ}K$/meter

B_z is the magnetic induction in the z-direction in webers/meter^2

W_x is the heat current density in the x-direction in joules/meter^2-sec.

The ETTINGS-HAUSEN-NERNST EFFECT is the appearance of an electric field mutually perpendicular to the direction of a longitudinal heat current and a transverse magnetic field. Thus, if a heat current is flowing in the x-direction, an electric field will appear in the y-direction when a magnetic field is applied in the z-direction. The equation defining the effect is:

$$E_y = -A_{EN} \, B_z \, W_x , \qquad (61)$$
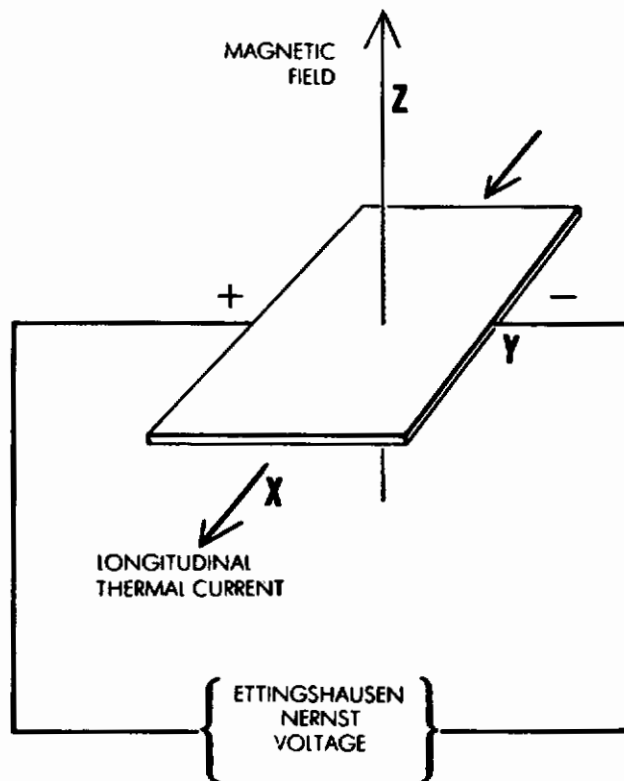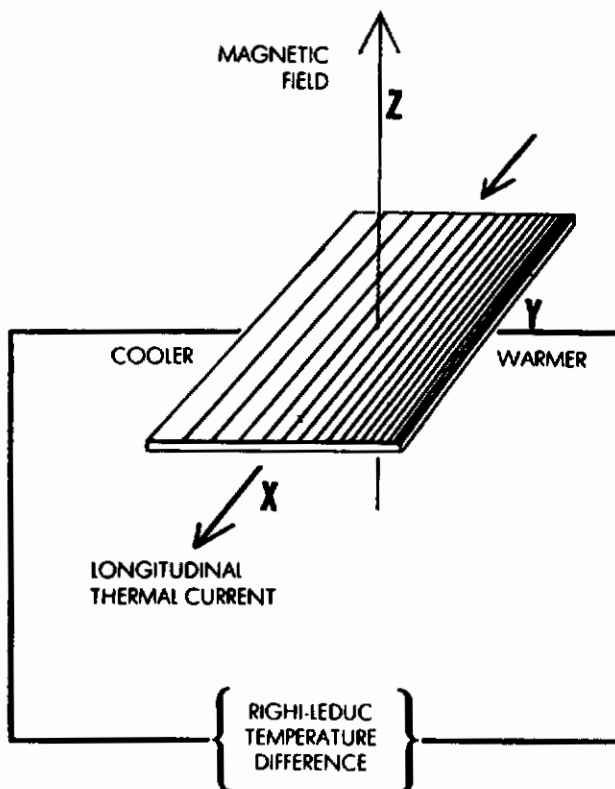
MAGNETIC FIELD

Z

COOLER

WARMER

Y

X

LONGITUDINAL THERMAL CURRENT

{ RIGHI-LEDUC TEMPERATURE DIFFERENCE }

MAGNETIC FIELD

Z

+

−

Y

X

LONGITUDINAL THERMAL CURRENT

{ ETTINGSHAUSEN NERNST VOLTAGE }

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where

E_y is the electric field in the y-direction in volts/meter,

B_z is the magnetic induction in the z-direction in webers/meter^2,

W_x is the heat current density in the x-direction in joules/meter^2-sec.

Both of these thermomagnetic effects can be defined in terms of the thermal gradient in the x-direction, rather than in terms of the heat current induced by this thermal gradiant as above. The defining equations and the relations between the coefficients are then as follows:

Righi-Leduc: $$\frac{\partial T}{\partial y} = S_{RL} \, B_z \, \frac{\partial T}{\partial x} \ , \tag{62}$$

where

$$S_{RL} = K A_{RL} \tag{63}$$

$$K = \text{Thermal conductivity}$$

Ettingshausen-Nernst: $$E_y = - R_{EN} \, B_z \, \frac{\partial T}{\partial x} \ , \tag{64}$$

where

$$R_{EN} = \tau A_{EN} \tag{65}$$

$$\tau = \text{Thermal conductivity}$$

As in the case of the galvanomagnetic effects, the temperature dependence of the various coefficients yields some information on the distribution in energy and the scattering mechanisms of the free charge carriers in the sample. The Ettingshausen-Nernst effect can lead to spurious results in Hall effect measurements if isothermal conditions are not maintained.

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WORK FUNCTION

Symbol: ϕ

Units: e.v. or e.V.

Work function is defined as the energy (usually measured in electron-volts) needed to remove an electron from the Fermi level in a metal to a point an infinite distance away outside the surface. The work function is important in the theory of thermionic emission, as for example, in the case of an electron escaping from the heated, negatively-charged filament of a vacuum tube, when the work function may be called the thermionic work function. Photoelectric emission has a corresponding work function.

APPENDIX VI

DATA SHEETS ON INDIUM PHOSPHIDE

The following pages present the results of compiling and evaluating the best available experimental data on indium phosphide.

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Absorption

Transmission characteristics of two n-type single-crystal specimens of InP at 300°K.   [Ref. 9]

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

<u>Absorption</u>

Free-carrier absorption (300°K) in various InP samples.   [Ref. 13]
(single crystal)

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE
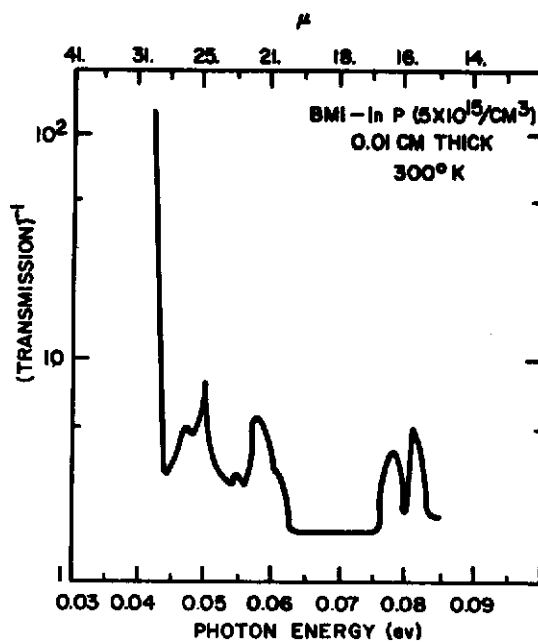
Absorption

Absorption spectrum (300°K) of an   [Ref. 13]
InP sample in the reststrahlen
region. (n-type single crystal)

