# Silver – Aluminium – Magnesium

*Qingsheng Ran, updated by Ibrahim Ansara†, K.C. Hari Kumar, Patric Wollants and Yong Du*

## Literature Data

The Al-AgMg section of the system was studied by [1933Ota] using thermal analysis, metallography and electrical resistance measurements on twenty alloys. The materials used were of 99.9 (Ag), 99.8 (Al) and 99.8 (Mg) mass% purity. [1933Ota] proposed the section to be a pseudobinary system, which was also mentioned by [1959Zam] and [1961Fri]. [1957Kus], however, disputed this on the basis of X-ray diffraction studies of the precipitates occurring in a Al-1.98 mole% AgMg and a Al-2.22 mole% AgMg alloy.
The Mg-rich corner was investigated by thermal and metallographic analysis ([1938Nis], 37 alloys; [1939Hau], 69 alloys; [1939Saw], 54 alloys; [1945Kus1], 52 alloys and [1945Kus2], 15 alloys) and X-ray diffraction [1945Kus1, 1945Kus2]. All the authors used metals with a purity better than 99.8 mass%.
The Al-rich corner was studied by metallography ([1959Zam], 38 alloys; [1961Fri], 38 alloys and [1969Ito], 10 alloys), thermal analysis (DTA) [1961Fri, 1969Ito], X-ray diffraction ([1972Wil], 22 alloys), microhardness [1961Fri] and electrical resistivity measurements [1969Ito]. The Al had a purity of 99.98 mass% or better. [1986Cou] studied the stable and metastable precipitates of three alloys in the Al-rich corner at 120, 183 and 235°C, and determined the precipitated phases and their structures using X-ray diffraction.
Alloys containing 99.99% pure Al and Ag and > 99.8% Mg were examined by [1986Sch]. The 400, 300 and 200°C sections in the Mg-rich corner were investigated based on ten samples. The equilibrium composition of the phases in two- and three-phase equilibria was determined by electron beam microanalysis and metallography.
The agreement between different experiments for the Mg-rich and the Al-rich corner is generally good, except for the concentrations of the liquid and the Mg solid solution at the invariant equilibrium. Values from [1939Saw] strongly differ from the other reported values. [1956Gla] reported the mutual solubilities of AgMg and $Ag_3Al$ based on X-ray and microstructural investigation, without details of the experimental procedures. [1933Ota] mentioned the existence of the ternary compound AgMgAl and its equilibria with other phases. [1957Kus] determined its structure. Another ternary compound T, with a composition near 8.92 Ag - 52.87 Al - 38.21 Mg at.%, was proposed by [1965Whe]. Using TEM, he found this phase to be body-centered cubic. This phase was confirmed at a slightly different composition by [1966Aul] using X-ray diffraction. Both ternary phases, AgMgAl and T, were confirmed by XRD [1972Wil, 1986Cou].
A metastable phase (T') with the same composition as T was detected by [1976Aul] and confirmed by [1986Cou] by means of X-ray precession camera photographs. The unit cell was determined.
The present evaluation was published in the MSIT Evaluation Program earlier and reflects today's state of knowledge.

## Binary Systems

The binary Ag-Al system from [Mas2], the Ag-Mg system from [Mas2] and the Al-Mg system from [1998Lia] are accepted.

## Solid Phases

The structure of phase T was suggested by [1966Aul] to be the same as that of $Mg_{32}(Al,Zn)_{49}$ [1957Ber] with the composition of $(Ag,Al)_{49}Mg_{32}$, Ag:Al = 1:6. The solid elements, the ternary compounds and the phases appearing in the phase diagrams presented are listed in Table 1.

