

Gold – Bismuth – Tin

Ortrud Kubaschewski

Introduction

The partial system AuSn–Bi–Sn has been investigated experimentally [1985Hum, 1987Max]. [1985Hum] studied the AuSn–Bi section and found it to be quasibinary, Fig. 1. [1987Max] determined the region of the miscibility gap at 386°C. The partial system is rather complex, including not only a miscibility gap but also three invariant reactions. The data reported by [1985Hum, 1987Max] are accepted. The liquidus surface and a reaction scheme constructed from their results are shown in Fig. 2 and Fig. 3.

Binary Systems

The Au–Sn system, evaluated by [Mas2], shows uncertainties concerning the equilibrium reactions for Au rich alloys. [1987Leg] have shown the existence of two peritectic reactions at 532 and 519°C, respectively. The solid state transformation requires further study. The Au–Bi system [Mas2] with a peritectic temperature of 377.5°C [1983Eva] is accepted. The Bi–Sn diagram by [Mas2] is accepted.

Solid Phases

No ternary phases have been found in the partial system. The phases of the partial AuSn–Bi–Sn system are listed in Table 1.

Quasibinary Systems

The AuSn–Bi section is quasibinary, Fig. 1 [1987Max]. Bi may be soluble in AuSn but the solubility has not been determined. A solubility of about 8 at.% Bi in AuSn is indicated by [1985Hum] at the eutectic temperature. A monotectic reaction occurs at 386°C: $L' \rightleftharpoons L'' + \text{AuSn}$.

Invariant Equilibria

Three ternary invariant equilibria, Table 2, are reported for the partial ternary system. The reaction scheme is presented in Fig. 3.

Liquidus Surface

Figure 2 illustrates the projection of the liquidus surface [1986Max]. The extent of the liquid immiscibility entering from the AuSn–Bi section is not known and shown here as a dashed curve, disappearing at a critical tie line $L \rightleftharpoons \text{AuSn}$ below 386°C. The regions of primary crystallization of (Bi) and (Sn) are confined to narrow regions adjoining the Bi–Sn binary edge.

Isothermal Sections

Figures 4, 5, 6 and 7 display the isothermal sections at 240, 200, 160 and 139°C respectively, for the partial Sn–AuSn–Bi system. The last one corresponds to the temperature of the invariant reaction E which is shown by dash lines in Fig. 7. The isothermal sections have been slightly amended from [1986Max] to be consistent with the vertical sections.

Temperature – Composition Sections

The vertical section at Au₅₀Bi₅₀ – Sn [1985Hum, 1986Max] is shown in Fig. 8.

References

- [1983Eva] Evans, D.S., Prince, A., “The Au–Bi Phase Diagram”, *CALPHAD XII Meeting*, Liège (1983)
- [1985Hum] Humpston, G., “The Constitution of Some Ternary Au–Based Solder Alloys”, Ph.D. Thesis, Brunel University, 67-68 and 95, Figs. 46-50 (1985) (Phase Diagram, Experimental, 2)
- [1986Max] Maxwell, C.A., M.Sc. Thesis, Univ. Manchester, Faculty of Technology (1986)
- [1987Max] Maxwell, C.A., Hayes, F.H., private communication
- [1987Leg] Legendre, B., Hancheng, C.H., Hayes, F., Maxwell, C., Evans, D.S., Prince, A., “Contribution Towards Clarification of the Au–Sn Phase Diagram for Sn Contents Less than 25 at.%”, *Mater. Sci. Technol.*, **3**, 875-876 (1987) (Phase Diagram, Experimental, 6)

Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(Au) < 1064.43	<i>cF4</i> <i>Fm$\bar{3}m$</i> Cu	<i>a</i> = 407.82	at 25°C [Mas2]
(Bi) < 271.442	<i>hR6</i> <i>R$\bar{3}m$</i> α As	<i>a</i> = 454.613 <i>c</i> = 1186.152	at 31°C [V-C2]
(Sn) 231.97 - 13	<i>tI4</i> <i>I4₁/amd</i> β Sn	<i>a</i> = 583.18 <i>c</i> = 318.18	at 25°C [Mas2]
AuSn < 419.3	<i>hP4</i> <i>P6₃/mmc</i> NiAs	<i>a</i> = 432.18 <i>c</i> = 552.30	[V-C2]
AuSn ₂ < 309	<i>oP24</i> <i>Pbca</i> AuSn ₂	<i>a</i> = 690.9 <i>b</i> = 703.7 <i>c</i> = 1178.9	[V-C2]
AuSn ₄ < 252	<i>oC20</i> <i>Aba2</i> PtSn ₄	<i>a</i> = 651.24 <i>b</i> = 651.62 <i>c</i> = 1170.65	at 25°C [V-C2]

Table 2: Invariant Equilibria

Reaction	<i>T</i> [°C]	Type	Phase	Composition (at.%)		
				Au	Bi	Sn
L' \rightleftharpoons L'' + AuSn	368	e ₁ (max)	L' L''	<35 <17.8	30 64.4	35 > 17.8>
L' \rightleftharpoons (Bi) + AuSn	262.5	e ₂ (max)	L	<2.65	94.7	2.65>
L + AuSn \rightleftharpoons AuSn ₂ + (Bi)	224	U ₁	L	1.9	76.8	21.3
L + AuSn ₂ \rightleftharpoons (Bi) + AuSn ₄	146	U ₂	L	2.7	44.7	52.6
L \rightleftharpoons (Bi) + (Sn) + AuSn ₄	137	E	L	0.8	40.0	59.2

values in brackets are estimated from Fig. 1.

Fig. 1: Au-Bi-Sn.
Quasibinary system
Bi-AuSn

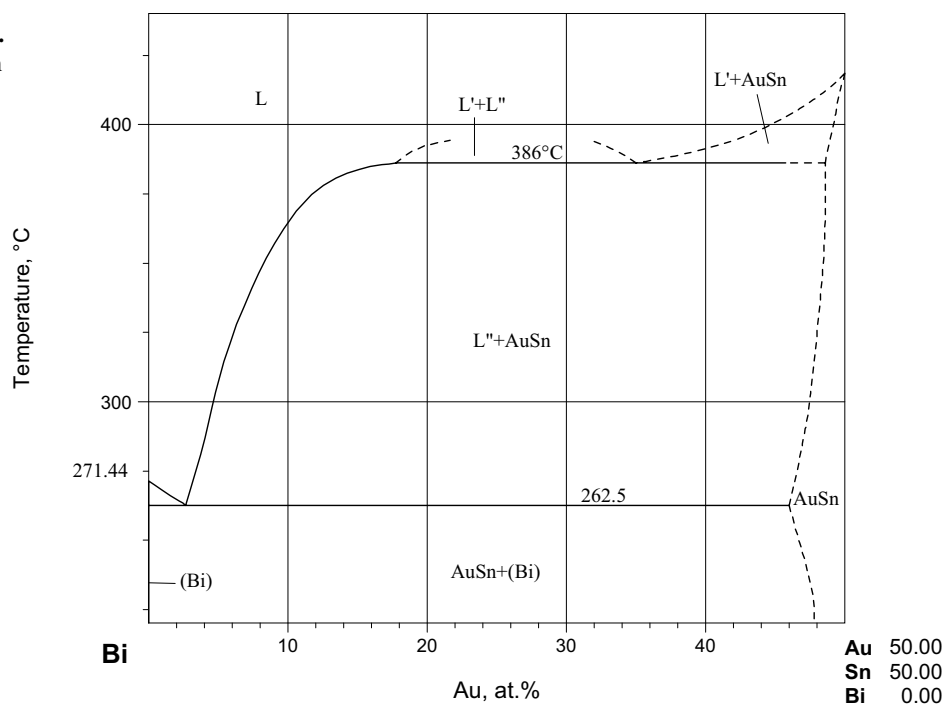
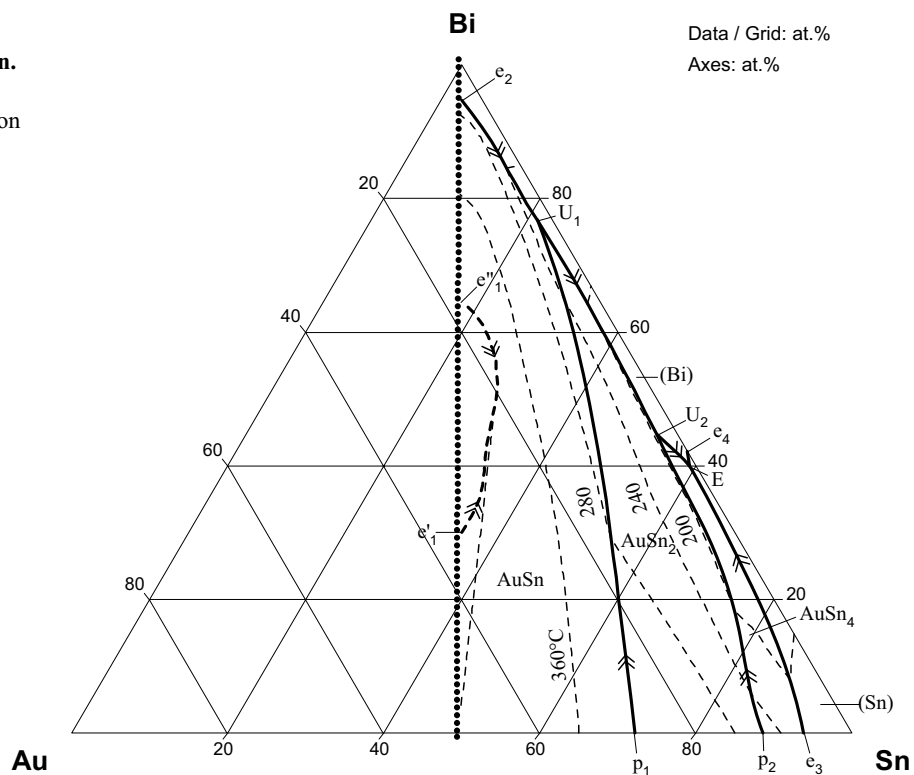