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE
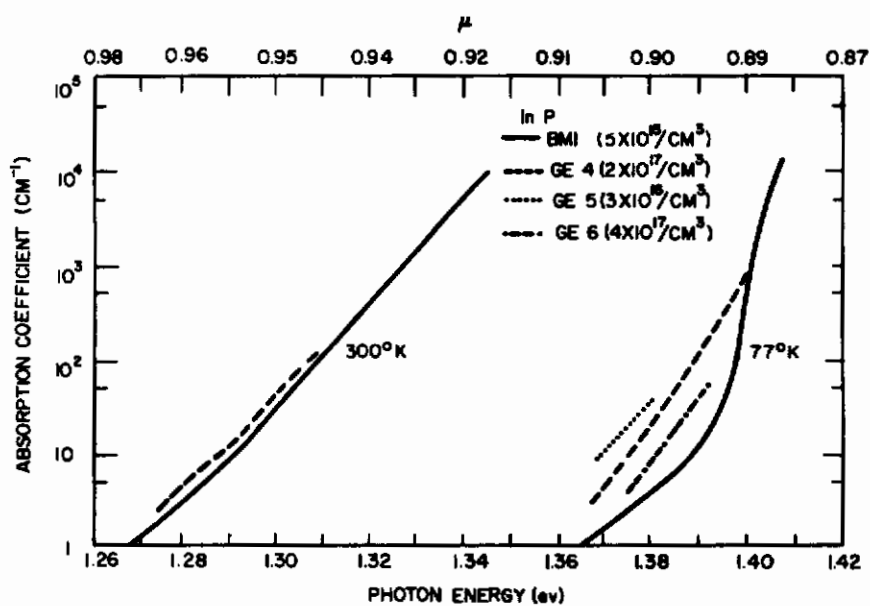
Absorption

Intrinsic absorption edge of InP at 77°K and 300°K. The   [Ref 13]
different curves refer to different ingots.
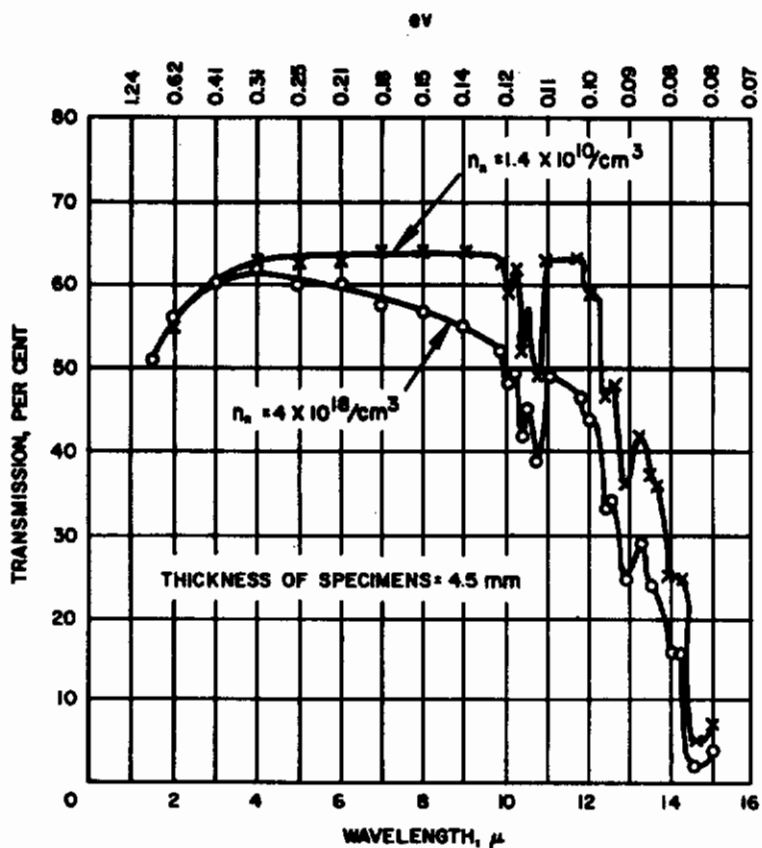n-type, single crystal.

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

<u>Absorption</u>

Infra-red absorption curves for n-type indium   [Ref. 18]
phosphide at 293°K and 84°K.   The broken line
corresponds to K∝ λ$^{1.5}$.
(probably single-crystal)

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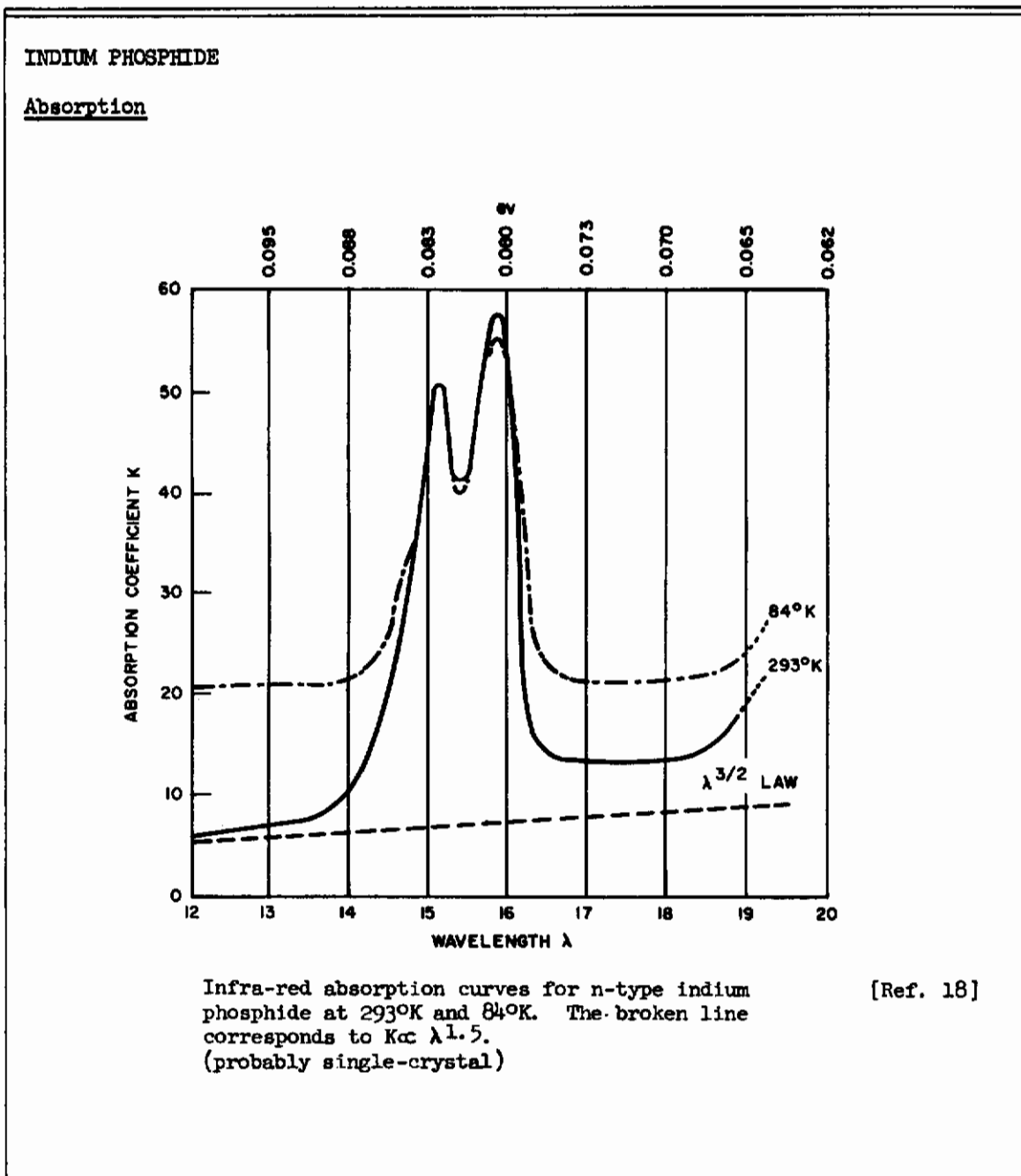
DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Absorption
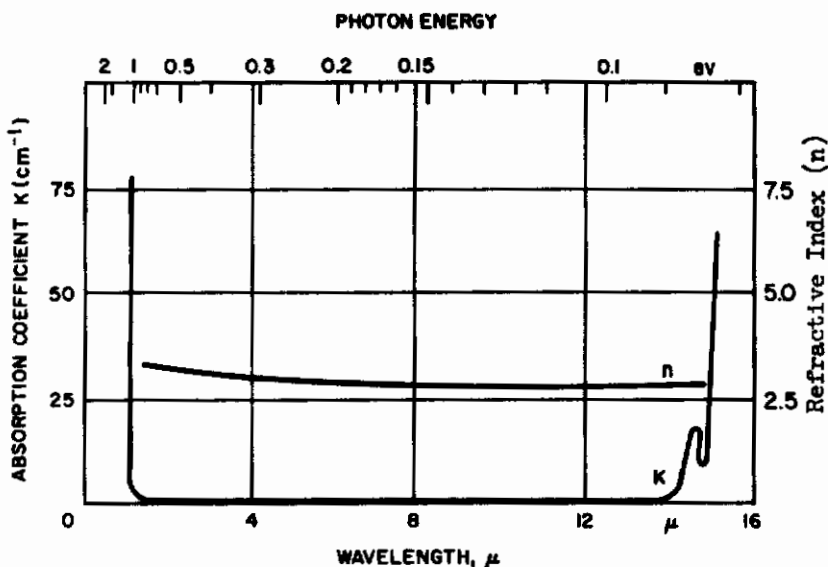
Indium Phosphide; $\rho = 0.1 \ \Omega \, cm$, n-type, poly-crystal. [Ref. 15]
n = 3.1 in infra-red.

