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TERNARY MINERALS AND COMPOUNDS: AN ANNOTATED BIBLIOGRAPHY

SPECIAL BIBLIOGRAPHY SB-62-4

FEBRUARY 1962
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TERNARY MINERALS AND COMPOUNDS: AN ANNOTATED BIBLIOGRAPHY

Compiled by
A.A.BELTRAN

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ABSTRACT

This annotated bibliography is concerned with ternary minerals and compounds of metallic elements with Group V metallics and Group VI nonmetallics (selenides, sulfides and tellurides). The literature primarily covers the period from 1959 to 1961. However, thesis from as early as 1947 and a few Russian articles from 1955 have been included.

Search completed January 1962.
INTRODUCTION

The literature search, from which this annotated bibliography resulted, was concerned primarily with ternary minerals as they occurred in nature. Literature on ternary compounds has been included for comparison. The search was concentrated over the three year period from 1959 through 1961. However, applicable thesis from as early as 1947, and a few continuing Russian articles from 1955 have been included.

Reports and articles on the properties of ternary minerals and compounds of the following elements are presented.

Metallic Elements

Cobalt (VIII)
Copper (Ib)
Iron (VIII)
Lead (IVb)
Manganese (VIIa)
Mercury (Ib)
Nickel (VIII)
Silver (I)
Thallium (III)
Zinc (II)

An excellent source of information on ternary minerals, not listed in this bibliography is:

Dana, James D.

In this volume one may find, for example, the following sulfides:

ArSENOPYRite --- ----- -FeAsS
Bourbonite- ---- -PbCuSbS3
Chalcopyrite -- ----- CuFeS2
Cobaltite - - - - - (Co, Fe)AsS
Enargite- -------- Cu3AsS4
Jamesonite - - - - - Pb4FeSbS6

The entries in the bibliography are arranged alphabetically by author. An extensive subject index makes every mineral, compound, selenide, sulfide and telluride readily available.

LOCKHEED MISSILES & SPACE COMPANY
1. Allgaier, R.S.
THE 1960 INTERNATIONAL CONFERENCE ON
SEMICONDUCTOR PHYSICS AT PRAGUE: THE
LEAD SALT SEMICONDUCTORS PbS, PbSe, AND
PbTe, AND OTHER SELENIDES AND TELLURIIDES.
Naval Ordnance Lab., White Oak, Md. Rept.
No. NAVWEPS 7332. 18 Oct 60, 9p.
ASTIA AD-252 874

Information obtained at the Prague Semiconductor Conference on the lead salts
(Sulphide, Selenides, and Tellurides) from papers and personal contacts, and
later, from follow-up correspondence is described. The Conference session,
entitled Selenides and Tellurides, is also summarized.

A structural study of the compound AgSbTe$_2$.
Westinghouse Res. Lab., J. APPL. PHYS.,

The use of x-ray, optical and electron microscope, and chemical etching tech-
iques to investigate a striated microstructure, observed in zone refined
single crystals of the AgSbTe$_2$ structure is reported. This microstructure,
originally thought to be fine twin lamellas, has been identified as a Widman-
statten precipitate of Sb$_2$Te$_3$ upon the (111) planes of the matrix face-centered
cubic material. In addition, the evidence obtained from all measurements made
on this material indicates that the ternary compound of the AgSbTe$_2$ does not
melt congruently.

3. Bennett, L.C. and Wiese, J.R.
Effects of doping additions on the thermo-
conductor B$_2$I$_2$Te$_2$.1Se$_{0.9}$. J. APPL. PHYS.
(USA) v. 32, n. 4, p. 562-4, Apr 1961.
An alloy of 70 mol % B$_2$I$_2$Te$_2$.30 mol % B$_2$I$_2$Se$_2$, or B$_2$I$_2$Te$_2$.1Se$_{0.9}$ is the intrinsic
semiconductor of the pseudobinary system B$_2$I$_2$Se$_2$. This V-VI alloy was doped
with lead(Group IV) and iodine (Group VII) separately and together. The effects of
3. (Cont'd) the dopants are analogous to those produced by Group III or Group V impurities in Group IV elemental semiconductors, the lower group impurity producing a p-type material and the higher group impurity an n-type material. Plots of the Seebeck coefficient, electrical conductivity, and thermal conductivity are given as a function of impurity concentration and show that the separate effects of the impurities are countered when the impurities are in the lattice together in the same amount. Doping was also done with silver and iodine, separately and together. The results indicate that the silver is in the lattice interstitially (lead and iodine substitutionally) and that the type material produced is dependent also on how the impurity atom enters the lattice.

4. Born, L. and Hellner, E.

A structural proposal for boulangerite. AMERICAN MINERALOGIST, v. 45, n. 11-12, p. 1266-71, Nov-Dec 60.

A structure for the sub-cell of boulangerite (5PbS.2Sb2S3) is proposed which explains the morphology (as needles) and shows the boundary between the "galena-like" and the "stibnite-like" structures of complex sulfides.

5. Bubyreva, N. S. and Obukhov, A. P.


The ternary system thallium-selenium-tellurium was investigated by measuring the specific conductivity, investigating the microstructure, and by thermal analysis. The synthesis of the samples was carried out by melting the chemically pure metals in evacuated vessels. For the surface construction of the liquid, 94 alloys were examined and the phase diagram was plotted. The system has no ternary eutectics nor ternary compounds. Five crystalline zones are formed. In the first crystallization zone, primary separation of tellurium and selenium takes place. In the second zone, solid solutions between Tl2Se and Tl5Te3 form in the third zone. The fourth crystallization zone has no solid solutions. The fifth zone probably has the compound Tl2Se3.
5. (cont'd) compounds in the second crystallization zone, Tl Se and Tl Te, have analogous chemical properties and similar crystalline structures as has been proved by X-ray analysis. The composition of the phases I, II, and III corresponds to solid solutions. The alloys of the system possess semiconductor properties. The specific electric conductivity of the alloys depends considerably on the composition and it changes from $1 \times 10^2$ to $1 \times 10^{-5} \text{ ohm}^{-1} \text{ cm}^{-1}$. The maximum conductivity of $1 \times 10^2$ is at the limit of metallic conductivity because these alloys contain admixtures of metallic thallium.

6. Buhrer, Carl F.

SOME PROPERTIES OF BISMUTH PEROVSKITES,

Laboratory for Insulation Research, Mass. Inst.
of Tech., Cambridge. Technical rept. no. 160,
Mar 61, 26p., (Contracts AF 19(604)6155 and
Nonr-184110). ASTIA AD-253 293.

The crystallographic and dielectric properties of complex perovskites are described in terms of average A- and B-site ionic radii, charges, electronic structures, etc. The relative importance of these to the ferroelectric state is evaluated by a study of a number of solid solutions containing trivalent bismuth. Two new ferroelectrics, Bi0.5K0.5Ti03 and Bi0.5Na0.5Ti03, and the phase diagrams of the systems BixKxBa1-2xTi03, Bi0.5KxNa0.5-xTi03, BixKxPb1-2xZr03, and BixNaxPb1-2xZr03 are reported.

7. Cosgrove, G.J., McHugh, J. P. and Tiller, W. A.

Effect of freezing conditions on the thermoelectric properties of BiSbTe3 crystals. J. APPL. PHYS. (USA)
v. 32, n. 4, p. 621-3, Apr 61.

The thermoelectric parameters $\alpha$, $1/p$, and $1/(K-Ke)$ of oriented polycrystals increase as the freezing rate decreases and as the temperature gradient in the liquid at the interface increases. The effects are primarily attributed to the variation in the degree of microsegregation produced in the crystals as a function of the freezing conditions.

8. Dudkin, L. D. and Ostranitsa, A. P.

Ternary Semiconducting compounds $A^IB^VB_2VI$.

DOKL. AKAD. NAUK SSSR v. 124, n. 1, p. 94-7,
Jan 1, 1959. (In Russian)
8. (cont'd) Four compounds were studied: CuSbSe₂, AgSbSe₂, AgSbTe₂, and AgBiSe₂, with melting points at 472, 634, 561 and 792°C, respectively. (AgBiSe₂ showed a polymorphic transformation at 298°C). Electrical and thermal conductivity, thermoelectric power and microhardness were measured. Thermal activation energies were (in eV): AgSbSe₂, 0.58; CuSbSe₂, 0.16 and 0.80; AgBiSe₂, 0.34 (low temperature form and 1.10 (high temperature form). A chemical bonding scheme is suggested in which Al⁺ ions are situated in a covalently bonded (BV-BVI⁻) structure.

9. Earley, J. W.


This is a contribution to the pure mineralogy (natural history) of the selenides. Its primary purpose is to improve the descriptive mineralogy of the group, as given in Dana, 1944 and Klockmann - Ramdohr, 1948 by verification, correction, and extension of the specific data, and to reconsider the classification of the selenides in the larger sulphide group. To supplement observations on natural material, which was almost always extremely scanty, the corresponding pyrosynthetic compounds were in most instances successfully prepared and studied as artificial minerals.

Elagina, E. I.

see Yelagina, Ye. I.


Semiconducting mixed crystals of the type

\[(\text{Al}^+_{1/2} \text{Bi}^{IV}_{(1-x)} \text{C}^{VI}_{x/2})^{DVI} \]. Z. NATURFORSCH., v. 14a, n. II, p. 999-1000, Nov 1959. (In German.)