### Pseudobinary Sections

[1933Ota] reported the pseudobinary section Al-AgMg with the ternary compound AgMgAl and two invariant equilibria. [1959Zam] and [1961Fri] mentioned this and measured the solubility limit of AgMgAl in Al and the temperature at which this limit was achieved. The temperature agrees well with that reported by [1933Ota]. However, the measured solubility was 1.98 and 2.62 mole% AgMg, whereas that determined by [1933Ota] was 3.37 mole%. [1957Kus] reported that X-ray diffraction lines of a second precipitate appeared in some of their Al+2.22 mole% AgMg samples, in addition to the lines of AgMg which were always present. Therefore they disagreed that this section was a pseudobinary one. The conclusion of [1957Kus] is quite doubtful, since AgAlMg is a stable phase, and a Al - 1.98 mole% AgMg sample of [1957Kus] did not show diffraction lines of this phase. [1972Wil] also suggested that the section Al-AgMg should not be pseudobinary at 200 °C. The pseudobinary section based on [1933Ota] is presented in Fig. 1.

### Invariant Equilibria

A ternary eutectic was reported between 403 and 405°C [1938Nis, 1939Hau, 1939Saw, 1945Kus1, 1945Kus2]. Concerning the liquid concentrations, four authors agree fairly well in the amounts of Ag and Mg whereas [1939Saw] gave the values with ≈7.6 at.% Ag and ≈13.5 at.% Mg. Other reported invariant equilibria are the peritectic and eutectic in the pseudobinary system Al-AgMg. The invariant equilibria are listed in Table 2.

### Liquidus Surface

[1939Hau] proposed a liquidus surface of the partial system with more than 50 mass% Mg. The contributions of [1938Nis, 1939Saw] and [1945Kus1] are in good agreement.

### Isothermal Sections

Isothermal sections of the Mg-rich region are shown in Fig. 3. With decreasing temperature the solubilities of Ag and Al go down to 1 mass% Ag and 3 mass% Al at 200°C. Isothermal sections of the Al-corner at 500 and 200°C are presented in Figs. 4 and 5.

### Thermodynamics

A thermodynamic calculation for the Ag-Al-Mg system has been performed by [1997Lim] who modelled the ternary compounds AgMgAl and T as $Ag_1Mg_1Al_1$ and $(Ag,Al)_{49}Mg_{32}$, respectively. The agreement between the measured and calculated invariant reactions is good. Also for the Al-AgMg pseudobinary system this is the case. However, some discrepancies between the calculated and experimentally determined isothermal sections remain.

### 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 |
|---|---|---|---|
| (Ag) | *cF*4<br>$Fm\bar{3}m$<br>Cu | *a* = 408.61 | 25°C<br>pure, [V-C2] |
| (Al)<br>< 660.452 | *cF*4<br>$Fm\bar{3}m$<br>Cu | *a* = 404.95 | 23°C<br>pure, [V-C2] |
| (Mg)<br>< 650 | *hP*2<br>$P6_3/mmc$<br>Mg | *a* = 320.944<br>*c* = 521.076 | 25°C<br>pure, [V-C2] |
| $Ag_2Al$<br>< 726 | *hP*2<br>$P6_3/mmc$<br>Mg | *a* = 287.79<br>*c* = 462.25 | [V-C2]<br>25°C |
| AgMg<br>< 820 | cP2<br>$Pm\bar{3}m$<br>CsCl | *a* = 331.14 | [V-C2] |
| $AgMg_4$<br>< 465 | *hP*? | | [Mas2] |
| $AgMg_3$<br>< 484 | *cF*? | | [Mas2] |
| $Mg_2Al_3$<br>< 452 | *cF*1168<br>$Fd\bar{3}m$<br>$Mg_2Al_3$ | *a* = 2823.9 | 1168 atoms on 1704 sites per unit cell [2003Luk])<br>60-62 at.% Al [1997Su] |
| $Mg_{17}Al_{12}$<br>< 458 | *cI*58<br>$I\bar{4}3m$<br>αMn | *a* = 1048.11<br>*a* = 1053.05<br>*a* = 1057.91 | 52.58 at.% Mg [L-B]<br>56.55 at.% Mg [L-B]<br>60.49 at.% Mg [L-B]<br>designated as $Mg_4Al_3$ in some publications |
| AgMgAl | *hP*12<br>$P6_3/mmc$<br>$MgZn_2$ | *a* = 538<br>*c* = 874 | [1972Wil] |

| | | | |
|---|---|---|---|
| * T, $(Ag,Al)_{49}Mg_{32}$ | *cI*162<br>$Mg_{32}(AlZn)_{49}$ | *a* = 1452±1 | [1966Aul]<br>prototype suggested but not proved,<br>Ag:Al ≈ 1:6 |
| * T', $(Ag,Al)_{49}Mg_{32}$ | *hP** | *a* = 1411<br>*c* = 2804 | [1976Aul] metastable |