Dielectric Constant

Symbol	Value	Type	Test Conditions		Ref.
ϵ	15	n-single	$300^\circ K$	photon freq. = 0.040eV	13
	10.6		$300^\circ K$	photon freq. = 0.060eV to band edge	13

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Effective Mass

Symbol	Value	Type	Test Conditions	Ref.
m^*	$0.2\ m_o$	n-Single Intrinsic	$n_n = 5 \cdot 10^{18}$, optical data	13
m_n^*	$0.05\ m_o$	n-Single Intrinsic		13
m_p^*	$0.35\ m_o$	n-Single Intrinsic		13
m^*	0.10	n-Poly	$77^{\circ}K$ cyclotron resonance absorption	17
→m_n^*	$0.077\ m_o \pm 0.005$		$n_n = 6.1 \times 10^{15}/cm^3$ $mu = 18{,}600\ cm^2/V$ sec	17
→m_n^*	$0.073 \pm .007$	n-Poly	Faraday effect data	12
m_p^*	$0.69\ m_o$	n-Poly		12
m^*	$0.02\ m_o$	n-Poly	$84^{\circ}K$, optical data	18
m^*	$0.2-0.8\ m_o$	p	Cd-doped, mobility data	5
m^*	0.23	p-Poly Intrinsic	Conductivity measurements	4
m^*	0.10		Faraday rotation, lambda = 2-17 mu room temperature $n_n = 1.1 - 1.17 \times 10^{17}/cm^3$	1

→ Best values.

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DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Electrical Conductivity
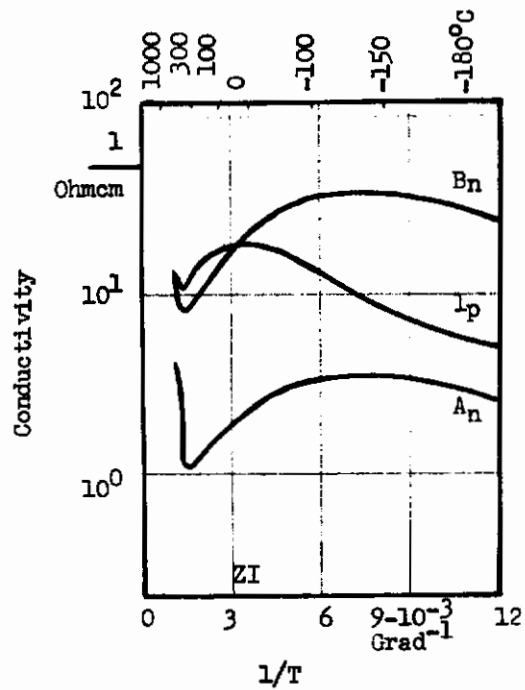
A_n = n-type, 4×10^{15} electrons/cm^3, 300°C
B_n = n-type
l_p = p-type, prepared by diffusion of zinc into A_n
T =-180° to 960°C

[Ref. 4]

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DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Electrical Conductivity
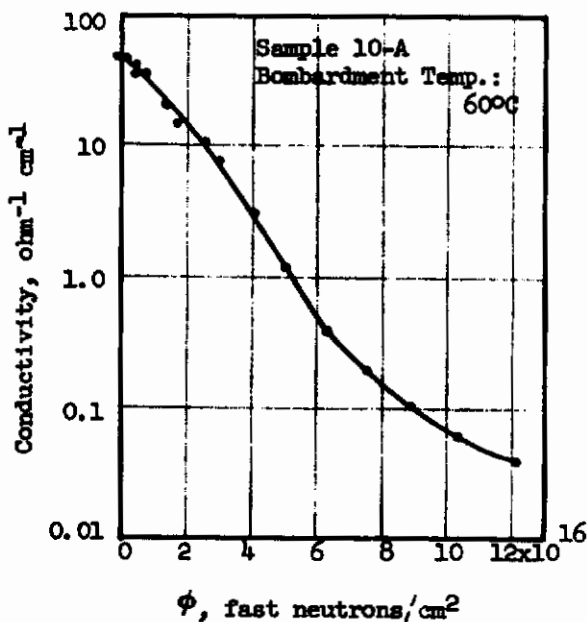
Irradiation of N-Type InP; variation in conductivity   [Ref. 2]
with neutron irradiation.

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Electrical Conductivity

$$\frac{1000}{T}, \ {}^{\circ}K^{-1}$$
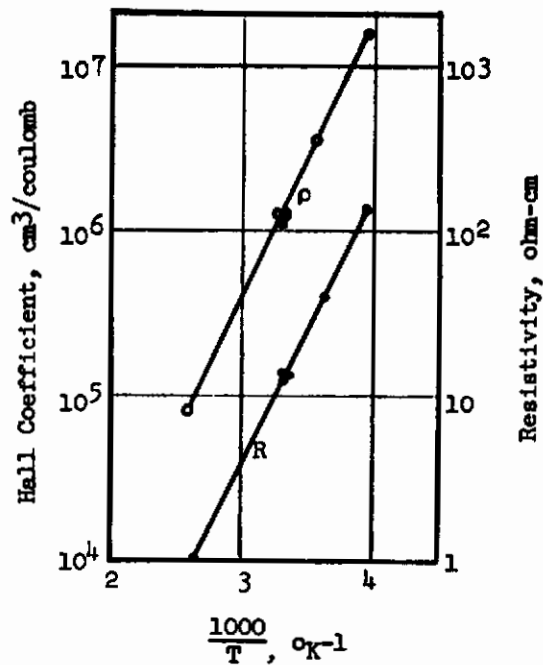
Before irradiation R = ~59 cm3/coulomb
ρ = 0.0179 Ω cm and
μH = 3300 cm2/volt sec.
n-type, single crystal, 250-360°K.

