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AND APPLYING THE JUSTIFICATION ISOTHERMAL SYSTEM

IN TEACHING CHEMISTRY

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ABSTRACT

For the complete definition of the properties of the ternary Bi–Cu–In system,there were performed the investigation of micro structures, hardness by Brinel alloys. In the range of this ternary system, numerous alloys were tested for three vertical sections, with molar ratio Sb: Cu= 1, Cu:In= 1, Sb:In=.1. By application of CALPHAD method, and software package PANDAT 8.1, there were calculated the isothermal cross section at 25^{0}C and 400^{0}C.

Keywords: *Bi–Cu–In ternary system, microstructure, hardness, isothermal sections.*

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INTRODUCTION

The relation between Cu and In in the couples and stable contacts are the main reasons for these systems investigations [1].Thermodynamic data for the constitutive binary systems included in COST531 thermodynamic database [2] and CALPHAD method [3], enabled calculation of isothermal section at 25^0C.

Thermodynamic data for binary Cu–In system were presented by *X. J. Liu et al.* [4], for the constitutive binary Cu–Sb system by *X. J. Liu et al.* [5] and for binary Sb–In system the thermodynamic data were taken from *I.Ansare*et al. [6]. *D. Manasijevicet al.* [7] has presented comparative quasi-binary sections, where thetemperatures of phase transformations determined by (DTA) and calculated values were compared. *S. Itabashi* et al. [8] determined activity of indium in ternary Cu–In-Sb system by EMF method using a Zirconia electrolyte.

EXPERIMENT

The alloy samples were prepared from high -purity (99.999%) indium, antimony and copper produced by Alfa Aesar (Germany). The samples mass weight of 4 g were prepared in inductive furnace in Argon atmosphere and cooled on air. The samples used for optic microscopy and hardness testswere prepared by classic metallographic procedure without penetration. Electron microscopy was done on Scanning Electron Microscopy instrument from JEOL (JSM6460), with Energy Dispersive Spectrometer, EDS by Oxford Instruments.

Optic microscopy was done using Optic microscope OLYMPUS GX41, hardness was measured by Duroscope method using HL-400DL instrument.

RESULTS AND DISCUSSION

Phase names used in this paper with phase names included in thermodynamic data base COST531 [2] with their Pearson's symbols [9] are listed in Table 1.Table 1. Considered phases, phase's name in the thermodynamic data base and Pearson's symbols [2, 9].

Considered phase	Phase's name in data base	Pearson's symbol
L	LIQUID	-
α(Fcc)	FCC_A1	*cF4*
β(Bcc)	BCC_A2	*cI2*
γ(CuIn)	CUIN_GAMMA	*cP52*
δ (Cu_7In_3)	CUIN_DELTA	*aP40*
η′	CUIN_ETA	*hP4*
η	CUIN_ETAP	*hP6*
$Cu_{11}In_9$	CUIN_THETA	*mC20*
(In)	TETRAGONAL_A6	*tI2*
ξζ($Cu_{10}Sb_3$)	CUSB_ZETA	*hP26*
γ($Cu_{17}Sb_3$)	CUSB_GAMMA	*hP2*
η(Cu_2Sb)	CUSB_ETA	*tP6*
ε(Cu_3Sb)	CUSB_EPSILON	*oP8*
δ(Cu_4Sb)	CUSB_DELTA	*hP?*
(Sb)	RHOMBO_A7	*hR2*
InSb	ZINCBLENDE_B3	*cF8*

Itabashi at al. [8] determined the activities of Indium for three vertical sections (In-$Cu_{0.2}Sb_{0.8}$, In-$Cu_{0.5}Sb_{0.5}$and In-$Cu_{0.8}Sb_{0.2}$) at 1200K.

Microstructure analysis

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In order to determine microstructure of the alloys of the ternary Cu-In- Sb system, the microstructures for numerous alloys were determined, nine to be precise, and the compositions of the considered alloys were given with quasi binary section at 25^0C on Figure 1.

