

The isothermal section at 400°C of the Yb–Ag–Sn ternary system

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Abstract

The Yb–Ag–Sn isothermal section at 400°C has been investigated by means of X-ray diffraction, optical and scanning electron microscopy and electron probe microanalysis. The following ternary compounds have been identified or confirmed: $\tau_1 \sim \text{Yb}_{25}\text{Ag}_{50}\text{Sn}_{25}$, $\tau_2 \sim \text{Yb}_{50}\text{Ag}_{25}\text{Sn}_{25}$ to $\text{Yb}_{46}\text{Ag}_{24}\text{Sn}_{30}$, $\tau_3 \sim \text{Yb}_{19}\text{Ag}_{50}\text{Sn}_{31}$, $\tau_4 \sim \text{YbAgSn}$. Moreover a phase $\tau_x \sim \text{Yb}_{50}\text{Ag}_{35}\text{Sn}_{15}$, not definitively confirmed, has been observed in a few samples. A subdivision of the composition triangle into tie-triangles has been obtained. The general characteristics of the section have been discussed in comparison with those of other R–Ag–Sn systems. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Rare earth compounds; Yb compounds; Phase diagrams; Ternary alloy systems

1. Introduction

The ternary alloys R–T–X of the rare earth metals (R) with the transition elements (T) and one of the metals (X) of the p-block of the Periodic Table represent a group of substances among which several materials of promising (magnetic, electric, etc) properties have been identified.

Different groups of researchers are interested in the preparation and characterisation of $\text{R}_x\text{T}_y\text{X}_z$ compounds; very often the investigations of these phases are carried out opportunely in the framework of a more or less complete determination of the R–T–X phase diagram. This is, of course, very convenient in order to have for each phase of interest more complete indications about its stability (ranges of composition and temperature of existence), its reactivity, and therefore preparation methods. A systematic description of R–T–X phases and systems has recently been presented by Gladyshevsky [1] and by Szytula [2,3]. The complexity of these systems and the high number of intermediate compounds found have been underlined and general aspects of the crystal chemistry of these phases and interrelations between their structures have been discussed. An analysis of phase equilibria in selected R–T–X (X=Si,Ge) systems and the influence of the size factor in several $\text{R}_x\text{T}_y\text{X}_z$ compounds have been presented by

Morozkin and Seropegin [4]. The relevance of a group of stoichiometries (RT_2X_2 , RTX_3 , RTX_2 , $\text{R}_2\text{T}_3\text{X}_5$, RTX , and R_2TX_3) has been underlined and it has been suggested that these phases can be considered to be obtained by a sort of chemical (or structural) interaction between binary compounds, which define a kind of ‘main’ equilibria line on which the ternary phases themselves generally lie. Recently special attention has been dedicated to the group of R–T–Sn systems and alloys, for which Skolozdra [5] has discussed the literature data.

Different properties of R–T–X phases have been presented and discussed in several recent papers. See for instance Bazela et al. [6] (magnetic properties of RAgSn compounds), Guillot et al. [7] (magnetic properties of R–(Ag, Pd)–(Sn, Ga) in high magnetic fields), Baran et al. [8] (neutron diffraction study of magnetic ordering in RAgSn), Latka et al. [9] (crystal and magnetic properties of GdT₂Sn), Kaczorowski et al. [10] (magnetic, thermodynamic, electrical transport properties of YbT₂Sn), Pottgen et al. [11] (¹¹⁹Sn Mossbauer spectroscopy of YbT(Sn, Pb) compounds).

A contribution to the investigation into the R–Cu–Sn systems has been made by our research team with the study of the isothermal sections of the Ce–Cu–Sn [12], Nd–Cu–Sn [13] and Yb–Cu–Sn [14] phase diagrams.

With regard to the work in progress on the ternary R–T–Sn alloys, our group has recently undertaken the study of the R–Ag–Sn systems.

An isothermal section of the Ce–Ag–Sn system has

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been recently published [15]. The results of an investigation of the isothermal section at 400°C of the Yb–Ag–Sn system are presented here.

2. Literature data

2.1. Binary systems

All the binary phases relevant to this investigation are listed in Table 1.

The following comments may be useful for the different binary systems involved.

2.2. Yb–Sn

The diagram as assessed by Palenzona and Cirafici [16] has been accepted here, with the addition of the Yb₃Sn₅

phase, which melts peritectically at 760°C as reported by Ref. [17]. This is in agreement with the data observed in the present investigation.