Temperature dependence of Hall coefficient,
R, and resistivity, ρ, of InP sample after
fast neutron irradiation.   [Ref. 2]

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES
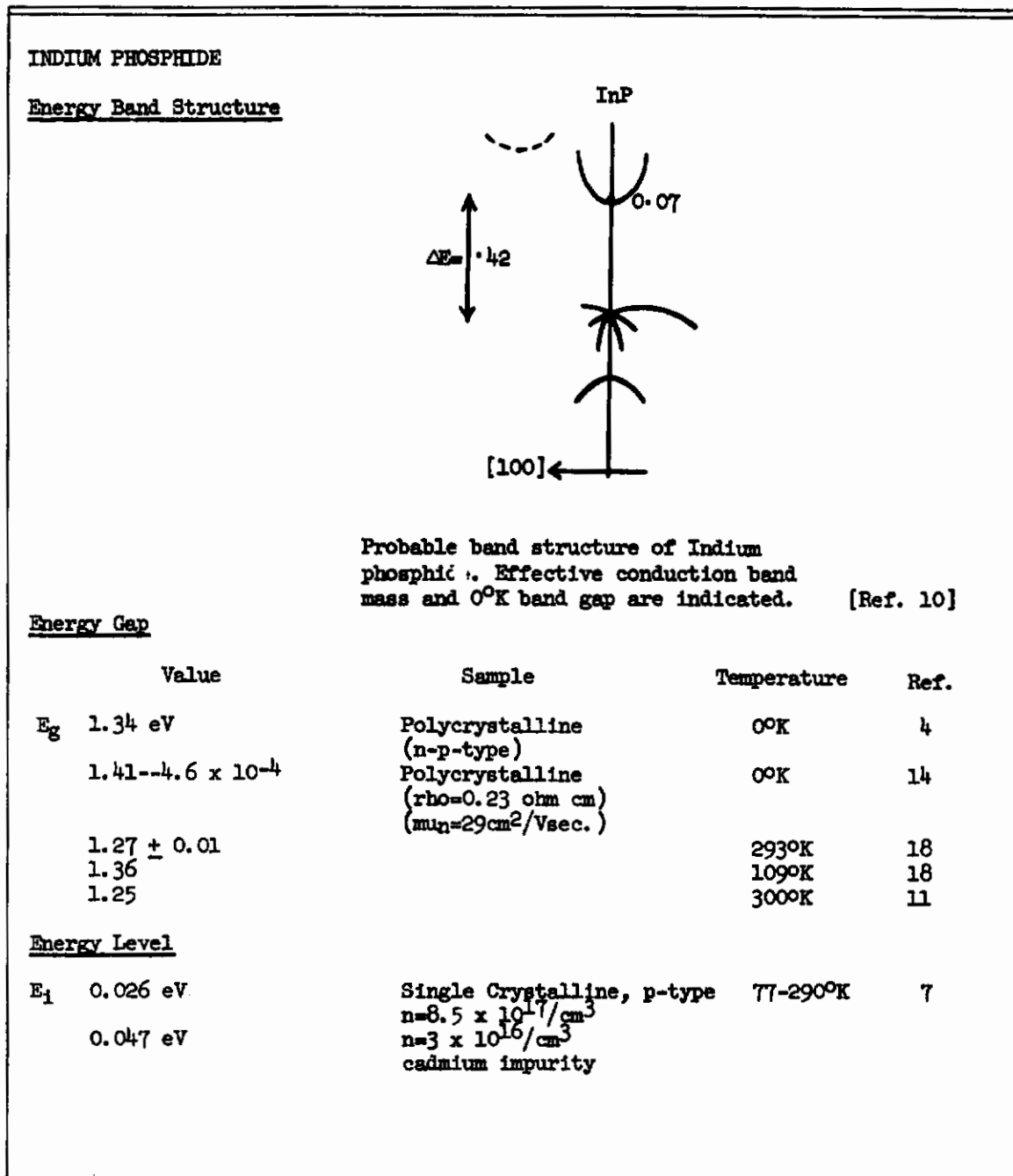
SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Energy Band Structure

InP

$\Delta E = \cdot 42$ 0.07

[100]

Probable band structure of Indium
phosphic. Effective conduction band
mass and $0^{o}K$ band gap are indicated.   [Ref. 10]

Energy Gap

	Value	Sample	Temperature	Ref.
E_g	1.34 eV	Polycrystalline (n-p-type)	$0^{o}K$	4
	$1.41 - 4.6 \times 10^{-4}$	Polycrystalline (rho=0.23 ohm cm) ($mu_n = 29 cm^2/Vsec.$)	$0^{o}K$	14
	1.27 ± 0.01		$293^{o}K$	18
	1.36		$109^{o}K$	18
	1.25		$300^{o}K$	11

Energy Level

	Value	Sample	Temperature	Ref.
E_1	0.026 eV	Single Crystalline, p-type $n=8.5 \times 10^{17}/cm^3$	$77-290^{o}K$	7
	0.047 eV	$n=3 \times 10^{16}/cm^3$ cadmium impurity		

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DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Hall coefficient
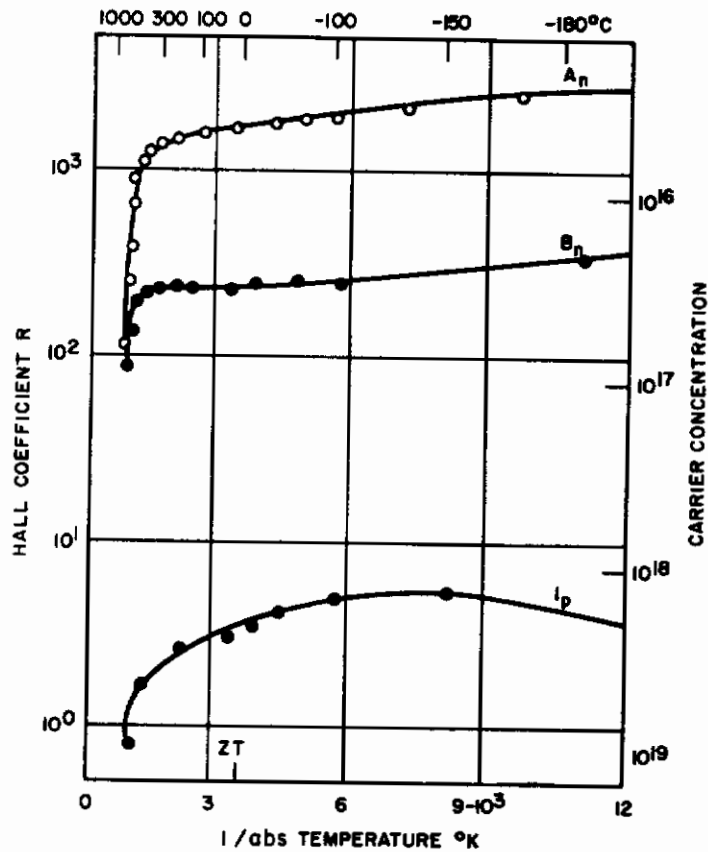
Specific conductivity and Hall coefficient of two   [Ref. 4]
n- and one p-conducting indium phosphide compounds.
I_p is zinc-doped, $n_n = 4 \times 10^{15}/cm3$

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Irradiation Effects

See Electrical Conductivity

Lifetime--Diffusion Length

Symbol	Value	Type	Test Conditions	Ref.
L_n	130 mu = 0.13 mm	p-n junction, single		6
r_1	2×10^{-6} sec.			6
L	0.2 mm (est.)		From photoconductive	18
r	5×10^{-6} sec. (est.)		threshold	18

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DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Magnetoelectric Properties

The magnetoresistance of *n*-type InP crystal 192 as a function of the angle the magnetic field makes with the [001] direction in the (Ī10) plane. The temperature was 292°K. [Ref.7]

The magnetoresistance of *n*-type InP crystal 192 as a function of the angle the magnetic field makes with the [001] direction in the (110) plane. The temperature was 292°K. [Ref.7]
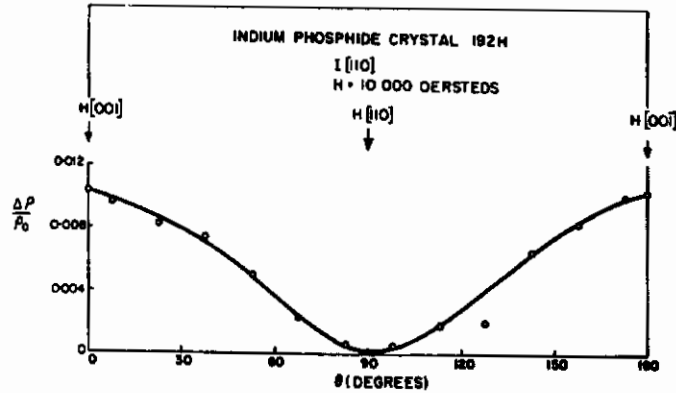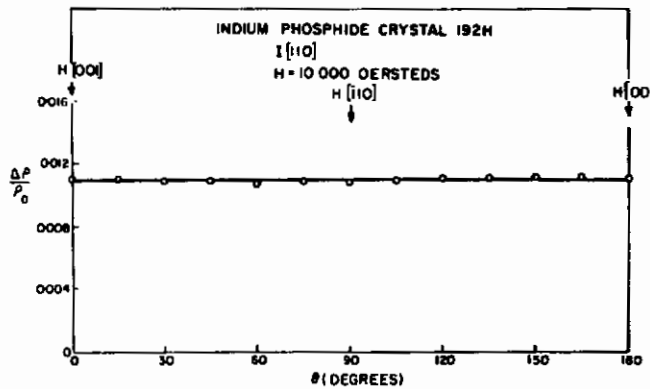
DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Magnetoelectric Properties

