Beryllium – Copper – Silicon

Nathalie Lebrun

Introduction

Only a few data are available concerning the ternary system Be-Cu-Si. Experimental details are reported in Table 1.
Two ternary compounds have been reported [1967Hof, 1967Sta]. Only solubility data are available in the literature. [1938Zak1, 1939Pog, 1939Zak, 1940Vel] reported results of the investigations on joint solubility of Be and Si in solid (Cu) at temperatures 350-800°C. The data of separate works agreed with each other enough well. [1977Mye] investigated ion implantation of Cu and Si together in Be and behavior of Cu and Si atoms in solid (Be) then during annealing at 400°C using the ion backscattering analysis. Conclusion about influence of Si on Cu solubility in solid (Be) was made. [1938Zak2] studied the solubility of Be in Cu_5Si and of Si in BeCu along the supposed quasibinary section Cu_5Si-CuBe. In this experimental work, solid state investigations are only available. Since no further complete experimental work had been done, it cannot be concluded in the present assessment that the section Cu_5Bi-CuBe is really quasibinary.
[1979Cha, 1979Dri] undertook a short review of the system Be-Cu-Si.

Binary Systems

The binary systems Cu-Si and Be-Cu are accepted from the MSIT Binary Evaluation Program: Cu-Si from [2002Leb], Be-Cu from [2006Wat]. The Be-Si phase diagrams is taken from [Mas2].

Solid Phases

All the crystallographic data for the unary, binary and ternary phases are reported in Table 2.
Two ternary compounds have been observed. [1967Hof] detected a ternary compound $Cu_{50}Be_{25}Si_{25}$ with a γ brass structure. [1967Sta] found a ternary Laves phase with a Cu_2Mg type structure with a composition of $CuBe_2Si$. The solubility of Be in Cu_5Si is established to be about 1 mass% at 800°C and that of Si in CuBe is less than 0.5 mass% at the same temperature along the section Cu_5Si-CuBe [1938Zak2].

Liquidus, Solidus and Solvus Surfaces

Figure 1 shows the solubility of Be and Si in (Cu) at 350 and 800°C taken from [1938Zak1] with slight modifications in accordance with the accepted binary systems. The solubility of Cu in solid (Be) decreases significantly in presence of Si amounting 2.82 at.% Cu at 400°C for at.% Si : at.% Cu = 1.6 [1977Mye].

Notes on Materials Properties and Applications

Only hardness measurements are found in the literature on cast and annealed alloys [1938Zak1, 1939Pog, 1939Zak], see Table 3. Agreement is observed. Increase of the Si content in the Be-Cu-Si alloys leads to an increase of their hardness which also strongly depends on the annealing and cooling processes [1938Zak1].

References

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Table 1: Investigations of the Be-Cu-Si Phase Relations, Structures and Thermodynamics

Reference	Method/Experimental Technique	Temperature/Composition/Phase Range Studied
[1938Zak1]	Microstructure, X-ray diffraction, Hardness	350 - 800°C / Cu rich alloys with 0.25-1.75 mass% Be and 0.5 to 5.75 mass% Si
[1938Zak2]	Microstructure, X-ray diffraction	87.9 to 90.3 mass% Cu; 0.5 to 8.8 mass% Si; 0.7 to 11.5 mass% Be
[1939Pog]	Microstructure, Hardness, Tensile properties	270 to 350°C / Cu rich alloys with 0 to 0.5 mass% Si and 1.9 to 2.5 mass% Si
[1939Zak]	Microstructure, Hardness	300, 350 and 800°C / Cu rich alloys with up to 1 mass% Be and 4 mass% Si
[1940Vel]	Hardness	400 and 800°C / Cu rich alloys with up to 2 mass% Be and 6 mass% Si
[1967Hof]	X-ray diffraction	$Cu_{50}Be_{25}Si_{25}$

Reference	Method/Experimental Technique	Temperature/Composition/Phase Range Studied
[1967Sta]	X-ray diffraction	$CuBe_2Si$
[1977Mye]	Ion implantation and ion backscattering	320 - 750°C / Be-Cu-Si