The obtained microstructures were presented on Figure 1.
By observing microstructures showed on Figure 1 it can be seen that all of them are very similar, and the presence of all three phases in microstructures can be confirmed. The basic of the microstructure is gray phase, than purple phase and light i.e. white phase, in most of the cases the least present in the microstructure.

The calculated isothermal section at 25^0C, presented on Figure 2, showed three large regions and four smaller regions. All seven regions have three phases each, every region is three-phase region. This corresponds to the presented microstructures of the alloys.

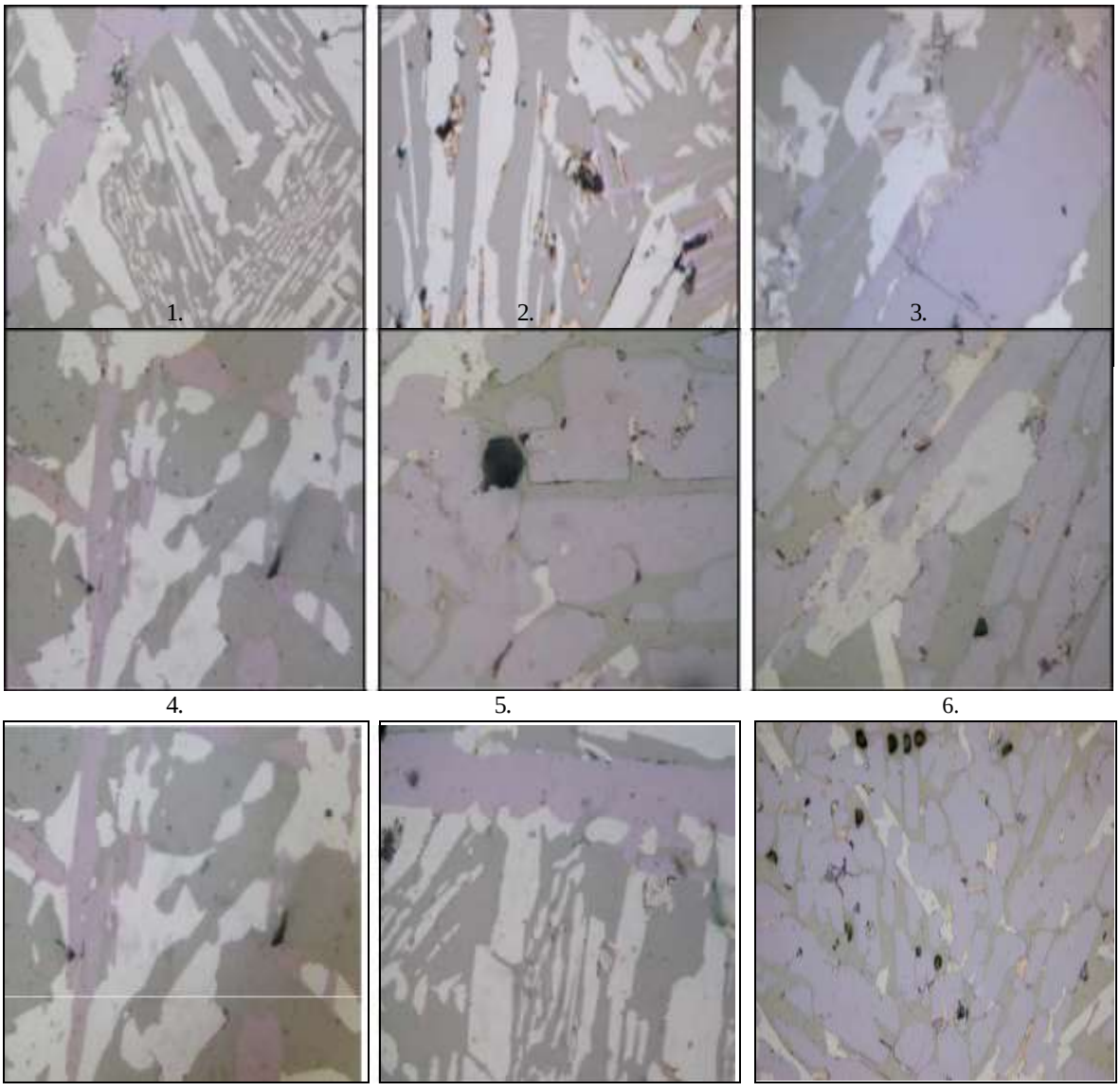

Fig. 1. Microstructures of alloys of Cu-In-Sb ternary system800X.

Mechanical properties-*hardness*

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The hardness of alloys in three vertical sections: Sb–InCu, In–SbCu i Cu–InSb were investigated. The compositions of the considered alloys and experimentally determined hardness were showed in Table 2.

Table 2.Alloys compositions and hardness by Brinel.

x(Sb)	HB(MN/m^2)	x(In)	HB (MN/m^2)	x(Cu)	HB (MN/m^2)
Sb–CuIn		In–CuSb		Cu–InSb	
0	243	0	150	0	170
0.2	223.7	0.2	135	0.2	303.3
0.4	220	0.4	126	0.4	305
0.6	218	0.5	143.3	0.5	295
0.7	215	0.6	166.7	0.6	376.7
0.8	204.7	0.8	138	0.8	475
1	294	1	8.83	1	874

The mathematic model presented by equation (1) for alloy's hardness by Brinel in the ternary Cu–In-Sb system could be written:

$$HB(MN/m^2) = 282.5354*x(Sb)+13.6987*x(In)+834.7551*x(Cu)+418.4058*x(Sb)*x(In)-1473.1515*x(Sb)*x(Cu)-536.8279*x(In)*x(Cu) \quad (1)$$