Crystal	Hall mobility (cm^2/V-sec)	Electron concentration (cm^{-3})	Temperature (°K)	Magnetoresistance $\Delta\rho/\rho_0 H^2$ (10^6 cm^4/v^2-sec^2)		
				I [110] H [110]	I [110] H [001]	I [110] H [110]
1	3150	$1\cdot4 \times 10^{17}$	289	0·31	0·55	0·26
51	3150	$1\cdot2 \times 10^{17}$	290	0·03	0·13	0·10
54	2800	6×10^{15}	290	0·37	1·15	1·22
T43	4300	$4\cdot3 \times 10^{16}$	293	0·20	0·66	0·25
T43	8700		77	0·6	8·2	6·6
192	4200	6×10^{15}	294	0·05	1·3	1·5
192	23400		77	0·4	34·0	31·0
192[†]	4600	6×10^{15}	292	0·02	1·11	1·09[††]
T5[†]	2750	$4\cdot6 \times 10^{17}$	293	0·02	0·14	0·10[††]
T43[†]	4000	5×10^{16}	292	0·02	0·28	0·21[††]
T43[†]	6900		77	0·09	6·2	5·8 [††]

[†]The side contacts were 0·002 in. diameter gold wires welded to the crystal.

[††]Purest.

Magnetoresistance of n-type InP. In the conventional notation three coefficients b, c, and d may be defined by

$$\frac{\Delta\rho}{\rho_0 H^2} = b + \frac{(I \cdot H)^2}{I^2 H^2} c + \frac{\sum_i I_i^2 H_i^2}{I^2 H^2} d.$$

The last three columns of Table refer respectively to measurements of b + c + 1/2d, b, and b + 1/2d.

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Mobility

Symbol	Value	Type	Temp.	Test Conditions	Ref.
μ_n	4600		300°K	$n=5 \times 10^{16}/cm3$	20
μ_p	100		300°K	$n=3 \times 10^{17}/cm3$	20
μ	190	p-single	300°K	$n=5 \times 10^{16}/cm3$ for	3
μ	1200	p-single	77°K	cadmium doping	3
μ_n	4500	n-single	300°K	$n=6 \times 10^{15}/cm3$	3
μ_n	23400	n-single	77°K	pure	3

n-type Crystal	Concentration of electrons at 290°K, $10^{16}cm^{-3}$	Mobility at 290°K, $cm^2/v\text{-}sec$	Mobility at 77°K, $cm^2/v\text{-}sec$
TA15	54	2910	2600
S51	7.4	3400	4170
S67	0.37	3800	4170
TAI43	4.3	4200	8300
C3	2.6	3800	13,500
S152	0.83	4300	21,000
S192†	0.63	4500	23,400

† These values represent the results for a number of samples.

[Ref.8]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES
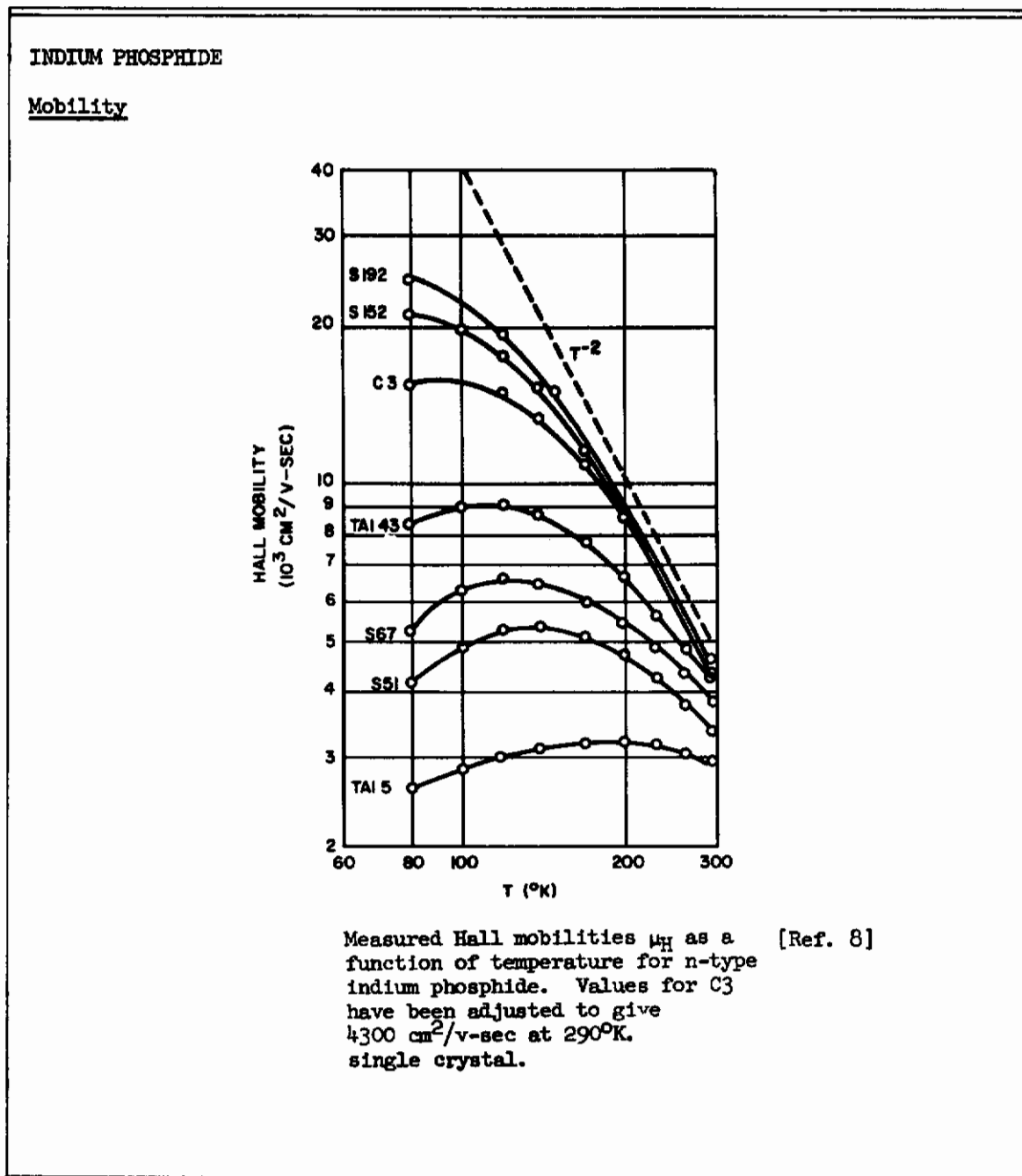
SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Mobility

Measured Hall mobilities μ_H as a   [Ref. 8]
function of temperature for n-type
indium phosphide. Values for C3
have been adjusted to give
4300 cm^2/v-sec at 290°K.
single crystal.