**Table 2:** Invariant Equilibria

| Reaction | *T* [°C] | Type | Phase | Composition (at.%) | | |
|---|---|---|---|---|---|---|
| | | | | Ag | Al | Mg |
| L + AgMg ⇌ AgAlMg | 570 | p (min) | L | 31.01 | 37.98 | 31.01 |
| | | | AgMg | 47.05 | 5.90 | 47.05 |
| | | | AgMgAl | 33.33 | 33.33 | 33.33 |
| L ⇌ Al + AgAlMg | 538 | e (max) | L | 21.03 | 57.94 | 21.03 |
| | | | Al | 2.52 | 94.96 | 2.52 |
| | | | AgMgAl | 33.33 | 33.33 | 33.33 |
| L ⇌ Mg + $Al_{12}Mg_{17}$ + $AgMg_3$ | 404 | E | L | 8.26 | 22.39 | 69.35 |
| | | | (Mg) | 1.43 | 7.62 | 90.95 |
| | | | $Mg_{17}Al_{12}$ | ~3 | ~37 | ~60 |
| | | | $AgMg_3$ | 25 | 0.4 | 74.6 |

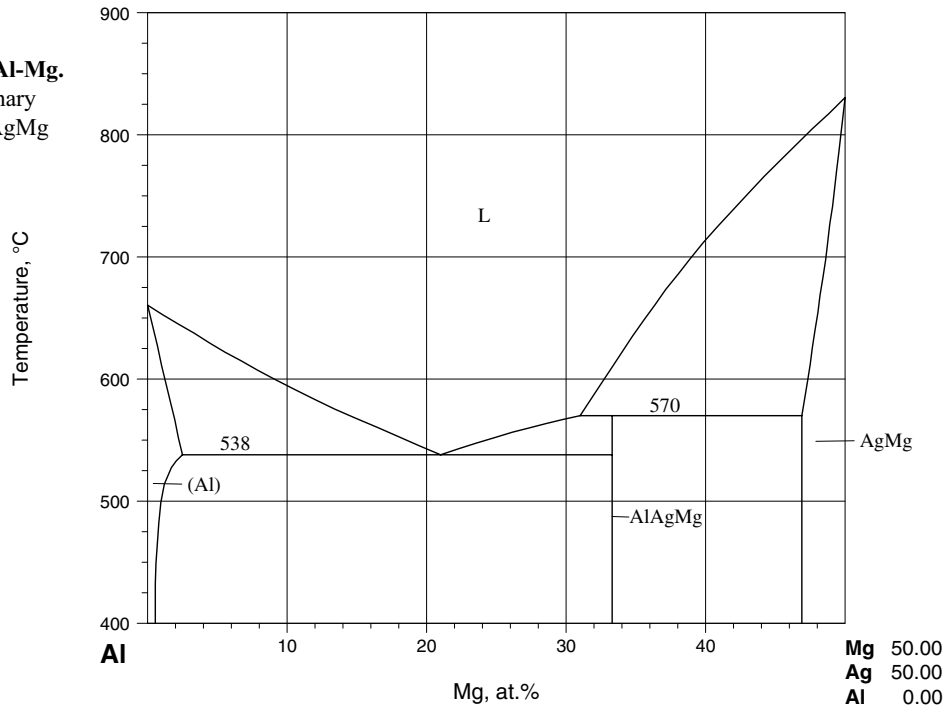


**Fig. 1: Ag-Al-Mg.** The pseudobinary system Al - AgMg

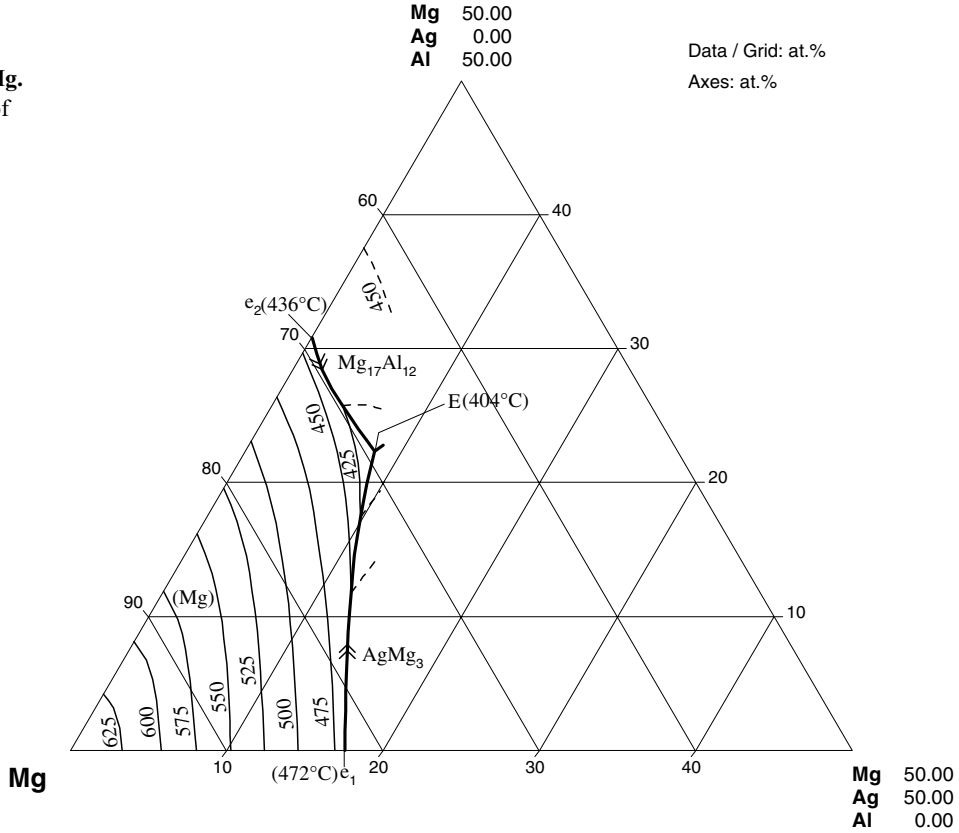


