

## Ag – Cu (Silver – Copper)

### Phase diagram

A thorough discussion of phase equilibria and thermodynamic functions is done by Subramanian et al. [93 Sub]. The assessed phase diagram is the same as that shown in [Landolt-Börnstein]. Only an enlarged version of the assessed Ag-rich (Fig. 1) and the Cu-rich part (Fig. 2) of the phase diagram should be given here (taken from [93 Sub]).

The phase equilibria are dependent on pressure. In Fig. 3 the phase diagram at atmospheric pressure is compared with that at  $10^9$  Pa [67 LeI].

### Metastable phases

By rapid quenching from the melt and due to reactions in the solid supersaturated alloys metastable phases can be obtained. A collection of such phases, published by [93 Sub], is shown in Table 1.

**Table 1.** Metastable Ag-Cu alloys [93 Sub].

Phase	Composition [at% Cu]	Description	Reference
$\gamma'$	14.1 ... 95	Solid solution with ~ 1% deviation from Vegard's rule	[60 Duw], [66 Lin]
$\gamma''$	14.1 ... 95	Solid solution with ~ 3% deviation from Vegard's rule	[69 Sto]
$\alpha'$	14.1 ... 75	Nonequilibrium solid solution of Cu in Ag. Can develop as a discontinuous reaction product with $\beta'$ .	[67 Sto]
$\beta'$	30 ... 90	Metastable solid solution of Ag in Cu; discontinuous product developing with $\alpha'$ .	[77 Bos]
$\beta''$	~ 50	Cu-rich solid solution; develops with $\gamma''$	[77 Bos]
$\delta$	-	Hexagonal solid solution; exact structure and composition uncertain	[67 Sto], [69 Sto]
Tetragonal	-	$a = 0.415$ nm $c = 1.167$ nm Develops from $\gamma'$ by a precipitation reaction; exact structure and composition uncertain	[57 Pin]



### Crystal structure

Lattice parameters of Ag-Cu metastable alloys (schematic) [93 Sub] are given in Fig. 4.

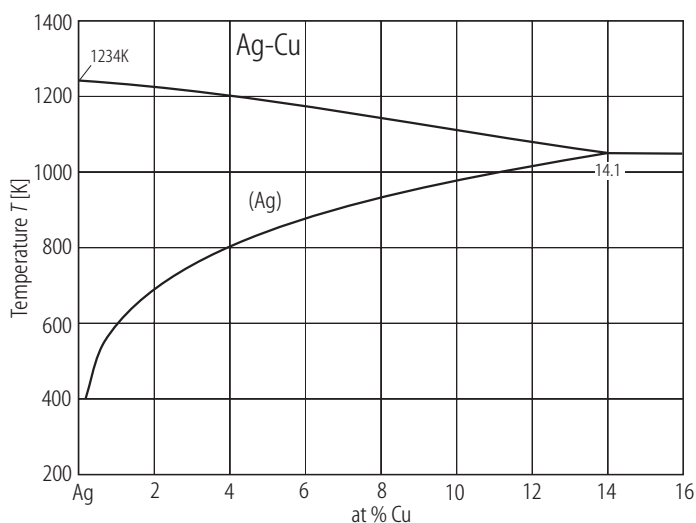
### Thermodynamics

Using a new in-situ mixing technique, Fitzner et al. [99 Fit] have determined enthalpies of mixing at 1375 K. The results are given in Fig. 5.

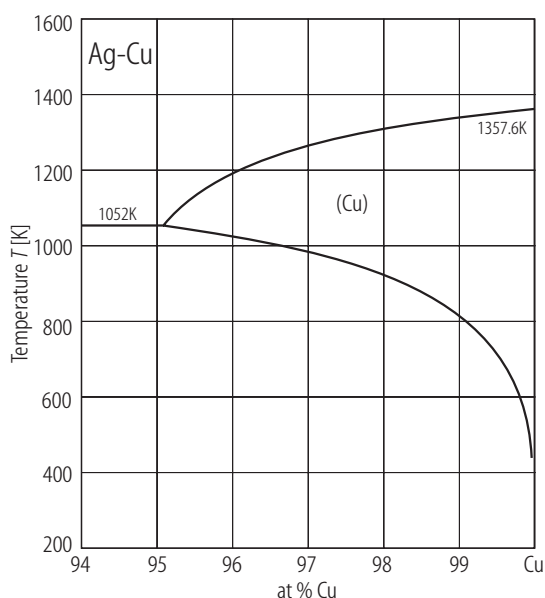
The maximal  $\Delta H^L$  is somewhat lower than recommended by [Hultgren].