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE
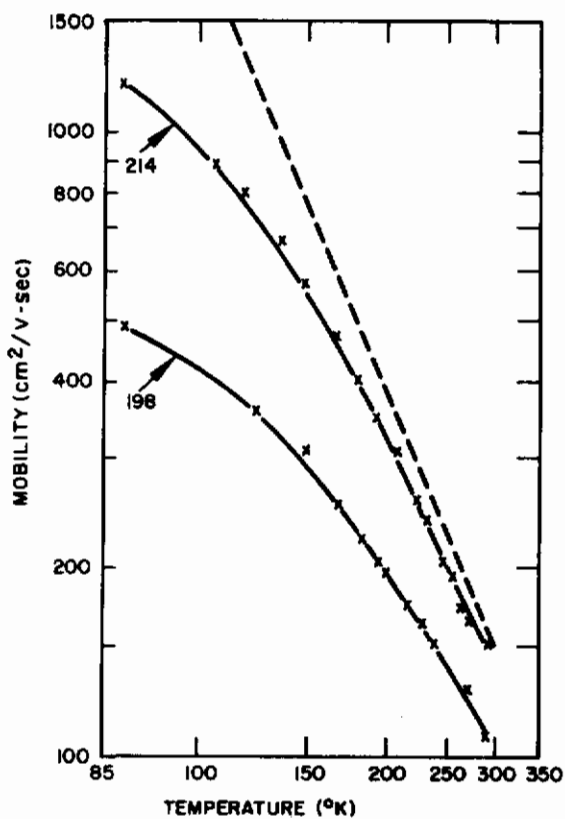
<u>Mobility</u>

The Hall mobility of p-type InP crystals as a function of temperature. The dashed curve is the lattice mobility calculated from the 214 curve, assuming $m^* = 0.2 m_0$.   [Ref. 5]

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Mobility
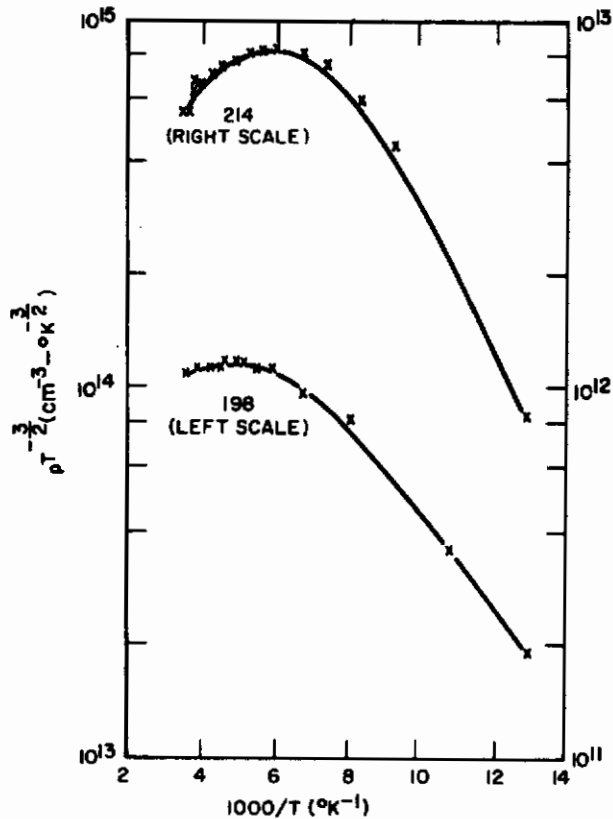
The product of hole concentration and (temperature)$^{-1.5}$ as a function of 1/T. The slope at low temperatures was used to estimate the ionization energy.   [Ref. 5]

DATA SHEET

ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Photoelectronic Properties
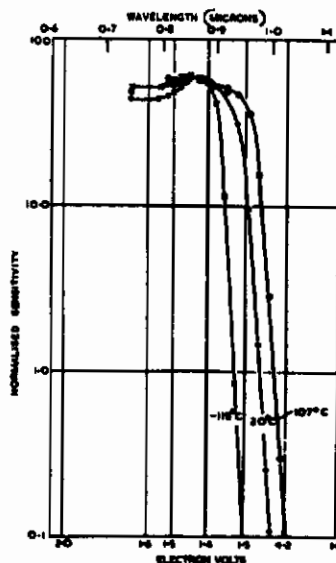
Response curves for a p-type indium phosphide photodiode.

Polycrystal
Diode was a point contact on p-type   [Ref. 18]
polycrystalline material. The
photovoltaic threshold (where response
is 1/2 peak value) is given as a
function of temperature by
$E_z = 1.44 - 4.5 \times 10^{-4}$ TeV

Piezoelectric Properties
    Piezoresistance

π n-single 300°K $n = 2.5 \times 10^{16}$ [Ref. 19]
                              isotropic compression

$-1/P \cdot \delta R/R = (\pi_{11} + 2\pi_{12}) = -(8.2 \pm 0.03) \times 10^{-12}$ cm^2/dyne
Current and stress along (110) direction:
$1/X \cdot \delta R/R = 1/2(\pi_1 + \pi_{12} + \pi_{44}) = -(1.3 \pm 0.5) \cdot 10^{-12}$ cm^2/dyne

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Reflectivity
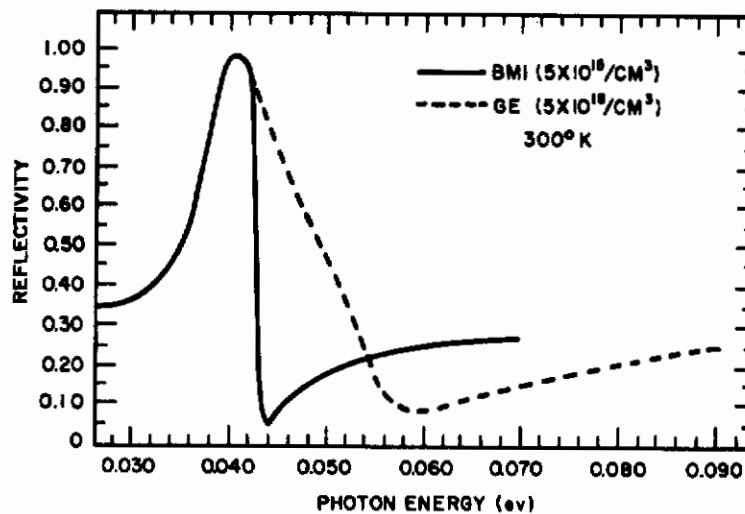
Reflectance spectra (300°K) of InP for two samples   [Ref. 13]
having different free electron densities as noted.
Low concentration sample exhibits clear reststrahl
peak from which longitudinal and transverse optical
phonon energies are found to be $h\omega_l$ = 0.043eV and
$h\omega_t$ = 0.036eV. Sample are n-type, polycrystal.

Symbol	Value	Test Conditions	
n-poly	0.25	γ = 4-15μ	[Ref. 16]
		ρ = 0.1 ohm cm.	

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

Refractive Index

Indium Phosphide; $\rho = 0,1$ Ω cm, n-type, single crystal. [Ref. 15]
n = 3.1 in infra-red.

Symbol	Value	Type	Test Conditions	Ref.
n	3.26		Room Temperature	10

Thermoelectric Properties
  Seebeck Effect

S	-400 μ V/^{o}C	n-single	300°K n=5 x 10^{15}	13
S	-100 μ V/^{o}C	n-single	300°K n=5 x 10^{18}	13