Notice however that more recently, Leon-Escamilla and Corbett [18] reported the formation of a new phase Yb₃₆Sn₂₃ in samples having a very high purity without any trace of hydrogen. They suggested, moreover, that Yb₅Sn₃, and possibly Yb₅Sn₄, could be an impurity (hydrogen) stabilised phase.

2.3. Yb–Ag

The Yb–Ag system has been studied by Palenzona [19] and then assessed by Gschneidner et al. [20]. Cordier et al. [21] revised the crystal structure of Yb₂Ag₇ phase, previously reported as hP18–Ca₂Ag₇, and refined the structure as pertaining to the new orthorhombic oC36–Yb₂Ag₇ type.

Table 1

The unary and binary phases of the Yb–Ag–Sn system^a

Phase	Melting and transf. temp. (°C)	Pearson Symbol Prototype	lattice parameters (pm)			Refs.
			<i>a</i>	<i>b</i>	<i>c</i>	
αSn	t 13	cF8–C	648.92			[22]
βSn	m.p. 231.97	tI4–βSn	583.15		318.14	[22]
YbSn ₃	m.p. 805	cP4–AuCu ₃	468.3			[16]
Yb ₃ Sn ₅	p 760	oC32–Pd ₃ Pu ₃	1019.1	816.3	1037.0	[17]
YbSn	p 1035	tP4–AuCu I	496.0		440.0	[16]
Yb ₅ Sn ₄ ^b	p 1160	oP36–Gd ₅ Si ₄	782.2	1581.3	828.0	[16]
Yb ₃₆ Sn ₂₃ ^b	unknown	tP118–Sn ₂₃ Yb ₃₆	1238.69		2293.5	[18]
αYb ₅ Sn ₃ ^b	t 1090	hP16–Mn ₅ Si ₃	947		690	[16]
βYb ₅ Sn ₃ ^b	p 1235	tI32–Cr ₅ B ₃	793.9		1468.6	[16]
Yb ₂ Sn	m.p. 1385	hP6–InNi ₂	537.1		706.3	[16]
Yb ₃ Sn ^c		cP4–AuCu ₃				[16]
αYb	t–3	hP2–Mg	387.99		638.59	[22]
βYb	t 795	cF4–Cu	548.48			[22]
γYb	m.p. 819	cI2–W	444			[22]
Yb ₅ Ag ₃	p 552	tI32–Cr ₅ B ₃	794.2		1488.1	[20]
Yb ₃ Ag ₂	p 632	tP10–U ₃ Si ₂	821.9		421.8	[20]
αYbAg	t 456	oP8–FeB	759.0	467.0	601.3	[20]
βYbAg	m.p. 724	cP2–CsCl	367.9			[20]
YbAg ₂	m.p. 661	oI12–CeCu ₂	466.7	720.8	818.1	[20]
Yb ₂ Ag ₇ ^d	m.p. 749	oC36–Yb ₂ Ag ₇	948.0	552.6	1407.6	[21]
Yb ₂ Ag ₉	p 727	unknown				[20]
(Ag, Yb)		cF4–Cu	408.6 to 408.9			[23]
0–1.92 at% Yb						
Ag	m.p. 961.93	cF4–Cu	408.626			[20]
(Ag, Sn)		cF4–Cu	408 to 413			[23]
0–11.5 at% Sn						
ζ (11.8–22.8 at% Sn)	p 724	hP2–Mg	292.8 to 297.6		478.5 to 478.2	[24]
ε (23.5–25 at% Sn)	p 480	oP8–βCu ₃ Ti	596.82	478.02	518.43	[24]

^a m.p., melting point; p, peritectic reaction; t, solid state transformation.

^b According to [18] Yb₃₆Sn₂₃ only is a stable binary phase in this composition range; Yb₅Sn₃ and possibly Yb₅Sn₄ could be impurity (hydrogen) stabilised phases.

^c This phase has not been described in the binary Yb–Sn system. This cubic compound has been observed, possibly as a metastable (impurity stabilised) phase, in the preparation of the ternary alloys.

^d Possibly previously reported as hexagonal hP18 *a*=548.1 *c*=1407.2 (Notice that *c*_{orth}=*c*_{hex}, *b*_{orth}≅*a*_{hex} and *a*_{orth}≅*b*_{orth}√3).

2.4. Ag–Sn

This well known diagram has been reported by Massalski [22] and then assessed by Karakaya et al. [24].