Thermodynamic activities of Cu in silver-rich solid solution have been determined by Bienzle et al. [92 Bie]. There has been used the EMF method with zirconia as a solid electrolyte. The obtained  $a_{\text{Cu}}^S$  values are shown as a function of concentration for temperatures between 950 K and 1150 K in Fig. 6.

### Figures

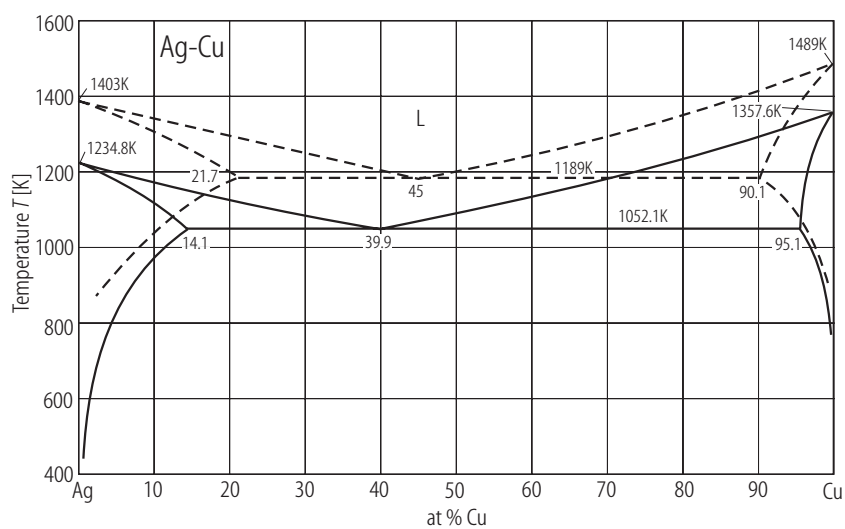


**Fig. 1. Ag-Cu.** Enlarged Ag-rich part of the phase diagram Ag-Cu [93 Sub].

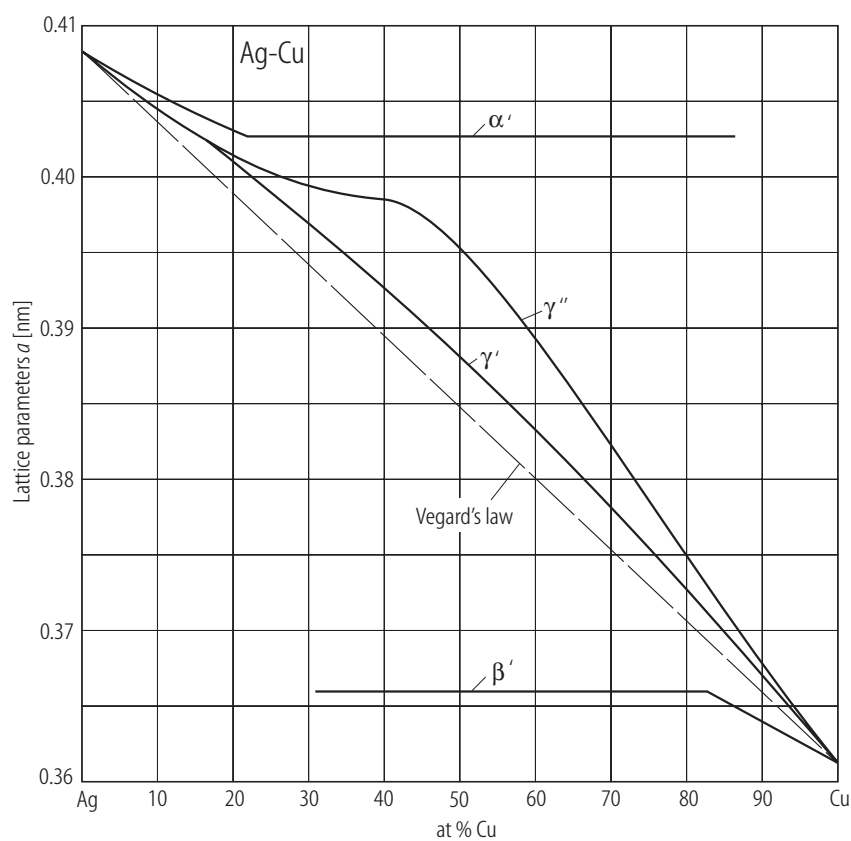


**Fig. 2. Ag-Cu.** Enlarged Cu-rich part of the phase diagram Ag-Cu [93 Sub].



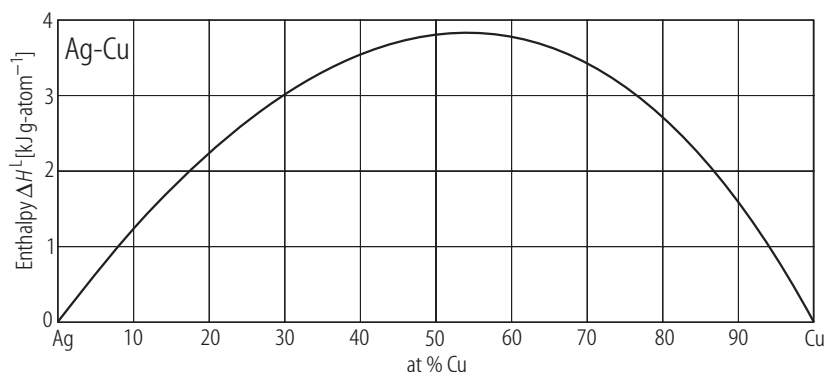


**Fig. 3. Ag-Cu.** Phase diagram Ag-Cu at atmospheric pressure [93 Sub] and at  $10^9$  Pa [67 LeI], respectively.

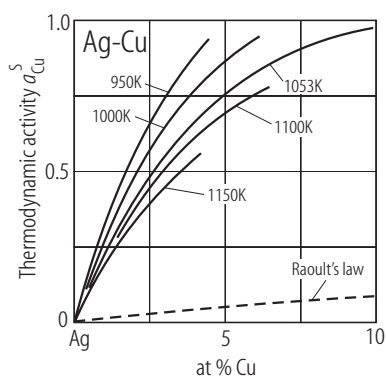


**Fig. 4. Ag-Cu.** Lattice parameters of stable and metastable solid Ag-Cu alloys [93 Sub].





**Fig. 5. Ag-Cu.** Enthalpies of mixing of liquid alloys determined by Fitzner et al. [99 Fit] at 1375 K.



**Fig. 6. Ag-Cu.** Thermodynamic activities of Cu in silver-rich Ag-Cu solid solutions determined using the EMF method [92 Bie].

## References

- [57 Pin] Pinsker, Z.G., Skobel'tsyna, N.A.: Sov. Phys. Crystallogr. **2** (1957) 610