The example investigated was \((\text{Ag}_{x/2} \text{Pb}_{(1-x)} \text{Bi}_{x/2})\text{Te}\) and this was found to have the NaCl structure, the lattice parameter varying linearly with composition. The thermal conductivity passed through a minimum value of only 0.005 W cm⁻¹ deg⁻¹ which, associated with an electrical conductivity of 300 ohm cm, could be of interest for thermoelectric applications.
The crystallography of petzite, $\text{Ag}_3\text{AuTe}_2$.  
AMERICAN MINERALOGIST, v. 44, n. 7-8,  
From small single crystals of petzite found intimately intergrown with hessite ($\text{Ag}_2\text{Te}$) from Botes, Transylvania, the space group was determined to be cubic, $I4_32$ with a cell edge of 10.38 Å. There are 8($\text{Ag}_3\text{AuTe}_2$) per cell and the atoms are located on the following special positions: 24 silver atoms on $x$, 0, $1/4$, etc. with $x = 0.365$; 8 gold atoms on $1/8$, $1/8$, $1/8$, etc.; 16 tellurium atoms on $x$, $x$, $x$, etc. with $x = 0.266$.

Glass-like semiconductors. IZVESTIYA AKADEMIII NAUK S.S.S.R., SERIYA FIZICHESKAYA, v. 20,  
p. 1496-1500, 1956, (In Russian). English Translation  
Compounds lying in the following composition ranges were examined: $\text{As}_2\text{Se}_3$-$\text{Sb}_2\text{Se}_3$, $\text{As}_2\text{Se}_3$-$\text{Tl}_2\text{Se}$, $\text{As}_2\text{Se}_3$-$\text{As}_2\text{Te}_3$, $\text{As}_2\text{Se}_3$-$\text{As}_2\text{S}_3$, $\text{As}_2\text{Se}_3$. $\text{Tl}_2\text{Se}$-$\text{Sb}_2\text{Se}_3$. $\text{Tl}_2\text{Se}$, $\text{As}_2\text{S}_3$-$\text{Sb}_2\text{S}_3$. The ternary and quaternary systems were either crystalline or glass-like, with a well-defined composition boundary separating the two phases; however, for some composition both phases were present. The electrical and optical properties of the compounds are briefly described.

Properties and structure of ternary semiconducting systems. II. Electrical properties and structure  
of materials in systems of the thallium, antimony and arsenic selenides. ZH. TEKH. FIZ.,  
13. (cont'd) Materials in the systems Tl₂Se, As₂Se₃-Tl₂Se, Sb₂Se₃ and Sb₂Se₃-As₂Se₃ were prepared by direct fusion and subsequent slow cooling. All specimens were p-type semiconductors. Curves of electrical conductivity v. temperature and the corresponding activation energies are given. Evidence of glass-like amorphous structure was found for compositions rich in As₂Se₃.

14. Goryunova, N. A., Kolomiets, B. T. and Mal'kova, A. A.
Properties and structure of ternary semiconducting systems. III.
Conductivity and photoconductivity in systems of the thallium, antimony and bismuth sulphides. ZH. TEKH. FIZ. v. 26, n. 8, p. 1625-33, 1956.
(In Russian)

Tl₂S-Sb₂S₃: a marked minimum in conductivity (σ) and a maximum in thermal activation energy were found near Tl₂S.3Sb₂S₃. X-ray analysis showed this to be a new compound; a further compound was indicated near 2Tl₂S.4Sb₂S₃. Substitution of As for Sb in the alloy Tl₂S.2Sb₂S₃ shifted the peak of the photoconductive spectral response (P) to longer wavelengths. Bi₂S₃-Sb₂S₃: a complete range of semiconducting solid solutions appeared to form. A minimum in σ was observed near 40% Sb₂S₃. Small additions of S to the 50:50 alloy shifted P to longer wavelengths, but larger amounts (i.e. Bi₂S₃-Sb₂S₃) gave the response of pure S.

15. Goryunova, N. A., Kolomiets, B. T. and Shilo, V P.
Vitreous semiconductors. IX. Vitrification in complex chalcogenides based on As₂S₃ and As₂Se₃. FIZ. TVERDOGO TELA. v. 2, n. 2, p. 280-3, Feb 1960. (In Russian)

Alloys of As₂Se₃ with the sulphides (or selenides) of elements of the groups Ib (Cu, Ag, Au), IIb (Zn, Cd, Hg), IIIb (Ga, In, Tl) and IVb (Ge, Sn, Pb) were prepared and the extent of vitrification in each ternary system was approximately determined. Tl and Ge showed a much larger vitrification than other elements. The results cannot be easily interpreted, but some correlation was found to exist between the heat of formation of the chalcogenides of the elements of groups I-IVb and the area of the vitrification zone.

PROPERTIES OF HgSe-HgTe ALLOYS. Lincoln
Soc.
Determination of the phase diagram for the pseudo-binary system HgSe-HgTe by
differential thermal analysis and x-ray diffraction techniques was reported. Melting
points measured for HgSe and HgTe are 799° and 670°C, respectively. Continuous
solid solution occurs over the whole range of composition. Large single crystals of
the alloys have been prepared by the Bridgman method. Data on the electrical
properties of the alloys as a function of composition, impurity concentration, and
temperature were presented.

17. Hockings, E. F.
The thermal conductivity of silver
antimony telluride. RCA Laboratories.
PHYSICS AND CHEMISTRY OF SOLIDS
The compound was prepared directly from the elements in an evacuated quartz ampule
by heating to 700°C, mixing the resulting liquid by agitation, and then cooling at 5°C/min.
The product was a macrocrystalline ingot with grains up to 5 mm in length and with an
electrical resistivity of 5.3 x 10^-8 Ω-cm. Thermoelectric measurements showed it be
a p-type, nondegenerate semiconductor. X-ray powder diffraction patterns showed a
single-phase face-centered cubic structure with α = 6.076 Å. The thermal conductivity
at 300 K was determined by the standard method of placing cylindrical specimens
between a heater and a heat sink. Measurements were made of the thermal gradients
associated with known heat flows. The thermal conductivity of AgSbTe2 is 0.0071
W./degree-cm at 300°K. The electronic component was estimated as 0.0008 watt/
degree-cm.

18. Ibrahim, M. A.
TERNARY PHASE IN THE M₉S₈ SECTION
OF THE SYSTEM Fe-Co-Ni-S. Master
College, Halifax, 1959, 85p., 44 refs.
The (Fe, Co, Ni)₉S₈ section of the quaternary system Fe-Co-Ni-S at room temperature
has been investigated by X-ray diffraction methods. The face-centered cubic pi phase,
which is known from the system Co-S and from the mineral pentlandite, has been shown
to exist in the quaternary system over an appreciable range of compositions. The
composition of natural pentlandite is discussed as well as the reasonability of the
crystal structure which has been proposed for it by Eliseev. Lattice constants of
natural pentlandite from widely separated localities have been found to be closely
similar to each other but lower than those of synthetic pentlandites of any composition.
Prolonged heat treatment at 350-390°C raises the lattice constants of practically pure
pentlandite to values comparable with the values obtained for synthetic samples.
Possible reasons for this behavior are discussed.
19. Johan, Z. and Hak, J.

Novakit -- \((\text{Cu, Ag})_4\text{As}_3\), ein neues Mineral. CHEMIE DER ERDE v. 20, p. 49-50, 1959. (In German)

Analysis (mean of 2) gave \(\text{Cu} 41.39\), \(\text{As} 43.30\), \(\text{Fe} 5.13\), \(\text{Ag} 1.96\), \(\text{Co} 0.79\), \(\text{S} 2.73\), \(\text{CaO} 2.72\), \(\text{CO}_2 2.13\) for a total of 100.15%. After deducting calcite, \(\text{S}\) as chalcocite, and \(\text{Fe}\) as loelfingite, and recalculation to 100 yields \(\text{As} 45.82\), \(\text{Cu} 50.91\), \(\text{Ag} 3.27\%\). This corresponds to \((\text{Cu, Ag})_{1.36}\text{As}\) or \((\text{Cu, Ag})_{4}\text{As}\) or \((\text{Cu, Ag})_{1.1}\text{As}_8\).

20. Kokosh, G. V. and Sinani, S. S.

Thermoelectric properties of alloys of the pseudobinary system \(\text{Sb}_2\text{Te}_3 - \text{Bi}_2\text{Te}_3\)


The effect of impurities on the properties of alloys of the system \(\text{Sb}_2\text{Te}_3 - \text{Bi}_2\text{Te}_3\) is considered. A general description of the effect of additions on solid solutions of semiconductors with disturbed stoichiometry is presented. The effect of firing on the electrical conductivity and thermal EMF of pressed specimens is described. The properties of alloys made of materials of different purity are compared. The part of the system exhibiting maximum values of the thermal EMF is examined.

21. Kolomiets, B. T. and Nazarova, T. F.

The effect of impurities on electrical conduction in vitreous \(\text{As}_2\text{SeTe}_2\).

FIZ. TVERDOGO TELA. v. 2, n. 1, p. 174-6, Jan 1960. (In Russian)

Zone purification of \(\text{As}_2\text{SeTe}_2\) \((\text{As}_2\text{Se}_3, 2\text{As}_2\text{Se})_3\) left the electrical conductivity \((\sigma)\) of a vitreous material practically unaffected \(2 \times 10^{-6} \text{ ohm}^{-1}\text{cm}^{-1}\), \(p\)-type) but lowered considerable \(\sigma\) of crystals (it fell from 60 to \(\sim 0.01 \text{ ohm}^{-1}\text{cm}^{-1}\)) and altered it from \(p\)-to \(n\)-type. This suggests that impurity conduction is important in crystals but not in vitreous material.