2.5. R–Ag–Sn ternary systems

As regards the R–Ag–Sn systems, very little information on the isothermal sections has been reported in the literature, except for R=Ce [15] and R=Nd [25].

Several series of compounds have been identified, for which the structure has been determined. In particular, the following stoichiometries and structures have been evidenced: **RAgSn**, hP6–CaIn₂ (R=La, Sm, Gd) [26], hP6–GaGeLi (R=Ce, Pr, Nd, Tb, Dy, Ho, Er) [8], hP9–CaLiSn (R=Yb) [27], oI12–CeCu₂ (R=Eu) [28]; **R₃Ag₄Sn₄**, oI22–Gd₆Cu₈Ge₈ (R=La, Ce, Pr, Nd, Sm) [29]; **R₅AgSn₃**, hP18–Ga₄Ti₅ (R=Ce) [30].

Fig. 1 shows the trend of the average atomic volume for the RAgSn and R₃Ag₄Sn₄ phases in comparison with the similar copper phases. The data relevant to the Cu phases have been reported from Gladyshevsky [1] and Skolozdra [5]. The value for Sm₃Cu₄Sn₄, recently obtained [31], has been added. Notice the nearly parallel trends of the atomic volumes of all the phases with the characteristic deviation of the Yb values. For Sm₃Ag₄Sn₄, however, a confirmation of the data may be interesting.

2.6. Yb–Ag–Sn ternary system

The data relevant to the crystal structure of the YbAgSn phase have been reported in the literature [27], but there are no data on phase equilibria.

3. Experimental details

Ytterbium (nominal purity 99.9 mass %) and silver and tin (nominal purity 99.999 mass %) were used as starting components. The alloys were prepared by sealing the appropriate amounts of the elements in small tantalum crucibles under an argon atmosphere. The crucibles were induction-heated until complete fusion of the constituent elements, in a vacuum-tube furnace, and the alloys were homogenized by repeated shaking and quickly cooled down to room temperature. The samples were then annealed at 400°C for 2 weeks and quenched in water.

X-ray diffraction analysis, metallographic analysis and electron probe microanalysis were used to characterise the samples.

X-ray examination was carried out on powder samples using a vertical diffractometer (CuK α radiation), with the addition of Si as a calibration standard.

The microstructure of the alloys was studied using standard optical and electronic micrographic methods on all the samples. The specimens were prepared by the

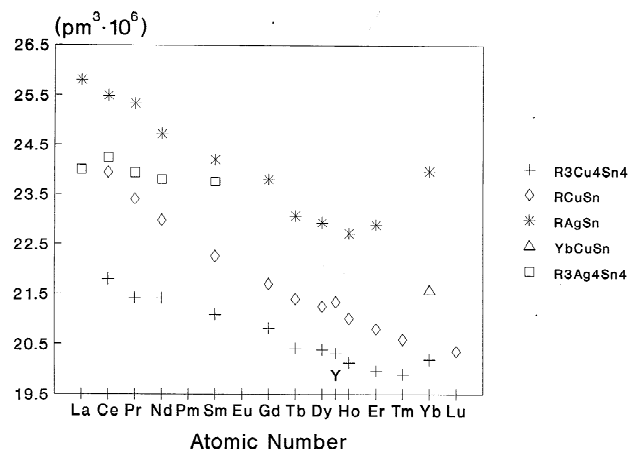


Fig. 1. Trend of the average atomic volume versus rare earth's atomic number for RAgSn, R₃Ag₄Sn₄, RCuSn, and R₃Cu₄Sn₄ compounds.

conventional method and generally etched in air except the silver richest ones, etched with diluted alcoholic nitric acid solution. Semiquantitative electron probe microanalysis of the phases was carried out by using an energy-dispersive X-ray analyzer with the pure elements as standards.

4. Results

The data obtained in the preparation and examination of the different alloys are reported in Table 2. The results obtained are also summarised in the isothermal section at 400°C proposed in Fig. 2 and some microphotographs of representative samples are reported in the Figs. 3–8.

