CANADA

EXPERIMENTS IN THE Au-Bi-Te SYSTEM

ERNST W. WINKLER &
NORMAN F. H. BRIGHT

EPARTMENT OF MINES AND
CHNICAL SURVEYS, OTTAWA

MINES BRANCH

RESEARCH REPORT

R 145

Price 25 cents.

MINERAL SCIENCES DIVISION

REPRINTED FROM SOLID STATE COMMUNICATIONS, VOL. 2, 293-295, 1964

FEBRUARY 1965

Available by mail from the Queen's Printer, Ottawa,
and at the following Canadian Government bookshops:

OTTAWA
Daly Building, Corner Mackenzie and Rideau

TORONTO
Mackenzie Building, 36 Adelaide St. East

MONTREAL
Aeterna-Vie Building, 1182 St. Catherine St. West

or through your bookseller

A deposit copy of this publication is also available
for reference in public libraries across Canada

Price 25 cents Catalogue No. M38-1/145

Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1965

Solid State Communications Vol. 2, pp. 293-295, 1964. Pergamon Press, Inc. Printed in the United States.

EXPERIMENTS IN THE Au-Bi-Te SYSTEM

Ernst W. Winkler* and Norman F. H. Bright§

Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada¶

(Received 15 July 1964 by B. N. Brockhouse)

The system Au-Bi-Te has been studied by thermal analysis, X-ray diffraction, DTA and metallographic polished section techniques. The join Au-Bi_2Te_3 has a eutectic point at 67.7 mol. per cent Au: 32.3 mol. per cent Bi_2Te_3 and 472°C. The join $AuTe_2$-Bi_2Te_3 has a eutectic point at 78.1 mol. per cent $AuTe_2$: 21.9 mol. per cent Bi_2Te_3 and 408°C. A ternary eutectic occurs at 12 per cent Au, 86 per cent Bi, 2 per cent Te and 210°C. The system contains no ternary compound. Seebeck coefficient, electrical conductivity, hardness and Hall coefficient measurements are being made.

THE system Au-Bi-Te is of technological importance in view of the use of bismuth telluride in components of thermoelectric refrigeration devices and the employment of gold as a connecting link between such components. The system also has mineralogical significance in that both gold and bismuth occur naturally as tellurides. The binary systems Au-Bi, Au-Te and Bi-Te are reasonably well established;[1] the compounds Bi_2Te_3 and $AuTe_2$ are both stable compounds with congruent melting points and well-established physical and chemical properties.[2] There is, however, virtually no information concerning phase relationships in the ternary system, and particularly in that portion of the system involving Bi_2Te_3 as one of the stable phases. A very limited solid solubility of Au in Bi_2Te_3 has been claimed.[3]

The phase relations have been studied using thermal analysis to give liquidus and solidus temperatures, DTA to give supplementary information on melting and transition points, X-ray diffraction for identification of phases, and metallographic polished sections to give information concerning the number of phases and physical structure of the assemblages (e.g. eutectic characteristics, etc.). Throughout this study, either the elements of 99.999 per cent purity or pre-formed compounds made from them were used.

All heating of compositions was done in quartz or Vycor tubes in the absence of oxygen in order to prevent oxidation of either the bismuth or the tellurium. Since the partial pressure of tellurium above all compositions in this system is fairly high, precautions were taken to ensure that no loss of tellurium occurred from a composition by arranging that, in the sealed tube in which it was prepared, the portion containing the sample itself was always a few degrees cooler than the remainder of the tube. It was found possible to prepare, by this technique, exactly stoichiometric Bi_2Te_3 and $AuTe_2$, as shown by chemical analysis, the examination of metallographic polished sections, X-ray diffraction examination, and the absence of uncombined, condensed tellurium.

The join Au-Bi_2Te_3 was found to be a true binary join with a eutectic composition at 67.7 mol. per cent Au: 32.3 mol. per cent Bi_2Te_3 and a melting point of 472°C. The liquidus and solidus relations in this sub-system are shown in Fig. 1. Very limited solid solubility of Au in Bi_2Te_3 may occur at temperatures near the liquidus but exsolution occurs on annealing at lower temperatures. The join $AuTe_2$ -

*National Research Council of Canada Postdoctorate Research Fellow assigned to the Mines Branch.
§Head, Physical Chemistry Section, Mineral Sciences Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada
¶Mineral Sciences Division Internal Report MS-64-57.