22. Kolomiets, B. T. and Pozdnev, V. P.

Glassy semiconductors. VII. Viscosity of vitreous semiconductors in the \(\text{As}_2\text{Se}_3 - \text{As}_2\text{Te}_3\) system.

FIZ. TVERDOGO TELA. v. 2, n. 1, p. 28-34, Jan 1960. (In Russian)

Compositions between \(\text{As}_2\text{Se}_3\) and \(\text{As}_2\text{Se}_3\) and \(\text{As}_2\text{Se}_3\text{As}_2\text{Te}_3\) were studied \((400-800^\circ\text{C})\) by a rotational method. Kinematic viscosity \((\nu)\) decreased smoothly with \(\text{As}_2\text{Te}_3\).
22. (cont'd) concentration (x) and with temperature (at \(400^\circ C\) it varied from \(10^{-2}\) to \(10^{-1}\) stokes; at \(700^\circ C\) from \(10^{-1}\) to \(10^{-2}\) stokes). Activation energies (E) for viscous flow were evaluated (24.3-21.8 kcal/mole, decreasing with increasing x) as were the corresponding entropies of activation (in the range \(+7.2\) to \(-8.75\) cal/deg.mole). This behaviour was interpreted in terms of a chain structure: the low softening temperatures (<200°C) were ascribed to the breaking of interchain Van der Waals bonds, and the constant E for a given composition to the breaking of intrachain covalent bonds.

23. Kolomiets, B. T. and Nazarova, T. F.
Hall effect in vitreous materials of the
Ti_2SeAs_2(Se,Te)_3 system. Phys. Tech.
Inst., Leningrad. FIZ. TVERDOGO TELA.
v. 2, p. 395-6, 1960. (In Russian)
The Hall mobility was measured at room temp. as a function of Te content. The mobility remained const. at \(10^{-2}\) sq. cm. /V. -sec. for all compns., although the carrier concn. increased linearly from \(10^1\) to \(10^2\) /cc. as the compn. was varied from Ti_2SeAs_2Se_3 to Ti_2SeAs_2Te_3.

24. Kolomiets, B. T. and Goryunova, N. A.
Properties and structure of ternary
semiconducting systems. I. Electrical
properties and structure of some materials
in the system Tl-Sb-Se. ZH. TEKH. FIZ.
v. 25, n. 6, p. 984-94, 1955. (In Russian)
Alloys between Ti_2Se and Sb_2Se_3 were prepared by direct fusion and slow cooling. All were p-type semiconductors. Thermoelectric power, electrical conductivity, Hall effect and photoconductive spectral response were studied and evidence was obtained of the formation of a compound Ti_2SeSb_2Se_3 (rhombic a = 4.15, b = 4.50, c = 12.0 Å). Preliminary work on alloys of Ti_2Se with As_2Se_3 and As_2Te_3 is reported. Amorphous glass-like materials were observed.

25. Kolomiets, B. T. and Lyubin, V. M.
Properties and structure of ternary
semiconductor systems. VI. Electrical
and photoelectric properties of Sb_2S_3-
Bi_2S_3 layers. FIZ. TVERDOGO TELA.
(In Russian)
The layers (0.5- 4μ thick) were prepared by evaporation in vacuo. Their V-I characteristics (Ohm's law was obeyed), dark resistance at temperatures from room
25. (cont'd) to 400° C, and spectral distribution of photoconductivity were recorded. It was found that heating to temperatures above 200-220° C reduces the resistance of the layers irreversibly by a factor of 2-3 and makes them opaque.

26. Kolomiets, B. T. and Nazarova, T. F.
The elec. cond. of cryst. and vitreous As$_2$Se$_2$ were measured after synthesis and various zone refining techniques. The cond. of the cryst. material varied between 0.04 and 60 ohm$^{-1}$-cm$^{-1}$ whereas the vitreous samples were quite insensitive to the method of prepn. (elec. 10$^{-5}$ ohm$^{-1}$-cm$^{-1}$). The temp. dependence of the cond. for both modifications was presented graphically between 170° and 500°K.

27. Kolomiets, B. T. and Ling, Ch'ung-Ming
Spectral distribution of the internal photoelectric effect in the ZnSe-CdSe system.
The spectral distribution of the internal photoelec. effect and the lattice parameters of the Zn$_x$Cd$_{1-x}$Se system were measured. $x$ took on the values 0, 0.2, 0.25, 0.33, 0.50, 0.67, 0.75, 0.8, and 1.0. Although the lattice type changed from wurtzite to sphalerite for $0.3 < x < 0.5$, the band gap varied smoothly (a neg. deviation from linearity) across the entire system. The effect of replacing Cd with Zn upon the shape of the spectral distribution was discussed.

28. Kolomiets, B. T. and Pavlov, B. V.
Vitreous semiconductors. VIII. Optical properties of glasses based on the chalcogenides of thallium, arsenic and antimony.
FIZ. TVERDOGO TELA v. 2, n. 4, p. 637-43, Apr 1960. (In Russian)
Optical absorption spectra were studied between 0.5 and 18 μ for various compositions in the systems: As$_2$S$_3$-As$_2$Se$_3$, As$_2$S$_3$--As$_2$Te$_3$, As$_2$Se$_3$--As$_2$Te$_3$, As$_2$Se$_3$--Tl$_2$Se, As$_2$S$_3$--Tl$_2$S, and As$_2$S$_3$--Sb$_2$S$_3$. Two more complex compositions: Tl$_2$Te$_2$Se$_3$, As$_2$Te$_3$, and Tl$_2$Se. 3Tl$_2$Te, As$_2$Se$_3$. 3As$_3$Te$_3$' with main absorption edges $\lambda_G$ at 2.07 and 3.50 μ respectively, were also studied. Optical absorption beyond the main edge.
28. (cont'd) was low for most glasses studied (0.5–1.0 cm⁻¹), and it is suggested that optical filters for the range 0.6–3.0 μ could be made by combining glasses with appropriate λ₀. Plots of numerous absorption spectra are presented. It is noted that polished sections cut from ingots and hot pressed discs gave almost identical plots.

29. Kostov, I.


(In Russian)

A mineral called bismuth jamesonite was described by M. S. Sakharova in 1955 (AMER. MINERAL v. 41, p. 814, 1958) with the formula Pb(Sb, Bi)₂S₄ with a 1 to 1 ratio of Sb to Bi. No new data are given; Kostov considers the mineral to be a new species and suggests the name sakharovite.


A natural cobalt analogue of pentlandite.


The pentlandite of Varislahti (Finland), Savonranta pyrrhotite deposits, and the pyrrhotite of the Outokumpu mine are described. These pentlandites, rich in cobalt, are associated with copper and iron sulfides.

31. Kupelk, V., Matherny, M. and Varcek, C.


(In Czechoslovakian)

Microchemical and spectrographic analysis of a mineral from Aurelia gave Pb 45.78 and Bi 28.32%, corresponding to the formula Pb₃Bi₂S₄. X-ray powder data are compared with those for cosalite, galenobismutite and kobellite; those for the mineral lead to a unit cell a 4.10 ± 0.01, b 15.84 ± 0.03, and c 19.02 ± 0.04 kX; space group is Pbnn (?), Z = 4, d. (measured) 7.10, and d. (calculated) 6.58.

32. Lowther, H. C.

THE APPLICATION OF POLARIZATION FIGURES AND ROTATION PROPERTIES
32. (cont'd) TO THE IDENTIFICATION OF CERTAIN
OF THE LEAD SULPHANTIMONIDES.
M. S. Thesis in Geology, University of
Wisconsin, 1952.

33. McHugh, J. P., Cosgrove, G. J. and Tiller, W. A.
THE EFFECT OF FREEZING CONDITIONS
ON THE THERMOELECTRIC PROPERTIES
OF BiSbTe$_3$ CRYSTALS. Westinghouse Res.
Labs. 1961 Symp. Thermoelectric Energy
Conversion.

An investigation of the effects of growth rate and interface temperature gradient on
the thermoelectric parameters $\alpha$, $1/p$ and $1/(K - K_e)$ using Bridgman grown, oriented
polycrystals of BiSbTe$_3$ was discussed. All four parameters were found to increase
as the freezing rate decreases and the temperature gradient in the liquid at the
interface increases. The effects are primarily attributed to the variation in the degree
of micro-segregation produced in the crystals by the freezing condition.

34. Mason, D. R. and O’Kane, D. F.
Preparation and properties of some
peritectic semiconducting compounds.
U. of Michigan. J. ELECTROCHEM.