The different alloys, generally obtained in the form of

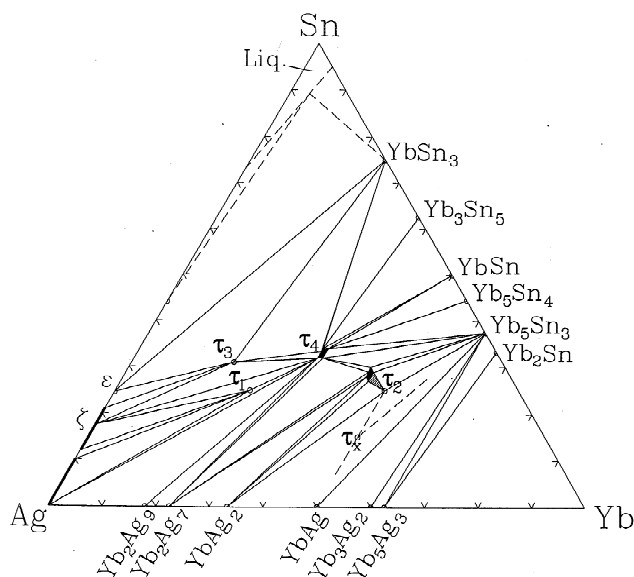


Fig. 2. Isothermal section at 400°C of the Yb–Ag–Sn system based on the data collected in Table 2.