Table 2: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(βBe) 1289 - 1270	*cI*2 $Im\bar{3}m$ W	a = 255.15	HT, dissolves 17 at.% Cu at 1199°C [Mas2, 1994Cha]
(αBe) ≲ 1275	*hP*2 $P6_3/mmc$ Mg	a = 228.59 c = 358.45	LT, at 25°C [Mas2] dissolves 9.5 at.% Cu at 1109°C [1994Cha]
(Cu) < 1084.62	*cF*4 $Fm\bar{3}m$ Cu	 a = 361.46 a = 360.82	[Mas2] at x = 0 [Mas2] at x = 0 [V-C2]
(Si) < 1414	*cF*8 $Fd\bar{3}m$ C-diamond	a = 543.06	0 to 0.003 at.% Cu [2002Leb]
β, Cu_3Be < 900	*cI*2 $Im\bar{3}m$ W	a = 281.0	24.5 to 43.5 at.% Be at 850°C [1994Cha]
γ, CuBe < 933	*cP*2 $Pm\bar{3}m$ CsCl	a = 270.2 ± 0.3	46.2 to 49 at.% Be [1994Cha, V-C2]
δ, $Cu_{1-x}Be_{2+x}$ < 1219	*cF*24 $Fd\bar{3}m$ Cu_2Mg	 a = 589.9	x varies from 0.071 at 930°C to 0.455 at 1090°C at 75 at.% Be [1994Cha]
κ, Cu_7Si 842 - 552	*hP*2 $P6_3/mmc$ Mg	 a = 256.06 c = 418.46	11.05 to 14.5 at.% Si at 12.75 at.% Si [2002Leb]
β, ~Cu_6Si 853 - 787	*cI*2 $Im\bar{3}m$ W	 a = 285.4	14.2 to 16.2 at.% Si at 14.9 at.% Si [2002Leb]
δ, Cu_5Si(h) 824 - 711	*t***	a = 881.5 c = 790.3	17.6 to 19.6 at.% Si Sample was annealed at 700°C [2002Leb]
γ, Cu_5Si(r) < 729	*cP*20 $P4_132$ βMn	a = 619.8	17.15 to 17.6 at.% Si [2002Leb]
ε, $Cu_{15}Si_4$ < 800	*c*I76 $I\bar{4}3d$ $Cu_{15}Si_4$	a = 961.5	21.2 at.% Si [2002Leb]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
η, Cu_3Si(h2) 859 - 558	*hR** $R\bar{3}m$ or *t***	*a* = 247 α = 109.74° *a* = 726.7 *c* = 789.2	23.4 to 24.9 at.% Si [2002Leb] [V-C2]
η', Cu_3Si(h1) 620 - 647	*hR** $R\bar{3}$	*a* = 472 α = 95.72°	23.2 to 25.2 at.% Si [2002Leb]
η'', Cu_3Si(r) < 570	*o***	*a* = 7676 *b* = 700 *c* = 2194	23.3 to 24.9 at.% Si [2002Leb]
* $CuBe_2Si$	*c** Cu_2Mg	*a* = 605	Be_2(Cu,Si) Laves phase [1967Sta]
* $Cu_{50}Be_{25}Si_{25}$	*c**	*a* = 829	γ brass structure [1967Hof]

Table 3: Investigations of the Be-Cu-Si Materials Properties

Reference	Method/Experimental Technique	Type of Property
[1938Zak1]	Hardness measurements	Mechanical properties
[1939Pog]	Hardness measurements, Tensile properties	Mechanical properties
[1939Zak]	Hardness measurements	Mechanical properties
[1940Vel]	Hardness measurements	Mechanical properties

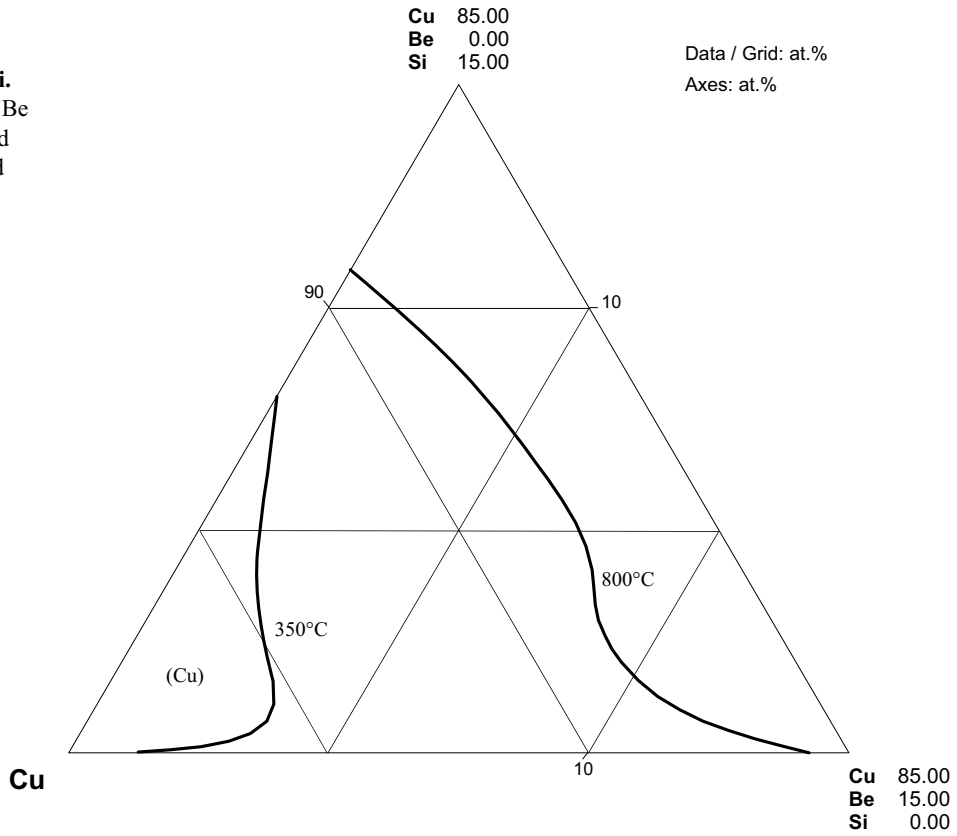

Fig. 1: Be-Cu-Si. Solubility range of Be and Si in (Cu) solid solution at 350 and 800°C