Preliminary results on the preparation and properties of ternary semiconducting
compounds in the homologous series $\mathrm{I}_b \mathrm{In}_2 \mathrm{V}_b$ and $\mathrm{II}_b \mathrm{In}_2 \mathrm{V}_{1-b}$ were presented. These
ternary compounds represent a linear combination of two binary constituents, each of
which has semiconducting properties. One constituent can be represented by the
chemical formula $\mathrm{II}_2 \mathrm{bV}_3$ and the other constituent either as $\mathrm{I}_2 \mathrm{bV}_1$ or as $\mathrm{II}_b \mathrm{V}_1$.
Since each of the binary constituents is a pure chemical component, adequate equilibrium
relationships can be obtained by investigating only the pseudobinary plane which joins
them in the ternary system. A redetermination of the melting points and phase
diagrams of some of the binary constituents has been undertaken in order to correct
several serious inaccuracies in the literature. The determination of the phase diagrams
for the various pseudobinary systems is in progress, using differential thermal
analysis, and microscopic and x-ray examinations. It has been found that HgIn$_2$Te$_4$
is the only compound in either series that is definitely known to be congruently melting;
the remaining nine compounds appear to be peritectics. The system CdTe-In$_2$Te$_3$ has
been characterized quite completely, and homogeneous samples of the peritectic
compounds in this system have been prepared using zone refining techniques.

12

LOCKHEED MISSILES & SPACE COMPANY
Milton, C. and Ingram, B.  
Revoredite from Cerro de Pasco, Peru consists of lead, arsenic, and sulfur, and is amorphous to X-rays. Another deposit consisting of $\text{As}_2\text{S}_3 - 2\text{PbS}$ from Quiruvilia, Peru was studied. Lead sulfarsenides similar to "revoredite" have also been found in Wiesloch, Baden, Germany.

Miyatani, Shin-ya  
Electrical properties of pseudo-binary systems of Ag VI's; $\text{Ag}_2\text{Te}_{x}\text{Se}_{1-x}$, $\text{Ag}_2\text{Te}_{x}\text{S}_{1-x}$, and $\text{Ag}_2\text{Se}_{x}\text{S}_{1-x}$.  
Department of Physics, Faculty of Science, Niigata University. PHYSICAL SOCIETY OF JAPAN, JOURNAL v. 15, p. 1586-1595, Sep 1960.  
The electrical properties such as the electronic and ionic conductivities, Hall coefficients, etc., of the alloys $\text{Ag}_2\text{(Te, Se; Te, S; Se, S)}$ are studied with use of the galvanic cell $\text{Ag} | \text{AgI} | \text{specimen} | \text{Pt}$, the excess Ag content being controlled by sending a current across the cell. The electrical properties of these alloy systems change continuously in the $\alpha$ phase as the mixing ratio $x$ is varied, while they change discontinuously or rapidly at certain $x$'s in the $\beta$ phase. The experimental results are compared with theory under simplifying assumptions such as the energy-independent relaxation time and the energy-momentum relation given by $\xi = \hbar \frac{k^2 (1 - \beta k^2)}{2m}$.

Miyatani, Shinya  
Infrared absorption of $\alpha-\text{Ag}_2\text{Te}_{x}\text{S}_{1-x}$.  
The experimental specimen had an $x$ value of 0.7. It was rolled into foil sufficiently thin to give large interference effects in infrared transmission. Electrical conductivities were determined in the galvanic cell (Ag | AgCl+5% AgC1 | specimen | Pt). The curves of absorption coefficient vs. wave number were obtained for various electrical conductivities. The spectral range was 1000 to 2500 cm$^{-1}$. The absorption coefficient varied between $10^{3}$ and $4 \times 10^{5}$, and had minimum between 1100 and 1500 cm$^{-1}$. Free-electron absorption was dominant at the longer wavelengths. The relaxation time, if assumed to be energy-independent, was $6.6 \times 10^{-14}$ sec. The Drude-Zener formula gave $5.4 \times 10^{-14}$ sec., which is considered to be in good agreement.
38. Murphy, M. J.

39. Niizeki, N.

40. Nitsche, R. and Merz, W. J.
Some photoelectric properties of single crystals of ternary compounds of the type V–VI–VII (V = Sb, Bi; VI = S, Se, Te; VII = Cl, Br, I) were studied. The wavelengths of maximum photocurrent, \( \lambda_{\text{max}} \), shift in a regular way towards longer wavelengths with increasing atomic weight of the components. For the compounds SbSBr and SbSI the dependence of photocurrent, dark current and \( \lambda_{\text{max}} \) on temperature was measured between -140 and +1200 °C.

A method for development of additional ternary semiconducting compounds is presented. In this method the crystal-geometric criterion which determines whether the original coordinational configuration is retained in the compounds obtained must be taken into account as well as the chemical bond. Thus for the compounds Cu\(_2\)PbS\(_3\), Cu\(_2\)PbSe\(_3\), and others, the chemical means of selection of semiconducting compounds and Goodman's method of "cross-" and "vertical" substitution of elements turns out unsuitable. Insofar as these compounds, being thermodynamically unstable, are not actually realized.

42. Rondohr, P. and Schmitt, M.
Oregonit, ein neues Nickel-Eisenarsenieder mit metallartigen
42. (cont'd) Eigenschaften. NEUES JAHRBUCH FUER MINERALOGIE, MONATSCHRIFTEN
n. 11-12, p. 239-47, 1959. (In German)

The mineral occurs as water-rolled pebbles in Josephine Creek, Oregon; the pebbles have a smooth brown crust. X-ray fluorescence analysis (data not given) corresponds to Ni$_2$Fe$_{10}$As$_9$ or Ni$_2$FeAs$_{2}$. A little Co and some traces of Cu are present. Oregonite is hexagonal, $a = 6.083 \pm 0.003$, $c = 7.130 \pm 0.005$, $c/a = 1.1732$, $Z = 3$(Ni$_2$FeAs$_{2}$), G. calculated 6.92.

43.

Rodot, H.
Study of the properties of the system AgSbTe$_2$-PbTe. C. R. ACAD. SCI. (PARIS) v. 249, n. 19, p. 1872-4, 9 Nov 1959.
(In French)

Up to 40% PbTe, the alloys are solid solutions of cubic structure (NaC type). For higher proportions two phases exist. For the solid solutions the lattice spacing is greater than for pure AgSbTe$_2$ and the melting points are lower. The electrical properties are investigated and the potentialities of the materials for thermoelectric devices are discussed.

44.

Semiletov, S. A. and Man, L. I.
Study of the structure of TlBiSe$_2$ and TlSbS$_2$ in thin films by the electron diffraction method. Crystallographical Institute of the Academy of Sciences of the USSR. KRISTALLOGRAFIYA v. 4, n. 3, p. 414-417, 1959. (In Russian)

The authors studied the structure of the two compounds in a manner similar to that of Pinsker, Z. G., Semiletov, S. A., and Belov, Ye. N., in studying the structure of TlSbSe$_2$. The latter substance was discovered by Kolomiyets, B. T., and Goryunova, N. A., while they investigated the electric properties of the semiconducting Tl$_2$S-Sb$_2$S$_3$ isomorphous series. The authors sublimated thin films of TlBiSe$_2$ and TlSbS$_2$ upon NaCl crystals or celluloid and let the films crystallize by annealing; in the case of a rapid sublimation, the films were readily crystalline. They obtained two kinds of electron diffraction patterns of TlBiSe$_2$: (1) a few diffuse lines; (2) numerous sharp lines, of which the most intensive ones correspond to the lines of the powder photographs of the same substance. Only the former pattern could be interpreted. The latter pattern indicates the presence of another modification whose structure is still unknown. The unit cell of the identified modification is face-centered cubic; $a = 6.18 \pm 0.02$ Å; volume of the unit cell = 238 Å$^3$; density = 8.25; there are two formula molecules per unit cell; Tl and Bi atoms occupy available positions statistically. The unit cell of
44. (cont'd) TlSbS₂ is also face-centered cubic; a varies from 5.87 to 5.94 Å because of slight variations in the composition. Harker diagrams point to the similarity of the structures of both compounds to that of NaCl. Both of these compounds, as well as some other ternary compounds studied by other authors, prove the existence of numerous semiconducting crystalline substances of similar compositions and of structure similar to that of NaCl. The generalized formula of these compounds is $A^{+}B^{5-}X^{4-}$ where $A^{+}$ stands for a one valence element; $B^{5-}$ for a five valence element; and $X^{4-}$ for a six valence element, such as S, Se, Te. Some of these compounds are likely to occur only in the form of orthorhombic modifications, like TlSbSe₂, but the others also in cubic crystals of NaCl type.

45. Shtrum, E. L.
Semiconducting properties of the AgFeTe₂
phase. FIZ. TVERDOGO TELA v. 2, n. 7,
p. 1489-93, July 1960. (In Russian)
Metallographic and X-ray diffraction studies showed that AgFeTe₂ undergoes two phase transitions (at 150 and 520°C) and that it is single-phased within a range of compositions departing up to 4 at. % from stoichiometry. Within this range the compound is a semiconductor, as shown by measurements of its electrical conductivity and thermoelectric power.

46. Talybov, A. G.
Electron diffraction study of the structure
of SnSb₂Te₄. SOVIET PHYSICS --
CRYSTALLOGRAPHY v. 6, n. 1, p. 40-44,
The results of an electron diffraction study of the structure of SnSb₂Te₄ are presented.

47. Thompson, R. M.
DESCRIPTIVE MINERALOGY OF THE
TELLURIDES. Ph.D. Thesis, University
Among the tellurides described, such ternary minerals as pelzite, sylvanite, nagyagite, and tetradyrmite are included.