DATA SHEET
ELECTRICAL AND ELECTRONIC PROPERTIES

SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

References

here

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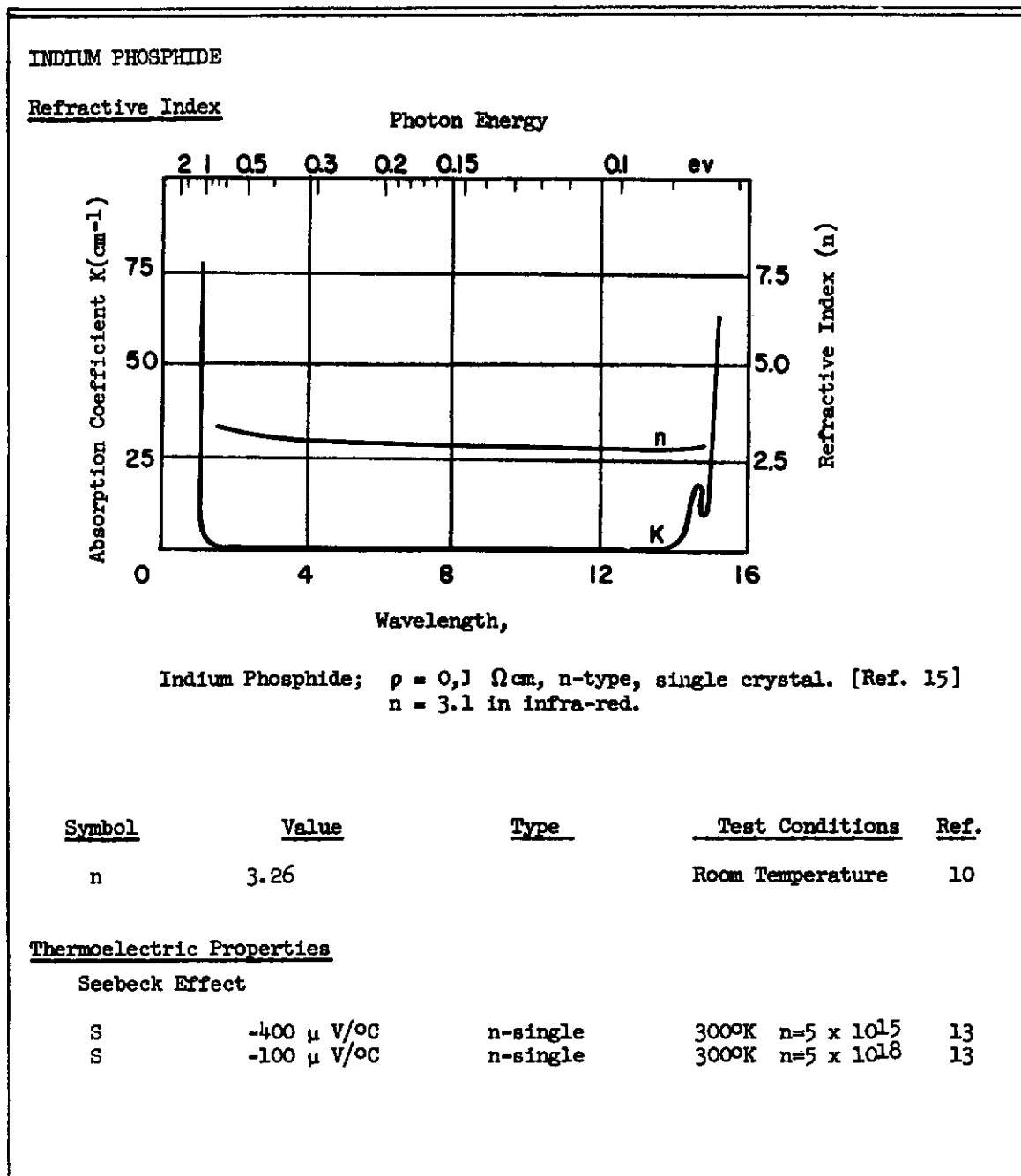
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SEMICONDUCTOR MATERIALS

INDIUM PHOSPHIDE

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KEY TO PROPERTY SYMBOLS

Property Name		Symbol	Unit
absorption coefficient		α	cm^{-1}
absorption index		k	
acceptor state		p	
activation energy		E_g, E_1	eV
band gap		g	
Boltzmann constant		k	$8.62 \times 10^{-5} eV/^\circ K$
bombardment flux (integrated bombardment flux density)		ϕ	electrons/cm^2
bulk		b	
carrier concentration	electron	n_n	n/cm^3
carrier concentration	hole	n_p	$n(cm^{-3})$
collision		c	
collision cross section		σ_c	
conductivity - see electrical conductivity			
cross section		σ_c	
recombination cross section		σ_r	
cyclotron frequency		ν_c	sec^{-1}
dark current conductivity		σ_o	$\rho^{-1}cm^{-1}$
Debye temperature		θ_D	$^\circ K$
dielectric constant		ϵ	
low frequency - static - dc		ϵ_o	
infinite - optical - high frequency		ϵ_∞	
dielectric relaxation time		r_ϵ	
diffusion coefficient for electrons		D_n	cm^2/sec
diffusion coefficient for holes		D_p	cm^2/sec

Property Name	Symbol	Unit
diffusion length for electrons	L_n	mm
diffusion length for holes	L_p	mm
donor state	n	
drift	d	
drift mobility	μ_d	$cm^2/V\ sec$
for electrons	μ_{dn}	"
for holes	μ_{dp}	"
effective electron charge	e^*	
effective mass		
unit effective mass, electron mass unit	m_o^*	
total effective mass	m^*	
electron mass	m_n^*	
hole mass	m_p^*	
electron intrinsic mass	m_{in}^*	
hole intrinsic mass	m_{ip}^*	
exciton effective mass	m_{ex}^*	
intrinsic effective mass	m_I^*	
electric field intensity	ϵ	eV
electric susceptibility	P	
electrical conductivity	σ	$\Omega^{-1}cm^{-1}$
for electrons	σ_n	"
for holes	σ_p	"
impurity	σ_I	"
electrical resistivity	ρ	Ωcm
for electrons	ρ_n	"
for holes	ρ_p	"
electroacoustic properties		
energy - phonon	E_{ph}	
temperature - phonon	θ_{ph}	^oK
electron, negative charge carrier	n	
electron charge	e	coulombs
electron concentration	n_n	cm^{-3}
electron conductivity	σ_n	$\Omega^{-1}cm^{-1}$

Property name	Symbol	Unit
electron mean free path	L_n	cm
electron mobility	μ_n	cm^2/V sec
electron velocity	v_n	cm/sec
energy	E	eV
energy gap	E_g	eV
energy levels	E, E_I, E_g	eV
Ettinghausen coefficient	A_E	
Ettinghausen-Nernst coefficient	A_{EN}	
exciton	ex	
exciton energy level	E_{ex}	eV
extinction coefficient	k	cm^{-1}
energy change for temperature	dE/dT	$eV/^\circ K$
energy change for pressure	dE/dP	eV/atm.
field mobility	μ_e	cm^2/V sec
for electrons	μ_{en}	"
for holes	μ_{ep}	"
figure of merit	Z	
forbidden energy gap	E_g	eV
frequency	ν	kc/sec
gap	g	
Hall coefficient	R_H	$cm^3/coul$
Hall mobility	μ_H	cm^2/V sec
for electrons	μ_{Hn}	"
for holes	μ_{Hp}	"
Hall voltage	V_H	
hole, positive charge carrier	p	
heavy hole effective masses	m_{2p}, m_{3p}	

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Property name	Symbol	Unit
hole concentration	n_p	cm^{-3}
hole conductivity	σ_p	$\Omega^{-1}cm^{-1}$
hole mean free path	L_p	cm
hole mobility	μ_p	cm^2/V sec
hole velocity	v_p	cm/sec
impurity	I	
impurity conductivity	σ_I	$\Omega^{-1}cm^{-1}$
impurity cross section	σ_{cI}	
impurity energy level measured from valence band edge	E_i	
impurity ionization energy measured from conduction band edge	$E_i - E_g$	

impurity mobility	μ_I	cm^2/V sec
index numbers	i, j	
ionization energy	$E, E_i, \phi_T, \phi_{h\nu}$	
k space vector	$\overrightarrow{k}$	
k space components	$\overrightarrow{k_i}$	
lifetime	r_i	sec
longitudinal acoustic	LA	
longitudinal optical	LO	
magnetic field intensity	X	gauss cm^2
magnetic induction	B	gauss
magnetic susceptibility	X	

Property name	Symbol	Unit
magnetoresistance coefficient	$\left(\dfrac{\Delta\rho}{\rho_o H_2}\right)$	
mean free path		
electron	L_n	cm
hole	L_p	cm
mean free time	τ_i	sec
mobility	μ	cm^2/V sec
electron	μ_n	"
hole	μ_p	"
momentum	$\vec{p}=\hbar\vec{k}$	
Nernst coefficient	A_N	
parallel	$\parallel$	
Peltier coefficient	π	μ volts/^{o}K
permittivity of free space	ϵ_o	
ϵ/ϵ_o dielectric coefficient k		
perpendicular (normal)	$\perp$	
phonon	ph	
longitudinal acoustic	LA	
longitudinal optical	LO	
transverse acoustic	TA	
transverse optical	TO	
phonon energy levels		
longitudinal acoustic	E_{LA}	
longitudinal optical	E_{LO}	
transverse acoustic	E_{TA}	
transverse optical	E_{TO}	
phonon temperature		
longitudinal acoustic	θ_{LA}	
longitudinal optical	θ_{LO}	
transverse acoustic	θ_{TA}	
transverse optical	θ_{TO}	
photoconductivity	$\Delta\sigma/\sigma_o$	
relative change in conductance per unit	$\Delta\sigma=(\sigma-\sigma_o)$	
radiant energy or per photon		
photoelectric properties	$\phi_{h\nu},\ \Delta\sigma/\sigma_o$	