Table 2
Yb–Ag–Sn system^a

Code N°	Nominal alloy composit. (at.%)		Phases observed in the alloys, reported in the order of their amount Composition from EPMA (at.%) and lattice parameters (pm)													Note		
	Yb	Sn	I st phase					II nd phase					III rd phase					
			Yb	Sn			unit cell	Yb	Sn			unit cell	Yb	Sn				unit cell
1	60.0	4.0	60.0	0.0	Yb ₃ Ag ₂	<i>a</i> =822.1 <i>c</i> =422.5	49.5	0.0	YbAg		62.5	36.5	Yb ₅ Sn ₃					
2	56	4.5	50.0	0.5	YbAg	<i>a</i> =758.0 <i>b</i> =466.2 <i>c</i> =602.5	60.0	0.5	Yb ₃ Ag ₂		63.0	36.5	Yb ₅ Sn ₃					
3	27.5	5.0	24.0	1.0	Yb ₂ Ag ₇		34.0	0.0	YbAg ₂		45.5	28.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅	**traces				
4	16.5	5.5	18.5	0.5	Yb ₂ Ag ₉		3.5	2.5	Ag		34.0	32.0	τ_4 YbAgSn**					
5	39.5	5.5	34.0	5.5	YbAg ₂	<i>a</i> =468.2 <i>b</i> =717.1 <i>c</i> =818.5	50.5	0.0	YbAg	<i>a</i> =757.5 <i>b</i> =466.2 <i>c</i> =602.2	46.0	20.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅					
6	49.0	6.0	51.0	2.0	YbAg	<i>a</i> =765.0 <i>b</i> =466.1 <i>c</i> =601.0	31.5	3.5	YbAg ₂	<i>a</i> =469.2 <i>b</i> =716.0 <i>c</i> =815.5								
7	49.0	9.0	50.5	12.0	τ_x Yb ₅₀ Ag ₃₅ Sn ₁₅		49.0	0.5	YbAg		34.5	0.0	YbAg ₂		see Fig. 3			
8	38.0	10.0	34.5	0.5	YbAg ₂		45.0	27.5	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅									
9	61.5	11.0	61.0	2.0	Yb ₃ Ag ₂	<i>a</i> =821.0 <i>c</i> =422.5	63.0	36.5	Yb ₅ Sn ₃	<i>a</i> =946.0 <i>c</i> =684.2	62.0	2.0	Yb ₅ Ag ₃		see Fig. 4			
10	53.0	13.0	50.5	0.0	YbAg		62.0	38.0	Yb ₅ Sn ₃		35.5	0.5	YbAg ₂ **		**traces see Fig. 5			
11	48.0	14.0	49.0	25.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		49.0	14.5	τ_x Yb ₅₀ Ag ₃₅ Sn ₁₅		33.5	0.5	YbAg ₂		+ YbAg			
12	43.0	15.0	49.5	25.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		34.5	0.0	YbAg ₂	<i>a</i> =463.0 <i>b</i> =727.2 <i>c</i> =810.0					see Fig. 6			
13	27.0	15.5	34.0	32.0	τ_4 YbAgSn	<i>a</i> =478.0 <i>c</i> =1088.3	21.5	1.5	Yb ₂ Ag ₇		18.0	1.5	Yb ₂ Ag ₉					
14	18.0	16.5	34.0	33.0	τ_4 YbAgSn	<i>a</i> =478.0 <i>c</i> =1089.2	0.5	0.5	Ag	<i>a</i> =408.6								
15	11.5	18.0	24.0	26.0	τ_1 Yb ₂₅ Ag ₅₀ Sn ₂₅		0.0	12.0	ζ	<i>a</i> =294.5 <i>c</i> =478.0	0.0	10.5	Ag		see Fig. 7			
16	16.0	19.0	24.5	25.5	τ_1 Yb ₂₅ Ag ₅₀ Sn ₂₅		0.5	8.0	Ag									
17	73.0	20.5	66.0	34.0	Yb ₂ Sn	<i>a</i> =536.1 <i>c</i> =707.2	62.5	36.5	Yb ₅ Ag ₃		98.0	1.0	Yb					
18	25.0	24.0	35.0	33.0	τ_4 YbAgSn		0.5	0.0	Ag									
19	30.0	24.0	35.0	32.0	τ_4 YbAgSn		19.8	5.8	Yb ₂ Ag ₉									
20	60.0	24.0	62.5	36.5	Yb ₅ Sn ₃	<i>a</i> =945.0 <i>c</i> =682.5	50.0	1.0	YbAg		60.0	3.0	Yb ₃ Ag ₂					
21	8.5	25.0	19.0	31.0	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		0.0	21.0	ζ		0.5	24.5	ϵ					
22	53.0	25.0	49.0	26.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		50.0	16.0	τ_x Yb ₅₀ Ag ₃₅ Sn ₁₅		62.5	36.5	Yb ₅ Sn ₃					
23	65.0	25.0	66.0	33.5	Yb ₂ Sn		63.5	1.0	Yb ₅ Ag ₃		62.5	37.5	Yb ₅ Sn ₃					
24	24.0	27.0	35.0	32.0	τ_4 YbAgSn		24.5	25.5	τ_1 Yb ₂₅ Ag ₅₀ Sn ₂₅		0.0	17.0	ζ					
25	43.0	27.0	45.0	28.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		35.0	32.0	τ_4 YbAgSn		25.0	2.5	Yb ₂ Ag ₇					
26	18.5	27.5	34.0	32.5	τ_4 YbAgSn		19.0	31.0	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		0.5	17.5	ζ					
27	8.0	28.0	0.0	25.0	ϵ	<i>a</i> =595.6 <i>b</i> =478.2 <i>c</i> =516.6	19.0	31.0	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		24.0	74.5	YbSn ₃					
28	26.0	28.0	34.0	32.5	τ_4 YbAgSn	<i>a</i> =478.8 <i>c</i> =1086.0	24.0	25.5	τ_1 Yb ₂₅ Ag ₅₀ Sn ₂₅		0.0	17.5	ζ		see Fig. 8			
29	43.0	28.5	46.0	29.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		33.0	32.0	τ_4 YbAgSn	<i>a</i> =478.9 <i>c</i> =1085.0	23.0	0.5	Yb ₂ Ag ₇					
30	44.0	28.5	46.0	28.5	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		35.0	32.0	τ_4 YbAgSn		23.5	0.5	Yb ₂ Ag ₇					
31	43.5	29.0	46.0	30.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		33.0	34.0	τ_4 YbAgSn	<i>a</i> =478.7 <i>c</i> =1088.0								
32	45.0	29.0	46.0	27.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		35.0	32.0	τ_4 YbAgSn									
33	35.0	30.0	35.0	32.0	τ_4 YbAgSn		45.5	28.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		24.0	2.0	Yb ₂ Ag ₇					
34	50.0	30.0	46.0	28.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		62.0	37.0	Yb ₅ Sn ₃									
35	43.0	30.5	45.0	30.0	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		35.0	32.0	τ_4 YbAgSn									