48. Tischendorf, G.
Ueber Eskebornit von Tilkerodl im Harz.
NEUES JAHRBUCH FUER MINERALOGIE
48. (cont'd) ABHANDLUNGEN v. 94, p. 1169-82, 1960. (In German)

The formula of eskebornite has been given as FeSe and Fe$_3$CuSe$_4$. Two analyses of synthetic preparations with a 5.53-5.55 Å (for natural material a 5.53 Å) gave Cu$_{0.43}$Fe$_{0.56}$Se and Cu$_{0.56}$Fe$_{0.43}$Se, and an X-ray fluorescence analysis of another synthetic preparation gave Cu$_{0.55}$Fe$_{0.55}$Se. The general formula may be (Cu, Fe)$_1.1$Se. X-ray powder data are given.

49. Uphoff, H. L. and Healy, J. H.


Ten compositions were prepared in the systems As-Se-Te and As-S-Te. Nine of these compositions were amorphous in structure. The resistivities and Seebeck coefficients of these materials were measured as functions of temperature. The resistivity varied exponentially with temperature, while the Seebeck coefficient varied linearly. At 298 K, the resistivity values for the amorphous samples ranged from $4.7 \times 10^2$ to $2.5 \times 10^3$ ohm cm, while the Seebeck coefficient values ranged from 830-1625 µV deg$^{-1}$ K (p type). At any temperature, the resistivity decreased with increase in tellurium content. For the amorphous materials, the thermal conductivity values ranged from 2.4 to 4.4 mW cm$^{-1}$ deg$^{-1}$ K.

50. Vul'f, V. K.

Ternary metal compounds. USPEKHI KHIMII v. 29, n. 6, p. 774-85, 1960.

(Translated by Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base, Trans. no. MCL-724, 13 Feb 61, 50p.)

Contents: General features of ternary metal compounds; Ternary Kurnakov phases; Valen ternary metal compounds; Electronic ternary metal compounds; Ternary Laves phases; Ternary Ni-arsenide phases; Ternary interstitial phases; Properties and practical application of ternary metal compounds. A bibliography of 174 references is appended.

51. Wachtel, A.

(Zn, Hg)S and (Zn, Cd, Hg)S electroluminescent phosphors. Westinghouse.
Solid solutions of (Zn, Hg)S prepared by firing in sealed silica tubes are discussed. The crystals are cubic in structure. With suitable additions of Cu and a coactivator, e.g. halides, Ga, or In, photoluminescence and electroluminescence are obtained. The electroluminescence in the red consists of two emission bands which do not appear to be analogous to the blue and green emission bands of Cu, Cl in ZnS. The quantum efficiency is of the same order of magnitude as that of ZnS:Cu, Cl, but the emission bandwidth is about twice as large and the red electroluminescence consists of emission located to a large extent in the infrared. HgS tends to retain the cubic structure of ternary (Zn, Cd, Hg)S systems provided the Cd/Hg ratio does not exceed certain limits; until this is so, the introduction of Cd causes increased electroluminescence.

Wernick, J. H., Geller, S. and Benson, K. E.
Constitution of the AgSbSe$_2$-AgSbTe$_2$-AgBiTe$_2$ system. J. PHYS. CHEM. SOLIDS v. 7, n. 2, p. 240-8, Nov 1958.

The six pseudo-binary phase diagrams in the semiconducting system AgSbSe$_2$-AgSbTe$_2$-AgBiSe$_2$-AgBiTe$_2$ have been determined. Complete series of solid solutions with the cubic structure exist in this pseudo-quaternary system. The locus of temperatures and compositions for the order--disorder transition has been determined. Lattice constants as a function of composition for the cubic phase and thermoelectric-power data for some of the solid solutions are presented.

Wernick, J. H.
Constitution of the AgSbS$_2$-PbS, AgBiS$_2$-PbS, and AgBiSe$_2$-AgBiSe$_2$ systems. AMERICAN MINERALOGIST v. 45, n. 5-6, p. 591-98, May-June 1960.

Complete series of solid solutions with the disordered NaCl-type structure exist in the pseudo-binary AgSbS$_2$-PbS and AgBiS$_2$-PbS systems. Thus, synthetic compositions corresponding to the minerals freieslebenite and diaphorite in the AgSbSe$_2$-PbS system have high temperature forms with the disordered NaCl structure. Only this cubic form was obtained for the composition corresponding to the mineral schermirite in the AgBiS$_2$-PbS system. Lattice constants as a function of composition for the cubic phase are presented. The high and low temperature modifications of AgBiSe$_2$ and AgBiS$_2$ form a complete series of solid solutions. The phase diagram for this system has been determined. Lattice constants as a function of composition for the cubic phase follow Vegard’s law, and this is presumed to be the case for the low temperature form.
54. Wernick, J. H.
Metallurgy of some ternary semiconductors and constitution of the AgSbSe$_2$-AgSbTe$_2$-AgBiSe$_2$-PbSe-PbTe System. Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.
(QC612.S4 Am35.7p)

Metallurgical techniques employed in the preparation of some semiconducting ternary compounds are discussed. Some electrical and thermal properties are presented. In addition, six pseudo-binary phase diagrams in the semiconducting pseudo-quinary system, AgSbSe$_2$-AgSbTe$_2$-Ag-BiSe$_2$-PbSe-PbTe, have been determined. A complete series of solid solutions with the disordered NaCl-type structure exists in this system. The locus of temperatures and compositions for the order-disorder transition has been determined. Lattice constants as a function of composition for the cubic phase are also presented. The valence electron to atom ratio increases from 4-1/2 to 5 in going from the ternary to the binary compound, and large negative deviations from Vegard's law occur in all but the AgSbTe$_2$-PbSe system. A positive deviation occurs in the AgSbTe$_2$-PbSe system. Possible reasons for these deviations are discussed.

55. Wernick, J. H.
SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S. PATENT 2,882,192, 14 Apr 59, assigned to Bell Telephone Laboratories, Inc.

Ternary semiconducting compounds are synthesized which have energy gaps of about 0.8 e.v. Cu$_3$SbS$_4$, melting at 555°, energy gap 0.8 e.v., and Cu$_3$AsS$_4$, melting at 655°, energy gap 0.8 e.v., are made by mixing the respective components in a C-coated SiO$_2$ crucible which is placed inside a second SiO$_2$ container. This container is evacuated and filled with N$_2$, and then sealed off. It is placed in the electric furnace which is wound so that there are three heating zones capable of operating independently. During 3 hours the middle zone heats the crucible to about 680°, while the two ends are maintained about 100° higher. This condition is maintained for 2 hours, then the lower zone of the furnace is shut off, creating a gradient of about 700° to 450°, which is held for 1 hour. Finally, all zones are shut off and the system is allowed to cool to room temperature. A device utilizing either of the materials can be made using 0.01 at. % I as the significant impurity.
56. Wernick, J. H.

SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S.
PATENT 2,882,193, 14 Apr 59, assigned to Bell Telephone Laboratories, Inc.

P-N junction devices having intrinsic energy gaps of from 0.8 to 2.0 e.v. are made by the addition of impurities from Group VII to the substances Cu$_3$SbS$_3$, Ag$_3$AsS$_3$, and Cu$_3$AsS$_3$. The process is similar to that described in the preceding abstract.

57. Wernick, J. H.

SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S.
PATENT 2,882,194, 14 Apr 59, assigned to Bell Telephone Laboratories, Inc.

Describes the means of producing p-n junction devices by the addition of iodine to the substances CuSbS$_2$ and AgBiS$_2$.

58. Wernick, J. H.

SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S.
PATENT 2,882,195, 14 Apr 59, assigned to Bell Telephone Laboratories, Inc.

P-N junction devices having intrinsic energy gaps of 0.7 to 0.9 e.v. are produced by introducing group VII impurities into the substances CuPbSbS$_3$, CuPbAsS$_3$ and CuPbBiS$_3$.

59. Wernick, J. H.

SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S.

LOCKHEED MISSILES & SPACE COMPANY
AgSbSe$_2$, melting at 6100, energy gap 0.6 e.v., exhibits p-type conductivity, and after passage of 20 zones in a zone-refining process, has a resistivity of 0.02 ohm-cm. AgBiSe$_2$, melting at 7800, exhibits n-type conductivity. AgAsSe$_2$, melting at 3900, has an energy gap of 0.9 e.v. A Device, either point-contact or junction, in which the significant impurity is up to 0.01 at. % I, (Mn, Zn, or Cd) can be made using these compounds.

AgBiTe$_2$, melting at 5100, energy gap 0.3 e.v., exhibits n-type conductivity. AgAsTe$_2$, melting at 3250, energy gap 0.8 e.v., exhibits p-type conductivity. A device, either point-contact or junction in which the significant impurity is up to 0.01 at. % I, can be made with any of these materials.

CuSbSe$_2$ and CuAsSe$_2$ are made according to the procedure described in U.S. Patent 2,882,468 at 1000$^\circ$ and CuAs$_2$ is made at 700$^\circ$. CuSbSe$_2$ melting at 460$^\circ$, has an energy gap of 0.6 e.v. CuAsSe$_2$ melting at 415$^\circ$, has an energy gap of 0.4 e.v. CuAs$_2$ melting at 625$^\circ$, has an energy gap of 0.8 e.v. All exhibit p-type conductivity. A device in which the significant impurity is up to 0.01 at. % I, can be made use of these compounds.
62. Wernick, J. H.

SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S.

PATENT 2,882,470, 14 Apr 59, assigned to Bell Telephone Laboratories, Inc.