Property name	Symbol	Unit
photoelectric magnetic effect	PEM	
photoelectric magnetic current (short circuit)	I_{PEM}	amp/gauss/flux density
photoelectric magnetic voltage (short circuit)	V_{PEM}	volts/gauss/flux density
photoemission work function	$\phi_{h\nu}$	
photon energy	$h\nu$	eV
piezoresistance coefficients	$\pi_{\parallel}$ $\pi_{\perp}$	$10^{-12} cm^2/dyne$
piezoresistance tensor coefficients	π_{ij}	$10^{-12} cm^2/dyne$
Planck's constant	h	$4.5 \times 10^{-5} eV$ sec
polarization, electric	P	
power	W	
pressure	P	atm.
pressure coefficient of energy	dE/dP	eV/atm.
recombination cross section	σ_r	
recombination lifetime	r_i	sec
recombination rate (velocity) bulk rate surface rate	r_b r_s	cm/sec cm/sec
reflection coefficient	R	
refractive index normal to chief axis parallel to chief axis	n $n_{\perp}$ $n_{\parallel}$	
resistivity	ρ	Ω cm
Righi-Leduc coefficient	A_{RL} S_{RL}/k	
Seebeck coefficient	S	$\mu V/^{\circ}K$
spectral absorption	α, k	

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Property name	Symbol	Unit
surface	s	
temperature	T	$^{\circ}$K, $^{\circ}$C
temperature coefficient of energy	dE/dT	
temperature coefficient of resistivity	$\frac{1}{\rho_o} \cdot \frac{d\rho}{dT}$	
thermal conductivity	K	watts/cm $^{\circ}$K
thermionic work function	ϕ_T	
thermoelectric figure of merit	Z	
Thompson coefficient	σ_{TH}	μV/$^{\circ}$K
time	t	sec
transverse acoustic	TA	
transverse optical	TO	
voltage	V	
wavelength	λ	mμ $\begin{aligned} \mathring{A} &= 10^{-8} \text{cm} \\ \mu &= 10^{-4} \text{cm} \end{aligned}$
work function	$\phi_T, \; \phi_{h\nu}$	

$$\text{Photon-wavelength Conversion} \qquad eV = \frac{1.24}{\lambda}$$

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Symbol	Property name
A_E	Ettinghausen coefficient
A_{EN}	Ettinghausen-Nernst coefficient
A_N	Nernst coefficient
$A_{RL} = S_{RL}/k$	Righi-Leduc coefficient
b	bulk
B	magnetic induction
$\overset{\cdot}{c}$	collision
d	drift
dE/dP	energy change for pressure
dE/dT	energy change for temperature
D_n	diffusion coefficient for electrons
D_p	diffusion coefficient for holes
e	electron charge
e^*	effective electron charge
ex	exciton
E	ionization energy
E	energy
E_g	energy gap, activation energy
E_i	impurity energy level measured from valence band edge
$E_i - E_g$	impurity ionization measured from conduction band edge
E_{ph}	phonon energy
E_{ex}	exciton energy
E_{LA}	longitudinal acoustic phonon energy level
E_{LO}	longitudinal optical phonon energy level

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Symbol	Property name
E_{TA}	transverse acoustic phonon energy level
E_{TO}	transverse optical phonon energy level
g	band gap
h	Planck's constant
$h\nu$	photon energy
i	index number
I	impurity
I_{PEM}	photoelectric magnetic current (short circuit)
j	index number
k	absorption index
k	spectral absorption
k	Boltzmann constant
k	extinction coefficient
$\vec{k}$	k space vector
$\vec{k_i}$	k space vector components
K	thermal conductivity
LA	longitudinal acoustic
LO	longitudinal optical
L_n	electron mean free path or diffusion length
L_p	hole mean free path or diffusion length
m^*	total effective mass
m_{ex}^*	exciton effective mass
m_{in}^*	electron intrinsic mass
m_{ip}^*	hole intrinsic mass

Symbol	Property name
m_I^*	intrinsic effective mass
m_n^*	electron mass
m_p^*	hole mass
m_{2p}, m_{3p}	heavy hole effective masses
n	refractive index
$n_\perp$	refractive index normal to chief axis
$n_\parallel$	refractive index parallel to chief axis
n	donor state
n	electron, negative charge carrier
p	acceptor state
p	hole, positive charge carrier
$\vec{p} = \hbar\vec{k}$	momentum
ph	phonon
P	electric polarization
P	electric susceptibility
P	pressure
PEM	photoelectromagnetic effect
r_b	bulk recombination rate
r_s	surface recombination rate
R	reflection coefficient
R_H	Hall coefficient
s	surface
S	Seebeck coefficient
T	temperature

Symbol	Property name
TA	transverse acoustic
TO	transverse optical
v	velocity
v_n	electron velocity
v_p	hole velocity
V	voltage
V_H	Hall voltage
V_{PEM}	photoelectromagnetic voltage (short circuit)
W	power
X	magnetic field intensity
Z	thermoelectric figure of merit
$\parallel$	parallel
$\perp$	normal, perpendicular

Symbol	Property name
α	spectral absorption
α	absorption coefficient
γ_1	mean free time
ϵ	electric field intensity
ϵ	dielectric constant
ϵ_0	dielectric constant, low frequency
ϵ_∞	dielectric constant, high frequency
ϵ/ϵ_0	dielectric coefficient k
ϵ_0	permittivity of free space
θ_D	Debye temperature
θ_{LA}	longitudinal acoustic phonon temperature
θ_{LO}	longitudinal optical phonon temperature
θ_{TA}	transverse acoustic phonon temperature
θ_{TO}	transverse optical phonon temperature
θ_{ph}	phonon temperature
λ	wave length
μ	mobility
μ_d	drift mobility
μ_{dn}	electron drift mobility
μ_{dp}	hole drift mobility
μ_e	field mobility
μ_{en}	electron field mobility
μ_{ep}	hole field mobility
μ_H	Hall mobility

Symbol	Property name
μ_{Hn}	electron Hall mobility
μ_{Hp}	hole Hall mobility
μ_I	impurity mobility
μ_n	electron mobility
μ_p	hole mobility
ν	frequency
ν_c	cyclotron frequency
π	Peltier coefficient
ρ	electrical resistivity
ρ_n	electron electrical resistivity
ρ_p	hole electrical resistivity
$\Delta\rho/\rho_o H^2$	magnetoresistance coefficient
$\frac{1}{\rho_o} \times \frac{d\rho}{dT}$	resistivity temperature coefficient
σ	electrical conductivity
σ_I	impurity electrical conductivity
σ_n	electron electrical conductivity
σ_p	hole electrical conductivity
σ_o	dark current conductivity
σ	cross section
σ_c	collision cross section
σ_{cI}	impurity cross section
σ_r	recombination cross section
σ_{TH}	Thompson coefficient
$\Delta\sigma/\sigma_o$	photoconductivity

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Symbol	Property name
$\Delta_\sigma = (\sigma - \sigma_o)$	relative change in conductance per unit radiant energy or per photon
r	time
r_1	lifetime, recombination lifetime
r_ϵ	dielectric relaxation time
ϕ	bombardment flux
ϕ_T	thermionic work function
$\phi_{h\nu}$	photoemission work function
$\pi_\perp, \pi_{\|}$	piezoresistance coefficients
π_{ij}	piezoresistance tensor coefficients
χ	magnetic susceptibility