Copper – Magnesium – Zirconium

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Introduction

[1959Ich] studied the solubility of zirconium in molten magnesium at 700°C with copper additions up to about 0.4 at.%. According to [1959Ich] copper diminishes the zirconium solubility in molten magnesium. Moreover [1959Ich] determined the phases formed in the Mg rich alloys with copper and zirconium after solidification by X-ray analysis and metallography. [1968Bab] studied the solubility of zirconium in molten magnesium between 780 and 800°C with copper additions up to 0.6 at.%. According to [1968Bab] copper does not change the zirconium solubility in molten magnesium in contradiction to [1959Ich]. [1982Kuz] constructed the vertical section of the phase diagram using differential thermal analysis, X-ray phase analysis, and metallography.

[1991Soa] studied liquid-solid equilibria in the Cu rich part of the Cu-Mg-Zr system by diffusion couple experiments and electron microprobe analysis (SEM). Pure copper crucibles where used containing Mg and Zr. An annealing treatment at 787°C followed by rapid quenching in water has been applied before analyzing the revealed phase structure and composition.

Binary Systems

The three binary systems Cu-Mg [2002Iva], Cu-Zr [2006Sem], and Mg-Zr [Mas2] are used as boundary systems.

Solid Phases

No ternary compounds have been found. All the binary solid phases are listed in Table 1, together with the small mutual solubilities of each metal. They may be used to estimate the expected small homogeneity areas of each metal in the ternary system.

Isothermal Sections

Figure 1 shows the influence of copper on the solubility of zirconium in molten magnesium at 700°C after [1959Ich] slightly adjusted to the Mg-Zr binary [Mas2]. It may be considered as a part of the isothermal section of the phase diagram at 700°C. In view of the more detailed experimental description, the results of [1959Ich] are preferred with respect to those of [1968Bab]. In the solid state, according to X-ray investigations [1959Ich], (Zr), Zr_2Cu, and $CuMg_2$ are in equilibrium with the (Mg) phase. The results of [1991Soa] in the Cu rich corner revealed at 787°C a three-phase-equilibrium between Cu, liquid and probably Zr_2Cu_9 (named $ZrCu_4$ by [1991Soa]). The composition of the liquid phase was determined to be 87.0 at.% Cu, 13.0 at.% Mg (Zr was not detectable), the composition of the needle shaped Zr_2Cu_9 as 82.3 at.% Cu, 17.7 at.% Zr (Mg was not detectable) and the composition of the Cu based solid solution as 95.9 at.% Cu, 4.1 at.% Mg.

Temperature – Composition Sections

Figure 2 displays the vertical section of the ternary phase diagram at constant Mg concentration of 1 at.% constructed by [1982Kuz]. The stoichiometry of the phase "Zr_2Cu_7" proposed by [1982Kuz] has been changed to $Zr_{14}Cu_{51}$ given by [1990Ari, 2006Sem] in the accepted Cu-Zr binary phase diagram.

References

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Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(Cu) < 1084.62	*cF*4 $Fm\overline{3}m$ Cu	*a* = 361.46	at 25°C [Mas2]
(Mg) < 650	*hP*2 $P6_3/mmc$ Mg	*a* = 320.94 *c* = 521.07	at 25°C [Mas2]
(βZr) 1855 - 863	*cI*2 $Im\overline{3}m$ W	 *a* = 356.8	dissolves up to 5.7 at.% Cu [2006Sem] pure βZr [V-C2]
(αZr) < 863	*hP*2 $P6_3/mmc$ Mg	 *a* = 323.2 *c* = 514.7	dissolves up to ~0.2 at.% Cu [2006Sem] pure αZr at 25°C [V-C2]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
$CuMg_2$ < 568	*oF*48 *Fddd* $CuMg_2$	*a* = 907 *b* = 528.4 *c* = 1825 *a* = 905 *b* = 528.3 *c* = 1824.7 *a* = 904.4 ± 0.1 *b* = 527.5 ± 0.1 *c* = 1832.8 ± 0.2	[2002Iva]
Cu_2Mg < 797	*cF*24 $Fd\bar{3}m$ Cu_2Mg	*a* = 702.1	64.7 to 69 at.% Cu [2002Iva]
$ZrCu_5$ < 1032	*cF*24 $F\bar{4}3m$ $AuBe_5$ or *t*** Zr_2Cu_9	*a* = 687.0	[2006Sem] long period superstructure derived from $AuBe_5$ type
$Zr_{14}Cu_{51}$ ≤ 1112	*hP*68 *P*6/*m* $Gd_{14}Ag_{51}$	*a* = 1124.44 *c* = 828.15	[2006Sem]
Zr_3Cu_8 ≤ 1028	*oP*44 *Pnma* Hf_3Cu_8	*a* = 786.93 *b* = 851.47 *c* = 646.0	[2006Sem]
$Zr_{24}Cu_{13}$ 960 - 915	*o**37	*a* = 1119.0 *b* = 791.2 *c* = 998.48	[2006Sem]
Zr_7Cu_{10} < 935	*oC*68 *C*2*ca* Zr_7Ni_{10}	*a* = 1267.29 *b* = 931.63 *c* = 934.66	[2006Sem]
ZrCu(h) 960 - 725	*cP*2 $Pm\bar{3}m$ CsCl	*a* = 326.6	at 49.9 at.% and 25°C [2006Sem]
ZrCu(l) < 140	*mP*4 $P2_1/m$ TiNi *mC*16 *Cm*	*a* = 328.2 *b* = 414.8 *c* = 524.9 β = 103.7° *a* = 633.7 *b* = 856.3 *c* = 534.5 β = 105.6°	martensite, [2000Kov] martensite, [2000Kov]
Zr_2Cu(h) 1025 - 950	*tI*6 *I*4/*mmm* $MoSi_2$	*a* = 322.04 *c* = 1183.2	[2006Sem]
Zr_2Cu(r) < 950	*tP*150	*a* = 1592.4 *c* = 1132.8	[2006Sem]