Cu$_3$SbSe$_4$ is made according to the procedure described in the previous patent (2,882,469) at 1000$^\circ$. However, for preparation of this material, the inner crucible must be first coated by exposure to a mixture of 4 parts N and 1 part CH$_4$ for 15 minutes at a flow rate of 250 cc./min. with the crucible at 1000$^\circ$. Cu$_3$SbSe$_4$, melting at 425$^\circ$, has an energy gap of 0.2 e.v., and exhibits p-type conductivity.

63. Wernick, J. H.

SEMICONDUCTING MATERIALS AND DEVICES MADE THEREFROM. U.S.

PATENT 2,882,471, 14 Apr 59, assigned to Bell Telephone Laboratories, Inc.

Ag$_3$AsSe$_3$, made as described in the previous patent (2,882,470), melts at 385$^\circ$, has an energy gap of 0.4 e.v., and exhibits n-type conductivity. A device in which conversion is caused by alloying with Ge containing Ga as the significant impurity, can be made with this compound.

64. Wiese, J. R. and Muldawer, L.


The Bi$_2$Te$_3$--Bi$_2$Se$_3$ quasi-binary system is rhombohedral for all compositions. Lattice constants $a_0$ and $c_0$ (based on a hexagonal lattice) for the entire range determined using powder pattern film techniques are reported. The constant $c_0$ follows Vegard's rule over the entire range of compositions, while the constant $a_0$ exhibits a positive deviation over the range from 40 mol% Bi$_2$Te$_3$ to Bi$_2$Se$_3$. Bi$_2$Te$_3$ has a layered structure with planes of atoms of a single type parallel to the basal plane. The lattice constant data can be explained in terms of Se-atom substitution in preferred planes.
64. (cont'd) for the range Bi$_2$Te$_3$–Bi$_2$Te$_2$Se. Interlayer spacings for Bi$_2$Te$_3$ and Bi$_2$Te$_2$S are given and discussed.

65. Wolfe, R., Nernick, J. H. and Haszko, S. E.

Anomalous Hall effect in AgSbTe$_2$.


The Hall coefficient of the ternary semiconductor AgSbTe$_2$ near room temperature is positive in some specimens and negative in others, although the Seebeck coefficient is always positive. The negative Hall coefficient decreases as the temperature is lowered from 180$^\circ$K to 70$^\circ$K and changes sign in lower temperatures. This negative Hall coefficient is associated with the presence in the AgSbTe$_2$ of a second phase consisting of Ag$_2$Te. The properties of the two-phase material are interpreted in terms of the theory of the transport properties of inhomogeneous semiconductors. In single-phase AgSbTe$_2$ containing 3 x 10$^{18}$ holes per cm$^3$, the hole mobility is 35 cm$^2$/V sec at 300$^\circ$K and it varies approximately as T$^{-0.5}$. (It has been suggested by Armstrong, Faust, and Tiller (Abstract 2, page 1) that the microstructure is associated with the presence of Sb$_2$Te$_3$ as a Widmanstatten precipitate along $\{111\}$ planes in the AgSbTe$_2$. This would indicate that none of the material was single phase. Even though the Sb$_2$Te$_3$ in the measured specimens is present in quantities too small to be detected in the present X-ray powder photographs, it may have some effect on the measured properties. Therefore, the electrical properties of single phase AgSbTe$_2$ have yet to be determined). The lattice thermal conductivity is so low (0.0064 W cm$^{-1}$ deg$^{-1}$ C at 290$^\circ$K) that the calculated "phonon mean free path" is less than the nearest neighbor distance. The thermal conductivity of a specimen rich in AgSbTe$_2$–Ag$_2$Te eutectic is higher than that of either of the components. This excess thermal conductivity is attributed to circulating thermoelectric currents.

66. Woolley, J. C. and Ray, B.

Solid solution in A$^{\text{II}}$B$^{\text{VI}}$ tellurides.


Alloys have been produced for the three systems CdTe–HgTe, CdTe–ZnTe and HgTe–ZnTe and annealed to obtain equilibrium conditions. It has been confirmed that solid solution occurs at all compositions in each system and the variation of lattice parameter with composition has been determined in each case. The form of the solidus curve has been obtained by X-ray methods in the HgTe–ZnTe system.
The present investigation was carried out with the intention of finding new semiconductors. No published data are available on the ternary system Pb-Bi-Te. The system Sn-Sb-Te has not been examined. In the alloys produced, microstructure was investigated, and the thermoelectromotive force referred to Cu at a temperature difference of 20 °C, as well as electric conductivity were measured. In the first mentioned system, the primary crystallizing phase consists of PbTe. With increasing Bi$_2$Te$_3$ content, the crystallization temperature drops, until, finally, at 82.7% Bi$_2$Te$_3$, a single-phase coarse-crystalline structure is formed, which corresponds to the compound PbTe•2Bi$_2$Te$_3$ and which is located in the phase diagram on the ordinate passing through the inflection of the solidus curve. X-ray analyses confirm the existence of the ternary intermediate phase. At 71.8% Sb$_2$Te$_3$ the compound SnTe•Sb$_2$Te$_3$ is formed.

A study of the phase diagrams of the ternary systems Pb-Bi-Te and Sn-Sb-Te along the PbTe•Bi$_2$Te$_3$ and SnTe•Sb$_2$Te$_3$ cross sections showed the existence of the ternary compounds PbTe$_3$•2Bi$_2$Te$_3$ and SnTe•Sb$_2$Te$_3$ which melt congruently.
69. (cont’d) Feb 57 – Aug 60; ARL TR 60-316,
Oct 60, 54p. (Contract AF33(616)
3959, Proj. 7021) ASTIA AD-252 808

Three compositions of the class of polyatomic semiconductors of the chalcopyrite structure A (I) B (III)C2 (6+) were investigated by thermal, microscopic, mechanical and electronic methods. Only the first two were found to be intermetallic semiconductors, the composition AuInTe2 showing the metallic character of a two phase alloy, Au. 25In. 25Te. 50. Melting points, Vickers hardness, micro and macrostructures of CuInTe2, AgInTe2, and Au. 25In. 25Te. 50 were determined. At room temperature the electrical resistivity of CuInTe2 was of the order of 1/100 ohm-cm, that of AgInTe2 of the order of 1-10 ohm-cm and that of Au. 25In. 25Te. 50 of the order of 1/10,000 ohm-cm.

70. Zhuze, V. P., Sergeeva, V. N. and Shtrum, E. L.

Semiconducting compounds with the general
formula ABX2. ZH. TEKH. FIZ. v. 28, n. 10,

A survey of some 25 compounds in two groups: (1) chalcopyrite and related structures for which A is Cu or Ag, B is Al, Ga, In, Tl or Fe, X is S, Se, Te; (2) derived NaCl and other structures for which A is Cu or Ag, B is Sb or Bi, X is Se or Te. Data are given for most of these compounds, on electrical and other physical properties (e.g. melting point, electrical conductivity). Chemical bonding is discussed for the first group. It is also noted that X-ray powder diagrams for CuBiTe2, AgBiTe2 and CuSbTe2 appear similar in type to those for Bi2Te3.
PART II

SUBJECT INDEX

Antimony–Bismuth Sulfide (Sb$_2$S$_3$–Bi$_2$S$_3$)
  Properties ....................................... 14, 25
  Structure ......................................... 14, 25

Antimony–Bismuth Telluride (Sb$_2$Te$_3$–Bi$_2$Te$_3$)
  Properties ....................................... 20

Antimony Chalcogenides
  Optical properties ................................. 28

Antimony Sulfur Bromide (SbSBr)
  Photoelectric properties ......................... 40

Antimony Sulfur Iodide (SbSI)
  Photoelectric properties ......................... 40

Antimony—Thallium Sulfide (Sb$_2$S$_3$–Tl$_2$S)
  Properties ....................................... 14
  Structure ......................................... 14

Arsenic–Antimony Selenide (As$_2$Se$_3$–Sb$_2$Se$_3$)
  Properties ....................................... 12, 13

Arsenic–Antimony Sulfide (As$_2$S$_3$–Sb$_2$S$_3$)
  Properties ....................................... 12

Arsenic Chalcogenides
  Optical properties ................................. 28
  Vitrification ..................................... 15

Arsenic Selenide–Sulfide (As$_2$Se$_3$–As$_2$S$_3$)
  Properties ....................................... 12

Arsenic Selenide–Telluride (As$_2$Se$_3$–As$_2$Te$_3$)
  Properties ....................................... 12, 22

Arsenic Selenium Telluride (As$_2$SeTe$_2$)
  Impurity effect .................................. 21, 26

Arsenic–Selenium–Tellurium system
  Properties ....................................... 49
Arsenic-Sulfur-Tellurium system
Properties ........................................ 49

Arsenic-Thallium-Antimony Selenides (As₂Se₃-Tl₂Se-Sb₂Se₃-Tl₂Se)
Properties ........................................ 12, 13

Arsenic-Thallium Selenide (As₂Se₃-Tl₂Se)
Properties ........................................ 12

Arsenides
Nickel iron ....................................... 42

Bismuth Antimony Telluride (BiSbTe₃)
Freezing effect .................................. 7, 33
Properties ........................................ 7

Bismuth Jamesonite (Lead-Antimony-Bismuth Sulfide) .................... 29

Bismuth Perovskites
Properties ........................................ 6

Bismuth Sakharovite (Lead-Antimony-Bismuth Sulfide) .................... 29

Bismuth Telluride (Bi₂Te₃)
Mineralogy ....................................... 47

Bismuth Telluride-Selenide (Bi₂Te₃-Bi₂Se₃)
Lattice constants ................................ 64
Structure ......................................... 64

