Gold – Indium – Tin

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Introduction

[1958Sch] reported the ternary $Au_4In_3Sn_3$ phase in a short communication. [1959Sch] investigated a section of the ternary system. They showed alloy equilibria after heat treatments at various temperatures for 0 to 340 d. Samples were melted in evacuated silica tubes. Solidified alloys as well as powder samples were vacuum heat-treated before they were examined by X-ray diffraction methods and metallography, respectively. One half of the 20 alloys were heat treated at 250°C, the other half was examined as cast or heat treated between 100 and 350°C.
[1968Sch] investigated the crystallographic structure of an alloy with the composition 50Au-37In-13Sn (at.%) and [1959Bur] that of 75Au-22In-3Sn (at.%). The alloy investigated by [1959Bur] contained ε' with some ζ. The same alloy was quoted by [1959Sch] to be single-phase ε' as a result of X-ray powder diffraction and 95% ε' + 5% AuSn in the grain boundaries according to metallographic examination of a sample heat treated at 250°C for 48 d. The $Au_{50}In_{37}Sn_{13}$alloy [1968Sch] is probably within the homogeneity range of AuIn.
[1985Hum] worked on the section AuIn-AuSn and found a two-phase region below ≈325°C and the section not to be quasibinary. There is a considerable solubility of Sn in AuIn (10 at.% at ≈250°C) and extensive solubility of In in AuSn (17 at.% at 250°C). The ternary compound, $Au_4In_3Sn_3$, melts congruently at 431°C.

Binary Systems

The binary systems Au-In, Au-Sn and In-Sn are accepted from [Mas2].

Solid Phases

Crystal structure data of the ternary $Au_4In_3Sn_3$ compound and the binary phases stable at 250°C and below are given in Table 1.

Isothermal Sections

Figure 1 shows the isothermal section at approximately 250°C. At this temperature the In-Sn binary alloys are all molten, the Au-In alloys have a L+$AuIn_2$ region ranging up to 98.8 at.% In and Au-Sn alloys have an L + $AuSn_4$ region from 80 to 89 at.% Sn, followed by a liquid region up to Sn. Therefore, the equilibria between solid phases on the Au-poor side of the $AuIn_2$-$AuSn_4$ joint, given by [1959Sch], present at 100°C section. This part of the section is omitted in Fig. 1.
The Au_9In phase forms a continuous series of solid solution (α_1) with the $Au_{10}Sn$ phase, over the temperature range of the $Au_{10}Sn$ stability. $Au_{10}Sn$ was not detected in the isothermal section. Therefore it is probable that it transforms to (Au) + ζ at a temperature higher than 250°C. The ζ phase is a continuous series of solid solution between $Au_{17}Sn_3$ and Au_4In phases. Instead of one three-phase region ε'+β_1/ζ+AuSn as given by [1959Sch] the isothermal section presented in Fig. 1 shows two three-phase regions: ε' +β_1 + AuSn and β_1 + ζ + AuSn.

References

[1958Sch] Schubert, K., Breimer, H., Gohle, R., Lukas, H.L., Meissner, H.G. Stolz, E., "Some Structural Results on Metallic Phases III" (in German), *Naturwiss.*, **45**, 360-361 (1958) (Crys. Structure, Experimental, 2)

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[1985Hum] Humpston, G., "The Constitution of Some Ternary Au-Based Solder Alloys", Ph.D. Thesis, Brunel University (1985) (Phase Diagram, Phase Relations, Crys. Structure, Experimental, 80)

Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(Au) < 1064.43	*cF*4 $Fm\bar{3}m$ Cu	*a* = 407.82	at 25°C [Mas2]
(βSn)(r) 231.97 - 13	*tI*4 $I4_1/amd$ βSn	*a* = 583.18 *c* = 318.18	at 25°C [Mas2]
(αSn)(l) < 13	*cF*8 $Fd\bar{3}m$ C (diamond)	*a* = 648.92	[Mas2]
(In) < 156.63	*tI*2 *I*4/*mmm* In	*a* = 325.3 *c* = 494.70	at 25°C [Mas2]
α_1 Au_9In < 649.25	*hP*16 $P6_3/mmc$ $TiNi_3$	*a* = 410.60	12 to 14.3 at.% In [Mas2] at 20°C [Mas2, V-C2]
$Au_{10}Sn$ < 649.25		-	[Mas2]
β_1, Au_7In_2 < 295	*hP*26 $P\bar{3}$ $Cu_{10}Sb_3$	*a* = 1054.5 *c* = 476.9	21.7 to 22.5 at.% In [Mas2, V-C2]
ε', Au_3In ≲ 339.5	*oP*8 *Pmmm* $\beta TiCu_3$	*a* = 586 *b* = 474 *c* = 516	24.5 to 25 at.% In [Mas2, V-C2]
		a = 590 *b* = 476 *c* = 518	$Au_{75}In_{22}Sn_3$ [1959Bur]
γ', Au_7In_3 < 374.6	*hP*60 $P\bar{3}$ Au_7In_3	*a* = 1221.5 *c* = 850.9	29.8 to 30.6 at.% In [Mas2, V-C2]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
ψ, Au_3In_2 457.5 - 224.3	*hP*5 $P\bar{3}m1$ Ni_2Al_3	*a* = 453.7 *c* = 565.9	35.3 to 39.5 at.% In [Mas2, V-C2]
AuIn < 509.6	*aP**	*a* = 430 *b* = 1059 *c* = 356 α = 90.54° β = 90.0° γ = 90.17°	[Mas2, V-C2]
$AuIn_2$ < 540.7	*cF*12 $Fm\bar{3}m$ CaF_2	*a* = 650.2	[Mas2, V-C2]
ζ', Au_5Sn < 195	*hR*6 $R\bar{3}$ Au_5Sn	*a* = 509.2 *c* = 1433.3	16.7 at.% Sn [Mas2, V-C2]
δ, AuSn < 419.3	*hP*4 $P6_3/mmc$ NiAs	*a* = 432.18 *c* = 552.30	50 to 50.5 at.% Sn [Mas2, V-C2]
ε, $AuSn_2$ < 309	*oP*24 *Pbca* $AuSn_2$	*a* = 690.9 *b* = 703.7 *c* = 1178.9	66.7 at.% Sn [Mas2, V-C2]
η, $AuSn_4$ 252 - ≈50	*oC*20 *Aba*2 $PtSn_4$	*a* = 651.24 *b* = 651.62 *c* = 1170.65	80 at.% Sn [Mas2, V-C2], lattice parameters at 25°C
β, In_3Sn < 143	*tI*2 *I*4/*mmm* In	*a* = 346.3 *c* = 440.4	12 to 44 at.% Sn [Mas2, V-C2], lattice parameter at 24°C
γ, $InSn_4$ < 224	*hP*1 *P*6/*mmm* BiIn	*a* = 320.8 *c* = 299.7	72 to ? at.% Sn [Mas2, V-C2], lattice parameter at –10°C
ζ $Au_{17}Sn_3$	*hP*2 $P6_3/mmc$ Mg	*a* = 293.05 *c* = 477.01	10 to 18.5 at.% Sn [Mas2, V-C2]
Au_4In		*a* = 291.57 *c* = 479.30	13 to 23 at.% In [Mas2, V-C2]
* τ_1, $Au_4In_3Sn_3$ < 431	*hP*10 $P6_3/mmc$ Pt_2Sn_3	*a* = 449.9 *c* = 1304.7	[1958Sch], melting point [1985Hum]
* τ_2?, Au_5In_4Sn	*oC*8 *Cmcm* Tl I	*a* = 360 *b* = 1049 *c* = 428	$Au_{50}In_{37}Sn_{13}$ [1968Sch], probably (Au,In) solid solution and not a ternary compound

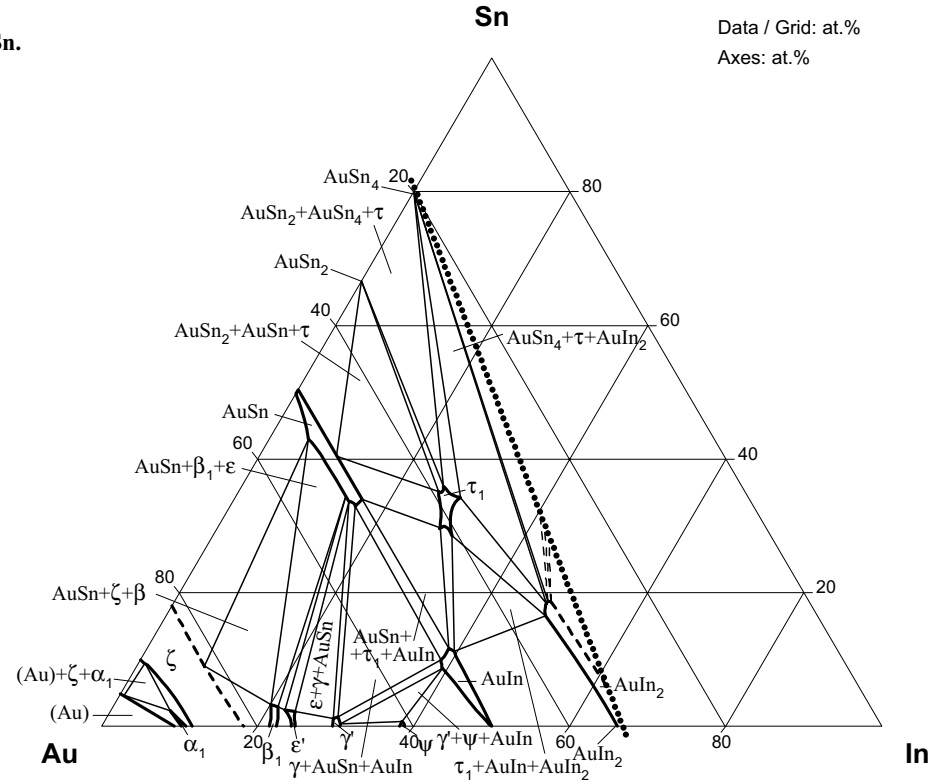

Fig. 1: Au-In-Sn. Partial isothermal section at 250°C