**Fig. 2: Ag-Al-Mg.** Liquidus surface of the Mg-corner

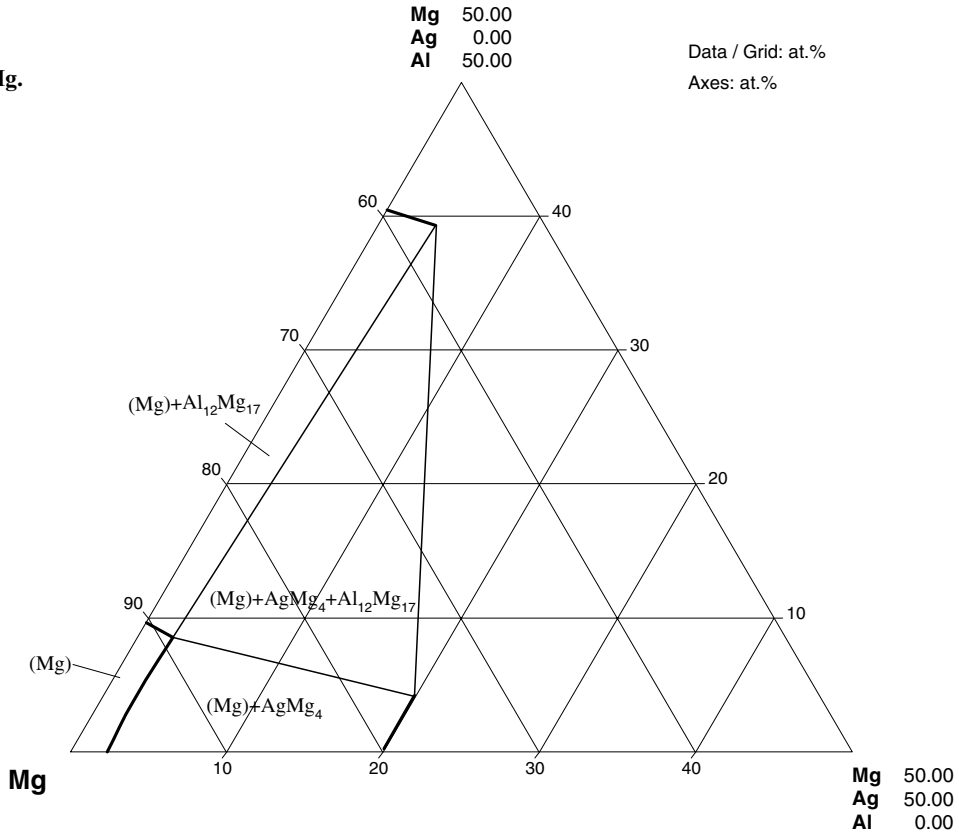


**Fig. 3a: Ag-Al-Mg.** Partial isothermal section at 400°C

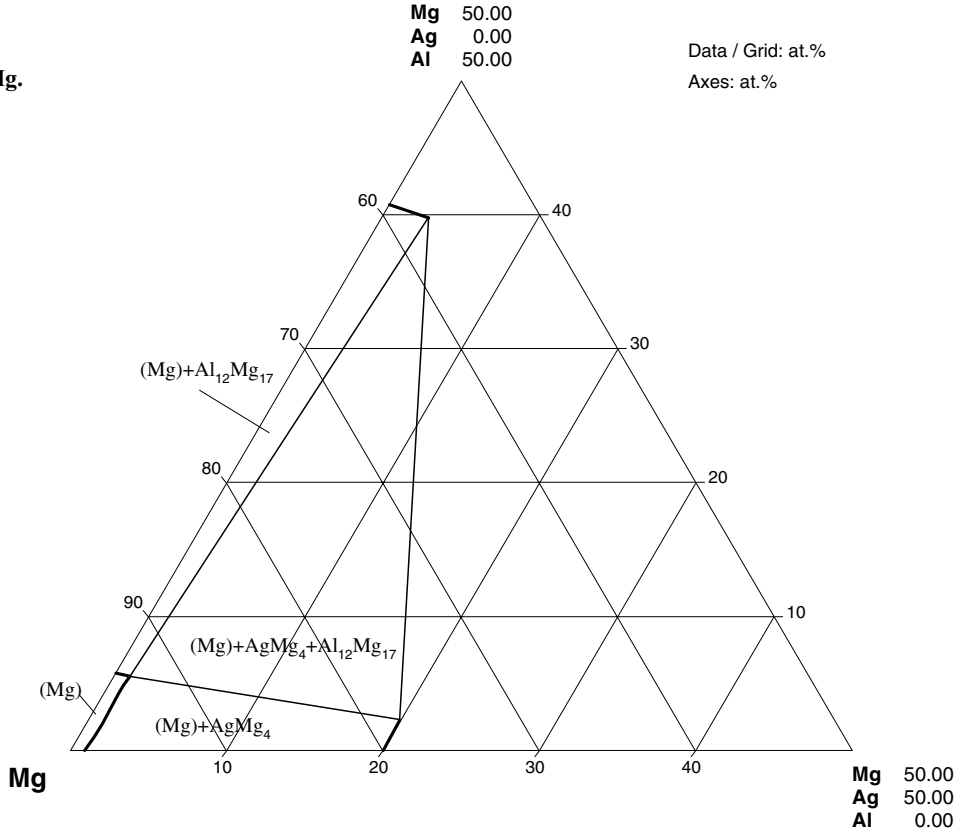


**Fig. 3b: Ag-Al-Mg.** Partial isothermal section at 300°C

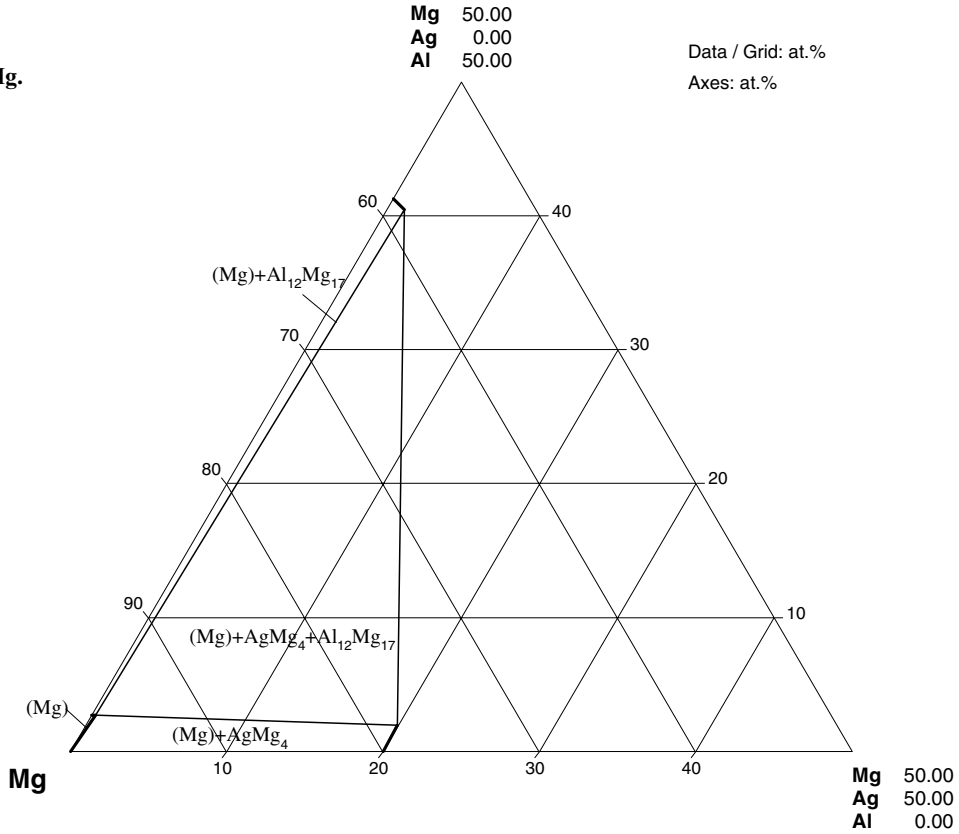