Bismuth Tellurium Selenide (Bi₂Te₂/Se₀.₉)
Doping effects ................................... 3
Properties ........................................ 3

Boulangerite (5PbS.2Sb₃S₃)
Structure ......................................... 4

Bromides
Antimony sulfur ................................... 40

Cadmium-Indium Telluride (CdTe-In₂Te₃)
Properties ........................................ 34

Cadmium-Mercury Telluride (CdTe-HgTe)
Lattice variation .................................. 66

Cadmium-Zinc Telluride (CdTe-ZnTe)
Lattice variation .................................. 66
### Chalcogenides

<table>
<thead>
<tr>
<th>Substance</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>28</td>
</tr>
<tr>
<td>Arsenic</td>
<td>15, 28</td>
</tr>
<tr>
<td>Optical properties</td>
<td>28</td>
</tr>
<tr>
<td>Thallium</td>
<td>28</td>
</tr>
<tr>
<td>Vitrification</td>
<td>15</td>
</tr>
</tbody>
</table>

### Chalcopyrites

<table>
<thead>
<tr>
<th>Substance</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Antimony Selenide (CuSbSe$_2$)</td>
<td>69, 70</td>
</tr>
<tr>
<td>Properties</td>
<td>8</td>
</tr>
<tr>
<td>Copper Antimony Selenide (Cu$_3$SbSe$_4$)</td>
<td>62</td>
</tr>
<tr>
<td>Preparation</td>
<td>62</td>
</tr>
<tr>
<td>Copper Antimony Sulfide (CuSbS$_2$)</td>
<td></td>
</tr>
<tr>
<td>Iodine added</td>
<td>57</td>
</tr>
<tr>
<td>Copper Antimony Sulfide (Cu$_3$SbS$_3$)</td>
<td></td>
</tr>
<tr>
<td>Energy gap</td>
<td>56</td>
</tr>
<tr>
<td>Preparation</td>
<td>56</td>
</tr>
<tr>
<td>Copper Antimony Sulfide (Cu$_3$SbS$_4$)</td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>55</td>
</tr>
<tr>
<td>Properties</td>
<td>55</td>
</tr>
<tr>
<td>Copper Antimony Telluride (CuSbTe$_2$)</td>
<td>70</td>
</tr>
<tr>
<td>Properties</td>
<td>70</td>
</tr>
<tr>
<td>Copper Arsenic Sulfide (Cu$_3$AsS$_3$)</td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>56</td>
</tr>
<tr>
<td>Properties</td>
<td>56</td>
</tr>
<tr>
<td>Copper Arsenic Sulfide (Cu$_3$AsS$_4$)</td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>55</td>
</tr>
<tr>
<td>Properties</td>
<td>55</td>
</tr>
<tr>
<td>Copper Bismuth Telluride (CuBiTe$_2$)</td>
<td>70</td>
</tr>
<tr>
<td>Properties</td>
<td>70</td>
</tr>
<tr>
<td>Copper Indium Telluride (CuInTe$_2$)</td>
<td></td>
</tr>
<tr>
<td>Properties</td>
<td>69</td>
</tr>
<tr>
<td>Copper Lead Antimony Sulfide (CuPbSbS$_3$)</td>
<td></td>
</tr>
<tr>
<td>Energy gap</td>
<td>58</td>
</tr>
<tr>
<td>Copper Lead Arsenic Sulfide (CuPbAsS$_3$)</td>
<td></td>
</tr>
<tr>
<td>Energy gap</td>
<td>58</td>
</tr>
</tbody>
</table>
Copper Lead Bismuth Sulfide (CuPbSiS₃)
Energy gap ........................................... 58
Copper Lead Selenide (Cu₂PbSe₃) .................. 41
Copper Lead Sulfide (Cu₂PbS₃) ..................... 41
Copper Silver Arsenide \([\text{Cu, Ag}_4\text{As}]\)
Analysis ............................................... 19
Cosalite (Lead-Bismuth Sulfide)
Structure ............................................. 31
Diaphorite (Silver Antimony-Lead Sulfide)
Structure ............................................. 53
Eskebornite (Iron Copper Selenide)
Analysis ............................................... 48
Freieslebenite (Silver Antimony-Lead Sulfide)
Structure ............................................. 53
Galenobismittite (Lead-Bismuth Sulfide)
Structure ............................................. 31
Gold Indium Telluride (AuInTe₂)
Properties ............................................ 69
Gold Silver Telluride \([\text{Au, Ag}_2\text{Te}_2]\)
Mineralogy ............................................ 47
Iodides
Antimony sulfur ...................................... 40
Iron-Cobalt-Nickel Sulfide
Composition ......................................... 18
Description ........................................... 30
Structure ............................................. 18
Iron Copper Selenide \((\text{Fe}_3\text{CuSe}_4)\) ................... 48
Kobellite (Lead-Bismuth Antimony Sulfide)
Structure ............................................. 31
Lead-Antimony-Bismuth Sulfide \((\text{Pb(Sb, Bi)}_2\text{S}_4)\)
Bismuth jamesonite .................................. 29
Bismuth sakharovite ................................ 29
Lead-Bismuth Antimony Sulfide \( \left( 2\text{PbS} \cdot (\text{Bi}_2\text{Sb})_2\text{S}_3 \right) \) ........................................... 31

Lead Bismuth Sulfide (\( \text{Pb}_3\text{Bi}_2\text{S}_6 \)) .................................................. 31

Lead-Bismuth Sulfide (\( \text{PbS} \cdot \text{Bi}_2\text{S}_3 \)) ............................................... 31

Lead-Bismuth Sulfide (\( 2\text{PbS} \cdot \text{Bi}_2\text{S}_3 \)) ........................................... 31

Lead-Bismuth Telluride (\( \text{PbTe} - \text{Bi}_2\text{Te}_3 \))
Properties .................................................. 68

Lead Sulfantimonides
Identification ................................................... 32

Lead Sulfarsenides .................................................. 35

Lead Sulfide (\( \text{PbS} \))
Semiconducting physics ........................................ 1

Lead Selenide (\( \text{PbSe} \))
Properties ..................................................... 54
Semiconducting physics ........................................ 1

Lead Telluride (\( \text{PbTe} \))
Properties ..................................................... 54
Semiconducting physics ........................................ 1

Lillianite (Lead Bismuth Sulfide)
Analysis ....................................................... 31
Structure ....................................................... 31

Mercury Indium Telluride (\( \text{HgIn}_2\text{Te}_4 \))
Properties ..................................................... 34

Mercury Selenide-Telluride (\( \text{HgSe} - \text{HgTe} \))
Properties ..................................................... 16

Mercury-Zinc Telluride (\( \text{HgTe} - \text{ZnTe} \))
Lattice variation ............................................. 66

Minerals
Bismuth jamesonite ............................................. 29
Bismuth perovokites ............................................ 6
Bismuth sakharovite ............................................ 29
Boulangerite .................................................... 4
Chalcopryrites .................................................. 69, 70
Cosalite ......................................................... 31
Diaphorite ....................................................... 53
Eskebornite ...................................................... 48
Freieslebenite ................................................... 53
<table>
<thead>
<tr>
<th>Minerals (cont'd)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Galenobismutite</td>
<td></td>
</tr>
<tr>
<td>Kobellite</td>
<td></td>
</tr>
<tr>
<td>Lillianite</td>
<td></td>
</tr>
<tr>
<td>Nagyagite</td>
<td></td>
</tr>
<tr>
<td>Novakite</td>
<td>47</td>
</tr>
<tr>
<td>Oregonite</td>
<td>42</td>
</tr>
<tr>
<td>Pelzite</td>
<td>47</td>
</tr>
<tr>
<td>Pentlandite</td>
<td>18, 30</td>
</tr>
<tr>
<td>Revoredite</td>
<td></td>
</tr>
<tr>
<td>Schermirite</td>
<td>53</td>
</tr>
<tr>
<td>Sylvanite</td>
<td>47</td>
</tr>
<tr>
<td>Tetradyomite</td>
<td>47</td>
</tr>
</tbody>
</table>

| Nagyagite                            |       |
| Mineralogy                           |       |
| Nickel Iron Arsenide (Ni$_{10}^{10}$Fe$_6^{6}$As$_9^{9}$) | 42    |

| Novakite (Copper Silver Arsenide)    |       |
| Analysis                             | 19    |

| Oregonite (Nickel Iron Arsenide)     |       |
| Analysis                             | 42    |

| Pelzite                              |       |
| Mineralogy                           |       |

| Pentlandite (Iron-Cobalt-Nickel Sulfide) |       |
| Composition                           | 18    |
| Description                           | 30    |
| Structure                             | 18    |

| Peritectics                           |       |
| Preparation                           | 34    |
| Properties                            | 34    |

| Perovskites                           |       |
| Bismuth                               | 6     |

| Petzite (Silver Gold Telluride)       |       |
| Structure                             | 11    |

| Revoredite (Lead Sulfarsenide)        |       |
| Properties                            | 35    |