Table 2. Continued

Code N°	Nominal alloy composit. (at.%) Yb Sn		Phases observed in the alloys, reported in the order of their amount Composition from EPMA (at.%) and lattice parameters (pm)												Note
			I st phase				II nd phase				III rd phase				
			Yb	Sn	unit cell		Yb	Sn	unit cell		Yb	Sn	unit cell		
36	50.0	32.0	46.0	28.5	τ_2 Yb ₅₀ Ag ₂₅ Sn ₂₅		62.0	38.0	Yb ₅ Sn ₃	$a=945$ $c=690$					
37	29.0	35.0	19.0	31.0	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		35.0	32.5	τ_4 YbAgSn	$a=479.1$ $c=1088.0$	25.0	74.0	YbSn ₃		
38	37.0	36.0	34.0	33.0	τ_4 YbAgSn	$a=479.2$ $c=1086.0$	49.5	49.0	YbSn						
39	42.5	38.5	33.5	32.5	τ_4 YbAgSn		53.0	44.0	Yb ₅ Sn ₄		48.0	46.5	YbSn		
40	48.0	38.5	35.0	33.0	τ_4 YbAgSn	$a=480.0$ $c=1088.0$	53.0	45.5	Yb ₅ Sn ₄		61.5	38.0	Yb ₅ Sn ₃		
41	15.5	44.5	19.0	31.5	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		0.0	25.0	ϵ		25.0	73.0	YbSn ₃	$a=469.0$	
42	18.5	50.0	19.0	31.0	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		0.0	25.0	ϵ		24.0	74.0	YbSn ₃		
43	25.5	50.0	34.0	33.5	τ_4 YbAgSn	$a=478.5$ $c=1088.5$	19.0	31.0	τ_3 Yb ₁₉ Ag ₅₀ Sn ₃₁		24.5	74.5	YbSn ₃		
44	40.5	51.5	38.0	62.0	Yb ₃ Sn ₅	$a=1019$ $b=817$ $c=1040$	34.0	35.0	τ_4 YbAgSn		48.0	50.0	YbSn		
45	5.5	55.0	0.0	25.0	ϵ	$a=596.1$ $b=478.2$ $c=517.0$	0.0	93.5	Sn		24.0	73.0	YbSn ₃		
46	28.0	62.0	25.5	74.5	YbSn ₃		34.0	35.0	τ_4 YbAgSn	$a=479.0$ $c=1089.2$					

^a Results obtained from selected alloys annealed at 400°C.

well-melted ingots, are fragile and easily oxidised, especially in the region close to the Sn–Yb axis where the micrographic examination was often very difficult.

The existence of the **YbAgSn** (τ_4) phase (hP9–CaLiSn), previously reported by Merlo et al. [15], has been confirmed. Other new phases having the following compositions have been identified: \sim **Yb₂₅Ag₅₀Sn₂₅** (τ_1), \sim **Yb₅₀Ag₂₅Sn₂₅** to \sim **Yb₄₆Ag₂₄Sn₃₀** (τ_2) and

\sim **Yb₁₉Ag₅₀Sn₃₁** (τ_3). Their crystal structures are still being determined. Another phase having a composition close to \sim **Yb₅₀Ag₃₅Sn₁₅** (τ_x) has been observed in some samples (see for instance alloys N. 7, 11, 22 and Fig. 3). The equilibria involving this phase, however, have not been clearly defined yet (see for instance the alloy N. 10 and Fig. 5, in the same composition range, which did not contain the τ_x phase).

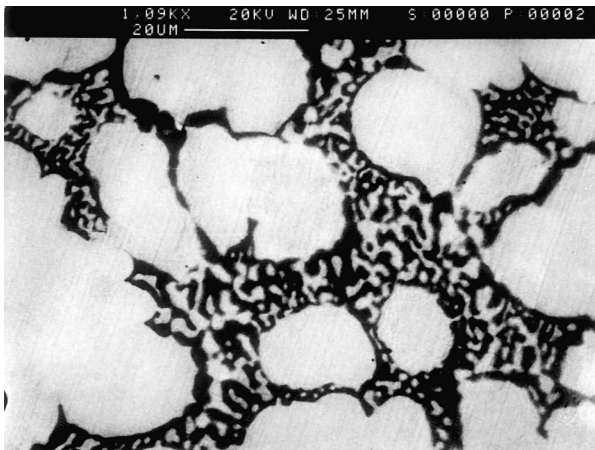


Fig. 3. Alloy N. 7: white round crystals of τ_x phase and eutectic based on YbAg (white) and YbAg₂ (black).



Fig. 4. Alloy N. 9: dendritic formation of Yb₅Sn₃ (black), Ag₂Yb₃ (grey) and Ag₃Yb₅ (light grey).