Fig. 2: Au-Bi-Sn.
Partial liquidus
surface in the region
AuSn-Bi-Sn



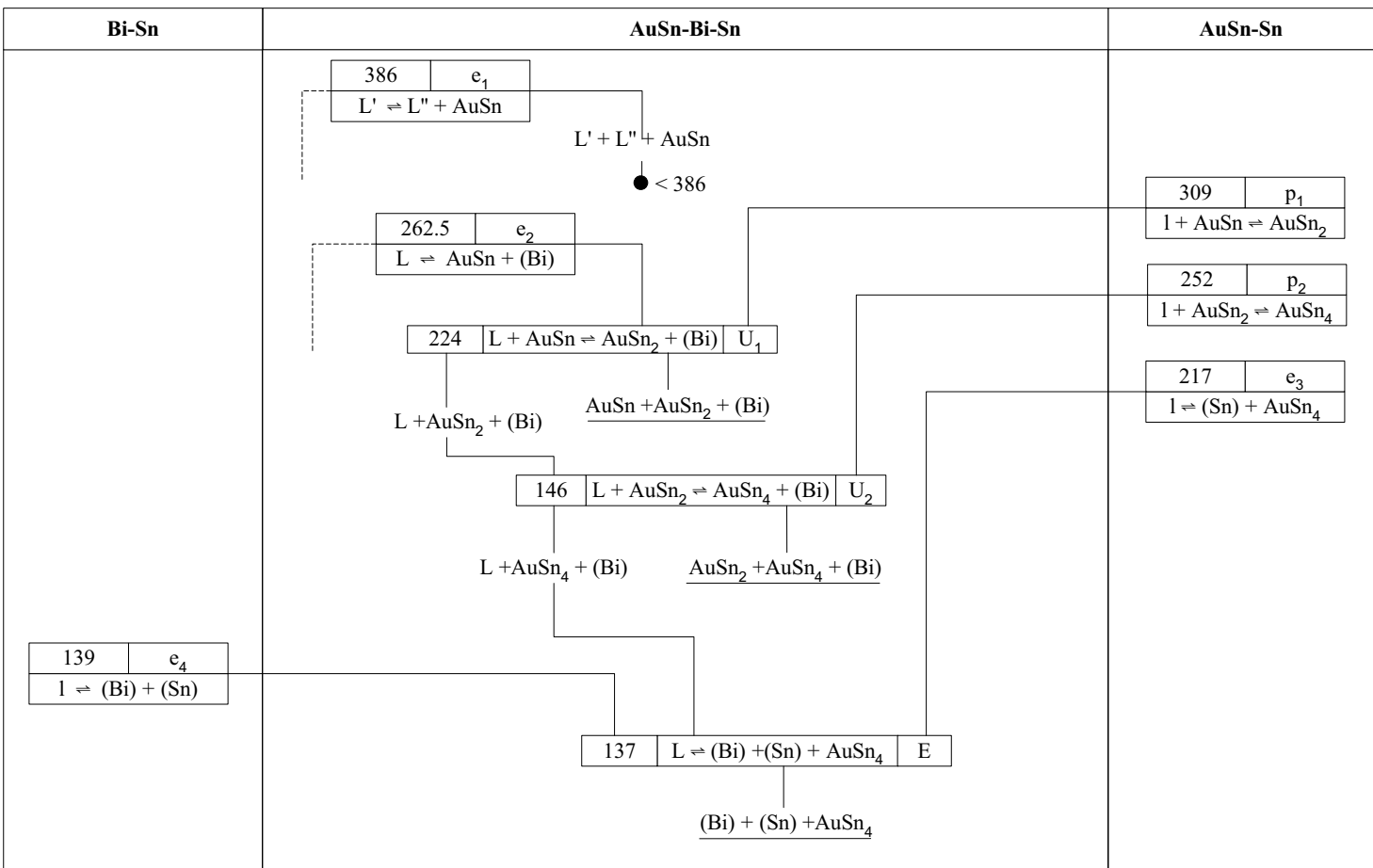


Fig. 4: Au-Bi-Sn.
Isothermal section at
240°C

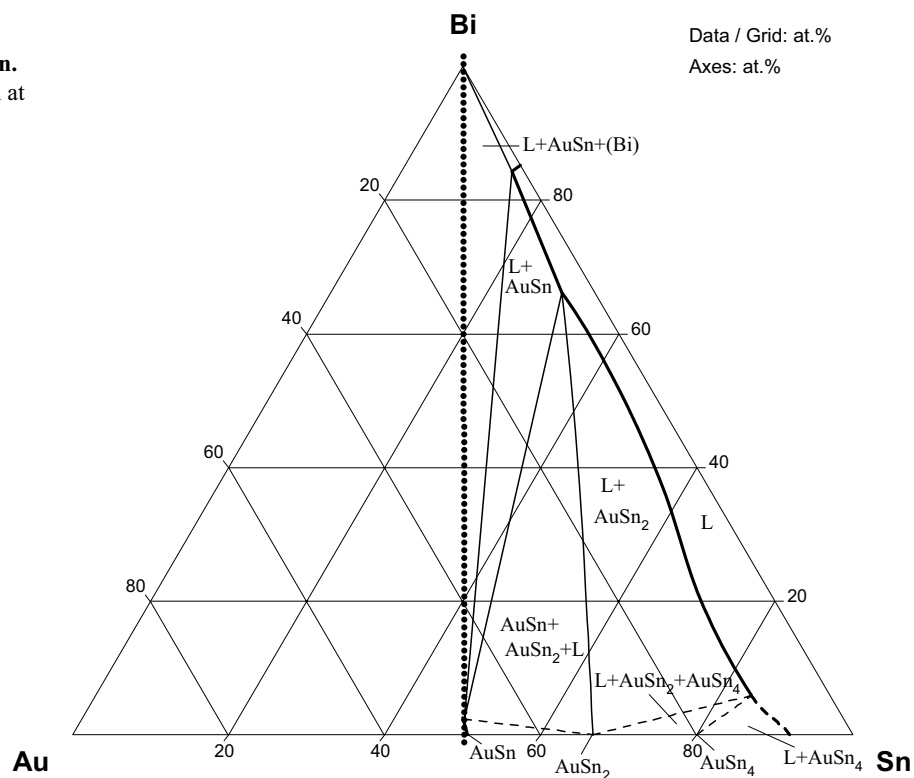