For quasi-linear model of multiplied regression, given by equation , the quadrates of discrepancies of empiric points from regression equation were calculated, and the sum of discrepancies quadrates was SK= 46723.42994. As absolute value of the largest discrepancy was ε_{max}= 94.54563 less than 3*E= 138.2538623 so based on three sigma rule, the assumed functional dependence was considered good.

Isothermal section at 400^{0}C

Calculated isothermal section at 400^{0}C was compared to two experimentally investigated samples or two alloys. The samples compositions were given in Table 3, also calculated three-phase region was determined by experiment and by using SEM-EDS.

Table 3. Calculated and experimentally determined phase compositions in the ternary Cu–In–Sb system at 400^{0}C.

Sample	Sample composition [at. %]	Calculated phases	Experimentally determined phases	Experimentally determined phase composition [at. %]		
				Cu	In	Sb
1.	80 Sb	CUSB_ETA	CUSB_ETA	64.78	1.1	34.22
	10 Cu	RHOMBO_A7	RHOMBO_A7	1.08	0.47	98.53
	10 In	ZINCBLENDE_B3	ZINCBLENDE_B3	1.52	47.75	50.73
2.	60 Sb	CUSB_ETA	CUSB_ETA	61.91	1.99	36.1
	20 Cu	RHOMBO_A7	RHOMBO_A7	1.92	1.75	96.33
	20 In	ZINCBLENDE_B3	ZINCBLENDE_B3	0.49	48.61	50.9

CONCLUSION

Microstructures of the considered alloys and calculated isothermal section at 25^{0}C showed presence of three phases. Those three phases are present in all microstructures, just the amount of the single phase is changed. The calculated section showed presence of seven three-phase regions, three of them were large, and four of them were smaller regions, the sudden raise of hardness was determined. Calculated and experimenatlly determined values for isothermal section at 400^{0}C showed good agreement.Based on these findings, we can conclude that the study of this field is necessary in chemistry teaching, to achieve better results in a given area.

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