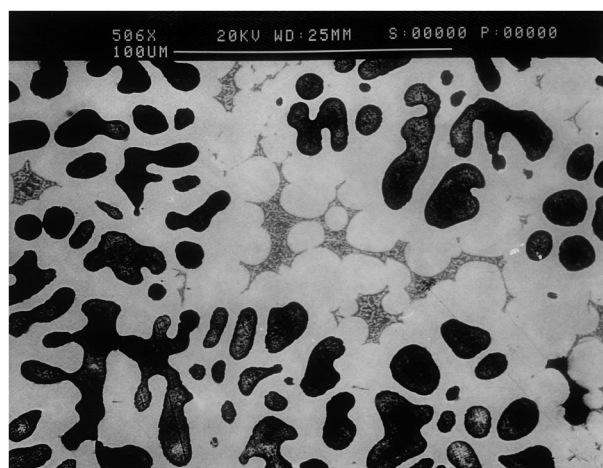


Fig. 5. Alloy N. 10: oxidised black Yb_5Sn_3 crystals, large crystals of YbAg (white) and eutectic based on YbAg and YbAg_2 (black).

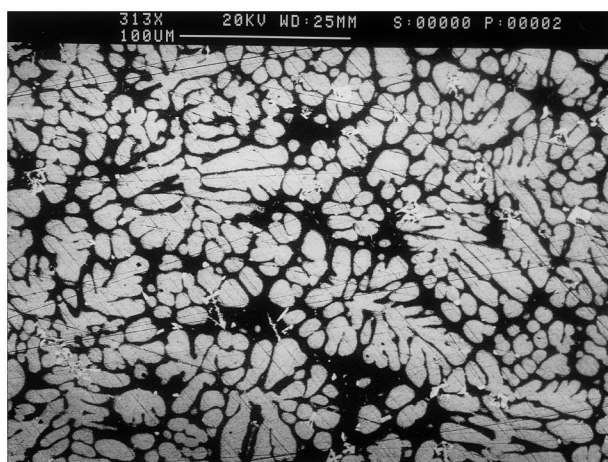


Fig. 6. Alloy N. 12: white dendritic, very soft crystals of τ_2 phase and YbAg_2 (black).

As for the τ_2 phase, it has been observed for compositions corresponding to $\sim\text{Yb}_{50}\text{Ag}_{25}\text{Sn}_2$ and to $\sim\text{Yb}_{46}\text{Ag}_{24}\text{Sn}_{30}$ which have been considered the limits of the same solid solution range. However the formation of two different phases very close to each other and corresponding to the two compositions previously given cannot be completely excluded. The dashed region in the diagram corresponds to these uncertainties.

A comparison with other similar systems is suggested in Fig. 9 even if the available isothermal sections have been obtained at different temperatures. Compared with the $\text{Yb}-\text{Cu}-\text{Sn}$ system (Fig. 9a), the system with silver is characterised by the presence of a smaller number of phases, especially in the Ag -rich region. Compared with the $\text{Ce}-\text{Ag}-\text{Sn}$ (three intermediate compounds, Fig. 9b)

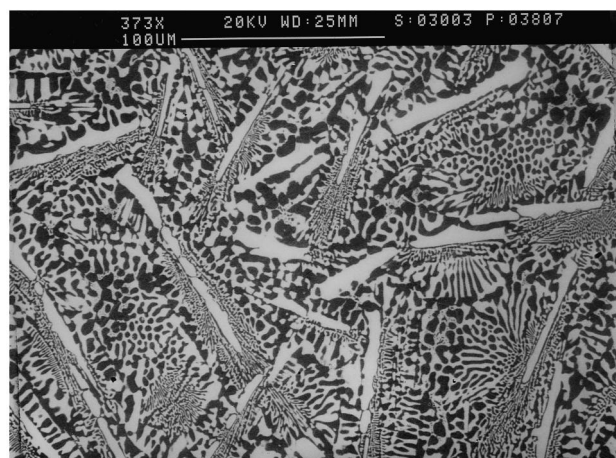


Fig. 7. Alloy N. 15: white crystals of τ_1 phase, black crystals of ζ ($\text{Ag}-\text{Sn}$) and little black crystals of Ag in the minute (smallest) structure.

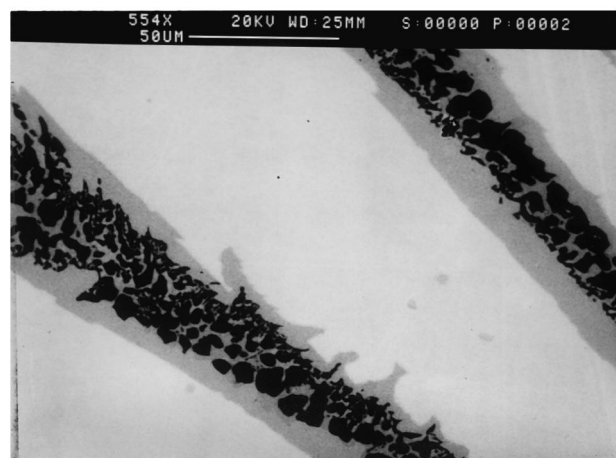


Fig. 8. Alloy N. 28: white large crystals of τ_4 phase, plus τ_1 phase (grey) together with ζ ($\text{Ag}-\text{Sn}$) (black).

and $\text{Nd}-\text{Ag}-\text{Sn}$ (two intermediate compounds, Fig. 9c) systems, the system with ytterbium presents a higher number of compounds. The RAgSn is the only phase which appears in all three systems presenting ordered variants of the CaIn_2 -type structure.