Fig. 5: Au-Bi-Sn.
Isothermal section at
200°C

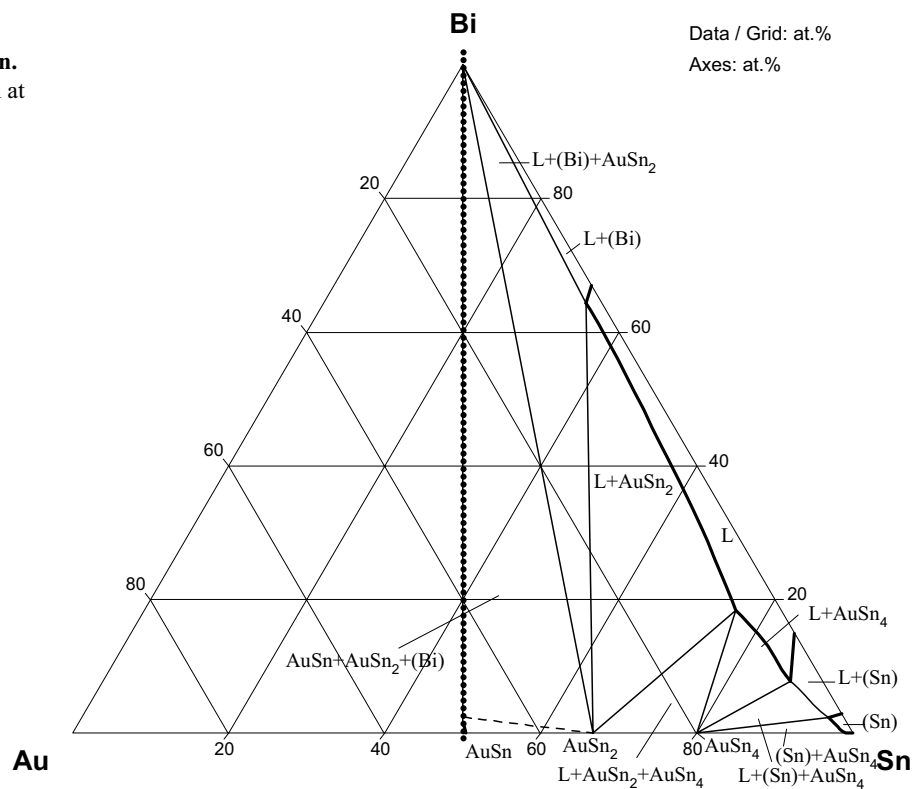


Fig. 6: Au-Bi-Sn.
Isothermal section at
160°C

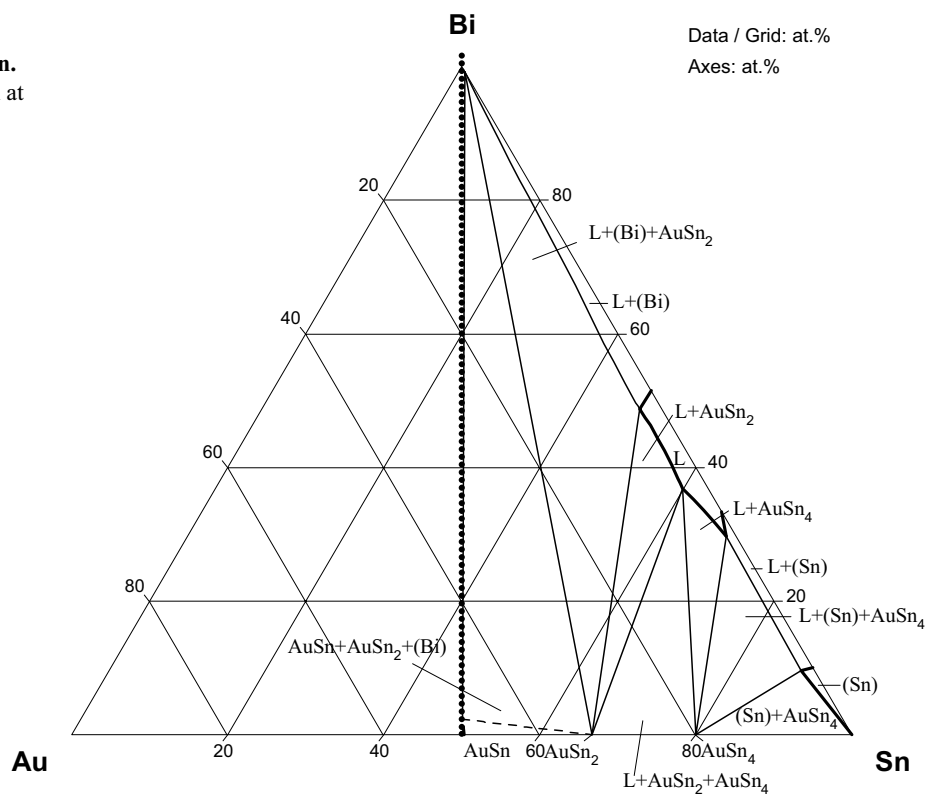