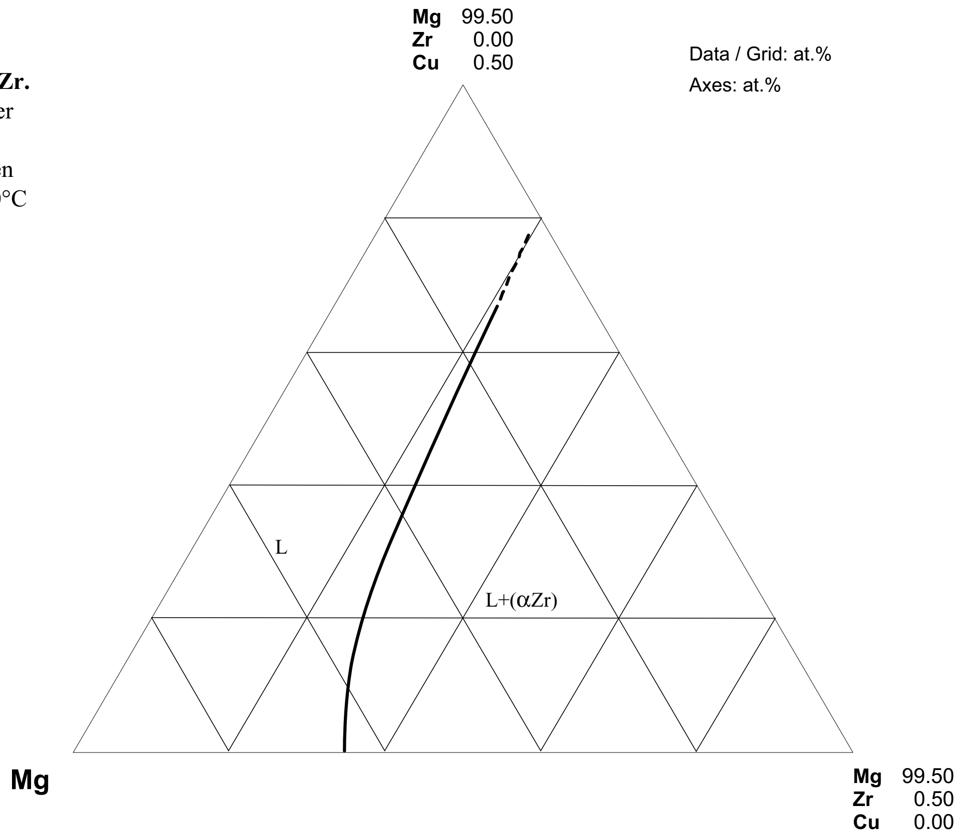

Fig. 1: Cu-Mg-Zr. Influence of copper on the zirconium solubility in molten magnesium at 700°C

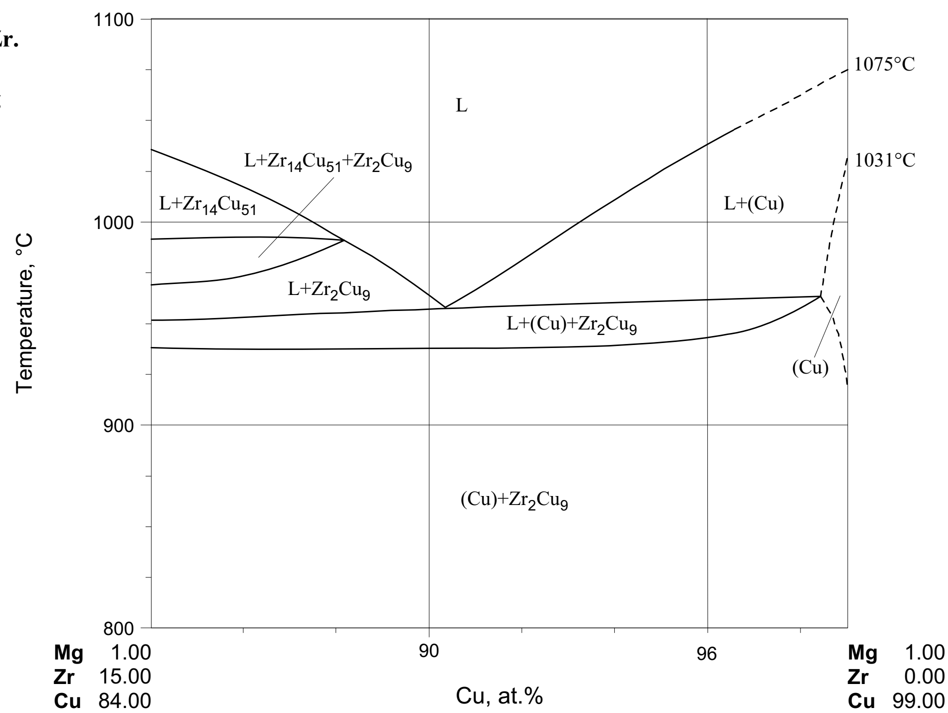

Fig. 2: Cu-Mg-Zr. Vertical section at constant 1 at.% Mg