**Fig. 3c: Ag-Al-Mg.** Partial isothermal section at 200°C

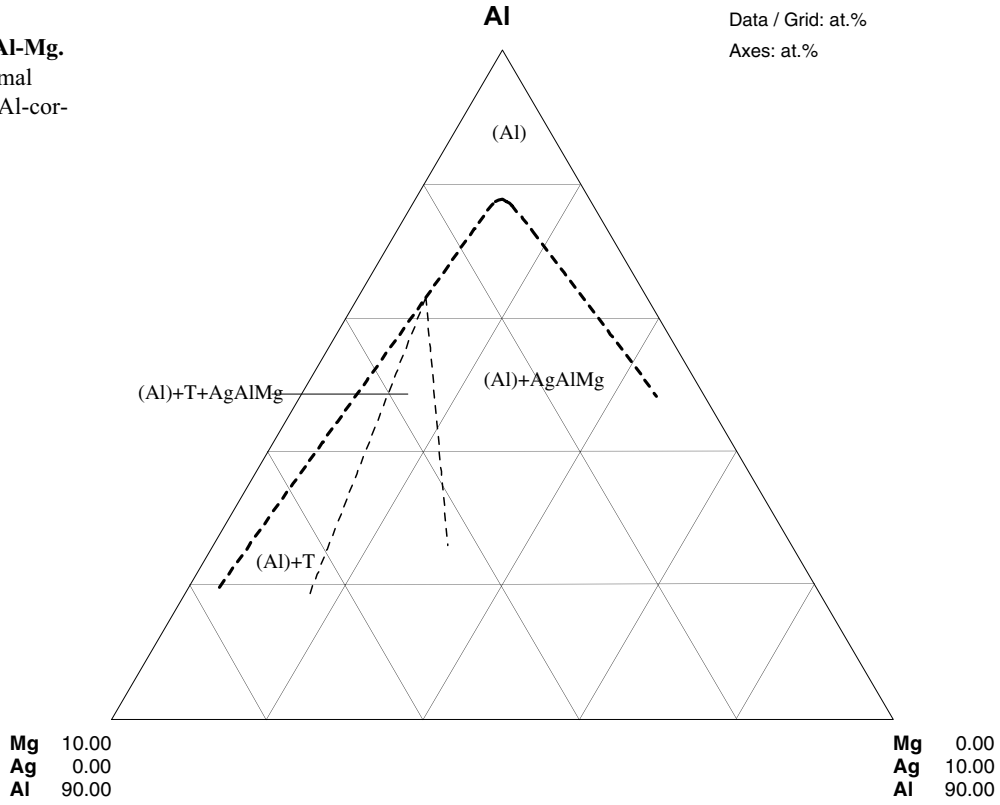


**Fig. 4: Ag-Al-Mg.** 500°C isothermal section of the Al-corner

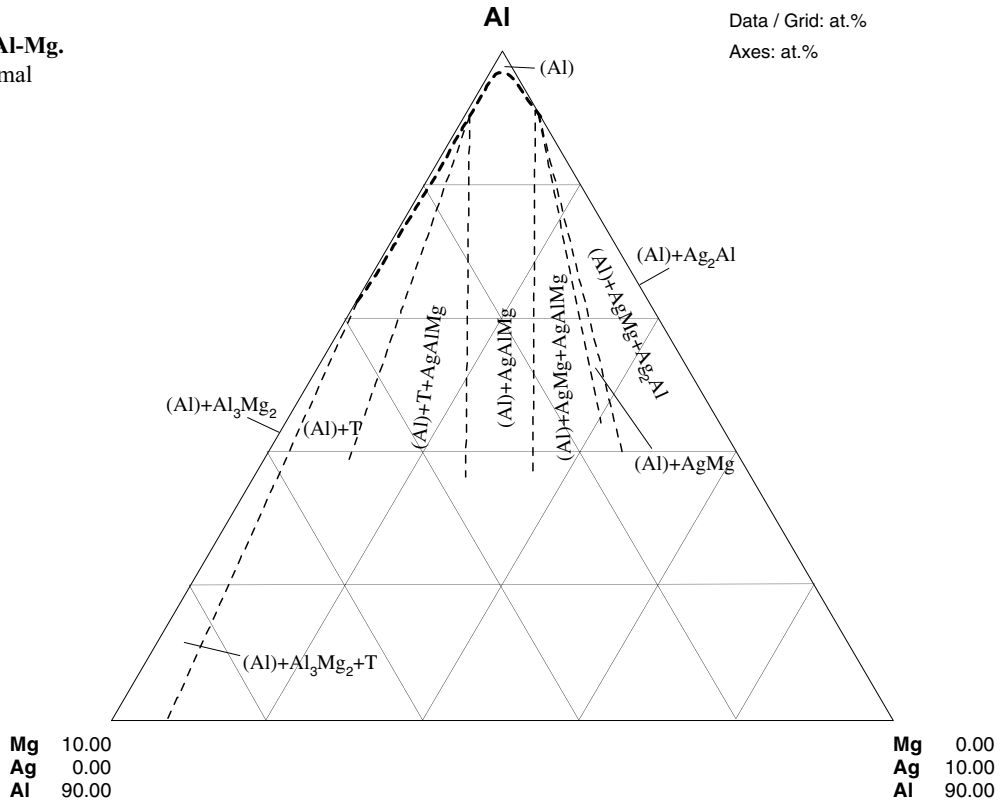


**Fig. 5: Ag-Al-Mg.** 200°C isothermal section of the Al-corner