Fig. 7: Au-Bi-Sn.
Isothermal section at
139°C

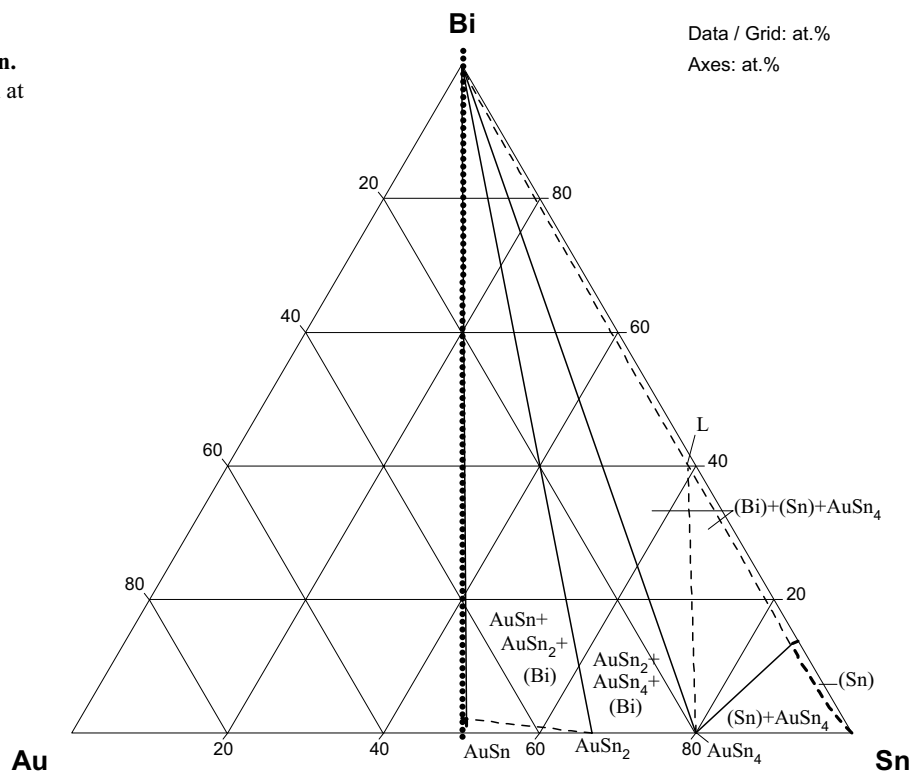


Fig. 8: Au-Bi-Sn.
Part of the vertical
section $\text{Au}_{50}\text{Bi}_{50}\text{-Sn}$