- [60 Duw] Duwez, P., Willens, R.H., Klement, W., Jr.: Appl. Phys. **31** (1960) 1136
- [66 Lin] Linde, R.K.: Appl. Phys. **37** (1966) 934
- [67 Lel] Leloup, G.: Cuivre-Laitons-Alliages **96** (1967) 21
- [67 Sto] Stoering, R., Conrad, H.: Final report F-C1869, The Franklin Institute Research Laboratories, Philadelphia, PA, 1-73 (1967)
- [69 Sto] Stoering, R., Conrad, H.: Acta Metallogr. **17** (1969) 933
- [77 Bos] Boswell, P.G., Chadwick, G.A.: J. Mater. Sci. **12** (1977) 1879
- [92 Bie] Bienzle, M., Oishi, T., Sommer, F., Ono, K.: Trans. Jap. Inst. Metals **33** (1972) 51
- [93 Sub] Subramanian, P.R., Perepezko, J.H.: J. Phase Equilibria **14** (1993) 62
- [99 Fit] Fitzner, K., Guo, O., Wang, J., Kleppa, O.J.: J. Alloys and Comp. **291** (1999) 190
- [Hultgren] Hultgren, R., Desai, P.D., Hawkins, D.T., Gleiser, M., Kelley, K.K.: "Selected Values of the Thermodynamic Properties of Binary Alloys", American Society for Metals, Metals Park, Ohio (1973)
- [Landolt-Börnstein] New Series, Group IV, Vol. 5, Subvolume a to j, Predel, B., Madelung, O. (ed.), Springer-Verlag (1991) to (1998)