<p>| Schermirite (Silver Bismuth-Lead Sulfide) |       |
| Structure                             | 53    |</p>
<table>
<thead>
<tr>
<th><strong>Selenide minerals</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Classification</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>Synthesis</strong></td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Selenides</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antimony</strong></td>
<td>12, 13</td>
</tr>
<tr>
<td><strong>Arsenic</strong></td>
<td>12, 13, 22, 23</td>
</tr>
<tr>
<td><strong>Bismuth</strong></td>
<td>2, 64</td>
</tr>
<tr>
<td><strong>Bismuth tellurium</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Cadmium</strong></td>
<td>27</td>
</tr>
<tr>
<td><strong>Copper antimony</strong></td>
<td>8, 62</td>
</tr>
<tr>
<td><strong>Copper lead</strong></td>
<td>41</td>
</tr>
<tr>
<td><strong>Lead</strong></td>
<td>1, 54</td>
</tr>
<tr>
<td><strong>Mercury</strong></td>
<td>16</td>
</tr>
<tr>
<td><strong>Silver antimony</strong></td>
<td>8, 52, 54, 59</td>
</tr>
<tr>
<td><strong>Silver arsenic</strong></td>
<td>59, 63</td>
</tr>
<tr>
<td><strong>Silver bismuth</strong></td>
<td>8, 52, 53, 54, 59</td>
</tr>
<tr>
<td><strong>Thallium</strong></td>
<td>12, 13, 23</td>
</tr>
<tr>
<td><strong>Thallium bismuth</strong></td>
<td>44</td>
</tr>
<tr>
<td><strong>Zinc</strong></td>
<td>27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Antimony-Lead Sulfide (AgSbS&lt;sub&gt;2&lt;/sub&gt;-PbS)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td>53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Antimony Lead Telluride (AgSbTe&lt;sub&gt;2&lt;/sub&gt;-PbTe)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Properties</strong></td>
<td>43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Antimony Selenide (AgSbSe&lt;sub&gt;2&lt;/sub&gt;)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Properties</strong></td>
<td>8, 52, 54, 59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Antimony Telluride (AgSbTe&lt;sub&gt;2&lt;/sub&gt;)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hall effect</strong></td>
<td>65</td>
</tr>
<tr>
<td><strong>Properties</strong></td>
<td>8, 17, 52, 54, 60</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Arsenic Selenide (AgAsSe&lt;sub&gt;2&lt;/sub&gt;)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Properties</strong></td>
<td>59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Arsenic Selenide (Ag&lt;sub&gt;3&lt;/sub&gt;AsSe&lt;sub&gt;3&lt;/sub&gt;)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preparation</strong></td>
<td>63</td>
</tr>
<tr>
<td><strong>Properties</strong></td>
<td>63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Arsenic Sulfide (Ag&lt;sub&gt;3&lt;/sub&gt;AsS&lt;sub&gt;3&lt;/sub&gt;)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy gap</strong></td>
<td>56</td>
</tr>
<tr>
<td><strong>Preparation</strong></td>
<td>56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Silver Arsenic Telluride (AgAsTe&lt;sub&gt;2&lt;/sub&gt;)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Properties</strong></td>
<td>60</td>
</tr>
</tbody>
</table>

32
Silver Bismuth-Lead Sulfide (AgBiS$_2$-PbS)
Structure ........................................... 53

Silver Bismuth Selenide (AgBiSe$_2$)
Properties ........................................... 8, 52, 54, 59
Structure ........................................... 53

Silver Bismuth Sulfide (AgBiS$_2$)
Iodine added ........................................... 57
Structure ........................................... 53

Silver Bismuth Telluride (AgBiTe$_2$)
Properties ........................................... 52, 60, 70

Silver Gold Telluride (Ag$_3$AuTe$_2$)
structures ........................................... 11

Silver Indium Telluride (AgInTe$_2$)
Properties ........................................... 69

Silver Iron Telluride (AgFeTe$_2$)
Properties ........................................... 45

Silver Lead Bismuth Telluride $\left[\text{Ag}_{x/2}\text{Pb}_{1-x}\text{Bi}_{x/2}\right]$ Te
Properties ........................................... 10

Silver VI systems
Electrical properties ................................ 36
Infrared absorption ................................ 37

Sulfides
Antimony ........................................... 12, 14, 25
Arsenic ........................................... 12
Bismuth ........................................... 14, 25
Bismuth jamesonite ................................ 29
Bismuth sakharovite ................................ 29
Boulangerite ........................................ 4
Copper Antimony .................................. 55, 56, 57
Copper arsenic .................................... 55, 56
Copper lead ........................................ 41
Iron-cobalt-nickel ................................ 18
Lead ............................................... 1
Lead-antimony-bismuth ............................ 29
Lead bismuth ....................................... 31
Pentlandite ......................................... 18
Silver antimony lead ................................ 53
Silver arsenic ...................................... 56
Silver bismuth ....................................... 53, 57
Silver bismuth-lead ................................ 53
<table>
<thead>
<tr>
<th>Section</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfides (cont'd)</td>
<td>Thallium: 14</td>
</tr>
<tr>
<td></td>
<td>Thallium antimony: 44</td>
</tr>
<tr>
<td></td>
<td>Zinc cadmium mercury: 51</td>
</tr>
<tr>
<td></td>
<td>Zinc mercury: 51</td>
</tr>
<tr>
<td>Sulfo-salts</td>
<td>Structure: 39</td>
</tr>
<tr>
<td></td>
<td>X-ray study: 38</td>
</tr>
<tr>
<td>Sylvanite (Gold Silver Telluride)</td>
<td>Mineralogy: 45</td>
</tr>
<tr>
<td>Telluride Minerals</td>
<td>Descriptive mineralogy: 47</td>
</tr>
<tr>
<td>Tellurides</td>
<td>Arsene: 12, 22, 23</td>
</tr>
<tr>
<td></td>
<td>Arsenic selenen: 21, 26</td>
</tr>
<tr>
<td></td>
<td>Bismuth: 64</td>
</tr>
<tr>
<td></td>
<td>Bismuth antimony: 7, 33</td>
</tr>
<tr>
<td></td>
<td>Cadmium-indium: 34</td>
</tr>
<tr>
<td></td>
<td>Cadmium-mercury: 66</td>
</tr>
<tr>
<td></td>
<td>Cadmium-zinc: 66</td>
</tr>
<tr>
<td></td>
<td>Copper antimony: 70</td>
</tr>
<tr>
<td></td>
<td>Copper bismuth: 70</td>
</tr>
<tr>
<td></td>
<td>Copper indium: 69</td>
</tr>
<tr>
<td></td>
<td>Gold indium: 69</td>
</tr>
<tr>
<td></td>
<td>Gold silver: 47</td>
</tr>
<tr>
<td></td>
<td>Lead: 1, 54</td>
</tr>
<tr>
<td></td>
<td>Lead bismuth: 67, 68</td>
</tr>
<tr>
<td></td>
<td>Mercury: 16</td>
</tr>
<tr>
<td></td>
<td>Mercury indium: 34</td>
</tr>
<tr>
<td></td>
<td>Mercury-zinc: 66</td>
</tr>
<tr>
<td></td>
<td>Silver antimony: 2, 8, 17, 52, 54, 60, 65</td>
</tr>
<tr>
<td></td>
<td>Silver antimony-lead: 43</td>
</tr>
<tr>
<td></td>
<td>Silver arsenic: 60</td>
</tr>
<tr>
<td></td>
<td>Silver bismuth: 52, 60, 70</td>
</tr>
<tr>
<td></td>
<td>Silver indium: 69</td>
</tr>
<tr>
<td></td>
<td>Silver iron: 45</td>
</tr>
<tr>
<td></td>
<td>Silver lead bismuth: 10</td>
</tr>
<tr>
<td></td>
<td>Tin antimony: 46, 67, 68</td>
</tr>
<tr>
<td>Ternary compounds</td>
<td>Development: 41</td>
</tr>
<tr>
<td></td>
<td>Metals: 50</td>
</tr>
<tr>
<td></td>
<td>Properties: 70</td>
</tr>
</tbody>
</table>

34
Ternary V-VI-VII Compounds
Photoelectric properties ........................................ 40

Tetradyride (Bismuth Telluride)
Mineralogy .......................................................... 47

Thallium-Antimony-Selenium
Properties ............................................................. 24
Structure .............................................................. 24

Thallium Antimony Sulfide (TlSbS$_2$)
Structure .............................................................. 44

Thallium-Arsenic Selenide (Tl$_2$As$_2$Se$_3$)
Hall effect ............................................................ 23

Thallium Bismuth Selenide (TlBiSe$_2$)
Structure .............................................................. 44

Thallium Chalcogenides
Optical properties .................................................... 28

Thallium Selenide-Arsenic Telluride (Tl$_2$Se$_2$As$_2$Te$_3$)
Hall effect ............................................................ 23

Thallium-Selenium-Tellurium
Properties ............................................................. 5

Tin-Antimony Telluride (SnTe-Sb$_2$Te$_3$)
Properties ............................................................. 68

Tin Antimony Telluride (SnSb$_2$Te$_4$)
Structure .............................................................. 46

Titanates
Bismuth ................................................................. 6
Potassium .............................................................. 6
Sodium ................................................................. 6

Zinc Cadmium Mercury Sulfide \((\text{Zn, Cd, Hg})_S\)
Electroluminescence .................................................. 51

Zinc-Cadmium Selenide (ZnSe-CdSe)
Lattice parameters .................................................... 27
Photoelectric effect .................................................... 27

Zinc Mercury Sulfide \((\text{Zn, Hg})_S\)
Electroluminescence .................................................. 51