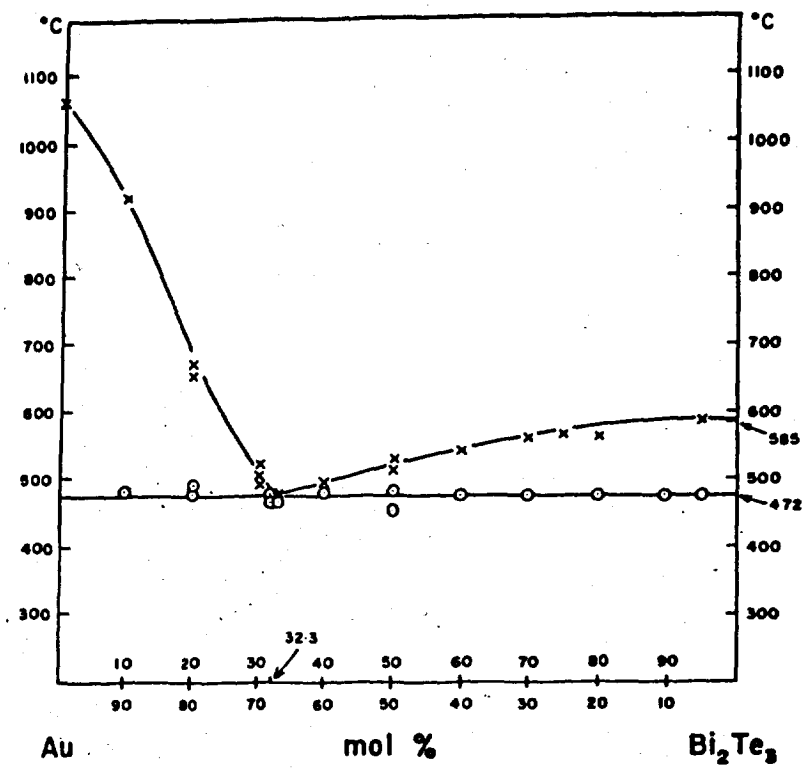

FIG. 1

The $Au-Bi_2Te_3$ Join.

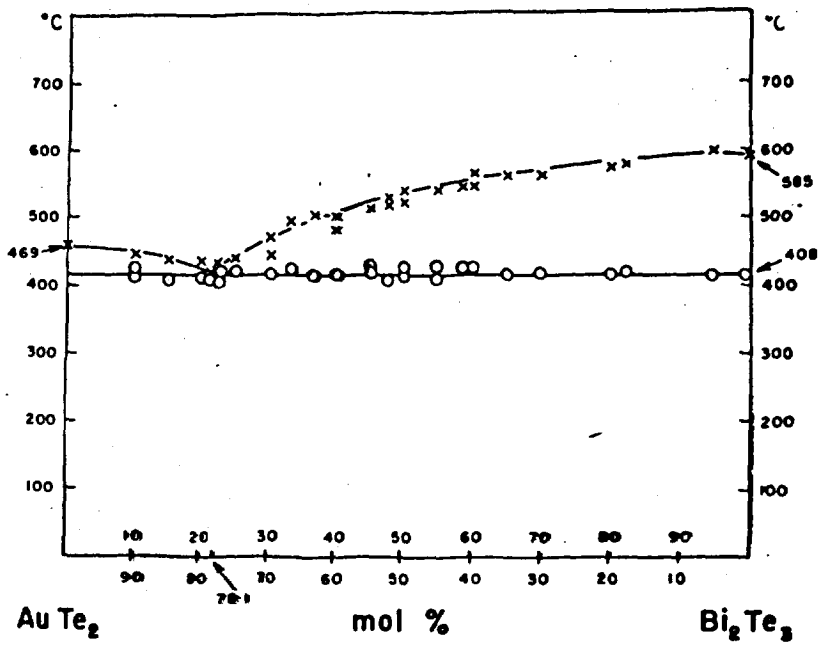

FIG. 2

The $AuTe_2-Bi_2Te_3$ Join.

Bi_2Te_3 was also found to be a true binary join with a eutectic composition at 78.1 mol. per cent $AuTe_2$: 21.9 mol. per cent Bi_2Te_3 and a melting point of 408°C. The compound $AuTe_2$ was found to have a melting point of 469°C with a crystalline transition at 435°C. This sub-system is shown in Fig. 2.

The join Au_2Bi-Bi_2Te_3 is suspected also to be true binary, although work on this sub-system is not complete and may be complicated by a possible incongruity of melting of the compound Au_2Bi. A ternary eutectic composition of melting point 210°C and composition 12 per cent Au: 86 per cent Bi: 2 per cent Te occurs in the compatibility triangle Bi_2Te_3-Bi-Au_2Bi. No evidence of the formation of any ternary Au-Bi-Te compound has been found anywhere in this system.

Work is in progress to complete the phase diagram of the ternary system with the establishment of other ternary eutectic compositions and the liquidus isotherms.

Measurements of the Seebeck coefficient along the join $AuTe_2$-Bi_2Te_3 have been made and will be reported elsewhere later. Similarly, Seebeck coefficient measurements along the join Au-Bi_2Te_3 are being made but have been complicated by the occurrence of segregation in the crystallization of these compositions. Measurements of the hardness, electrical conductivity and Hall coefficient of selected compositions in the system will be made and reported elsewhere when complete.

References

1. HANSEN M., Constitution of Binary Alloys pp. 188-189, 234 and 339. McGraw-Hill, New York (1958).

2. BROWN A. and LEWIS B., Int. J. Phys. Chem. Solids 23, 1597 (1962).

3. KEYS J.D. and DUTTON H.M., J. Appl. Phys. 34, 1830 (1963).

Das System Au-Bi-Te wurde mittels thermischer Analyse, Röntgenaufnahmen, differentieller Thermoanalyse und Metallschliffe untersucht. Der Schnitt Au-Bi_2Te_3 zeigt bei 67.7 mol. % Au: 32.3 mol. % Bi_2Te_3 ein bei 472 ° schmelzendes Eutectikum. Im Schnitt $AuTe_2$-Bi_2Te_3 liegt das Eutectikum bei 78.1 mol. % $AuTe_2$: 21.9 mol % Bi_2Te_3 und 408°. Ein ternäres Eutectikum tritt bei 12% Au, 86% Bi und 2% Te und 210°C auf. Es wurde keine ternäre Verbindung gefunden. Seebeck-koeffizienten, elektrische Leitfahigkeit, Härte und Hall-koeffizienten, werden bestimmt.