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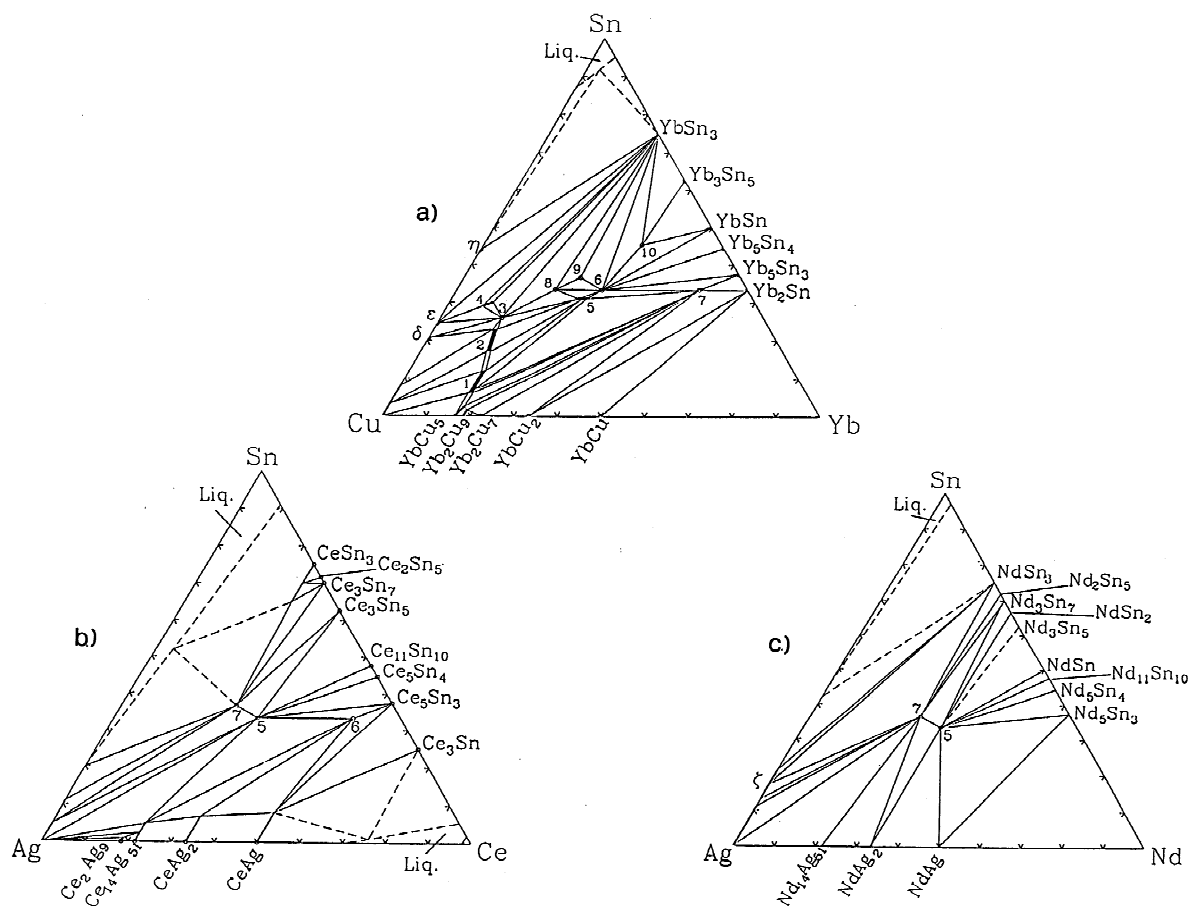


Fig. 9. Isothermal section of reference R-T-Sn systems: (a) Yb-Cu-Sn at 400°C [14], (b) Ce-Ag-Sn at 750°C [15], (c) Nd-Ag-Sn at 600°C [25].

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