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The Au-Mo (Gold-Molybdenum) System

96.9665 95.94

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and

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Equilibrium Diagram

The equilibrium phases in the assessed Au-Mo phase diagram (Fig. 1) are (1) the liquid, L; (2) the fcc terminal solid solution (Au), with a maximum solid solubility of about 1.25 at.% Mo at the eutectic temperature of 1055 ± 3 °C; and (3) the bcc terminal solid solution, (Mo), with a maximum solid solubility of about 0.4 at.% Au at ~2160 °C.

The Au-Mo system has a simple eutectic diagram with no intermediate phases, as indicated previously by [Hansen], based on the work of [24Dre] and [53Gea]. The eutectic temperature, as determined by thermal analysis, was reported to be 1054 °C [53Gea], or 1058 °C [60Rau].

The (Au)/[(Au) + (Mo)] solvus was determined by [53Gea] from lattice parameter values measured at high temperatures and also in quenched alloys (Table 1). The reported solubilities at lower temperatures should be much smaller because the data give too negative partial molar entropies of Mo [80Bre]. As a compromise, [80Bre] predicted other phase boundaries in terms of simple analytical forms by a regular solution calculation. The expressions given in Table 2 are slightly different from the original because the melting points of Au and Mo are accepted here from the IPTS-68 values [Melt] to be 1064.43 and 2623 °C, respectively, instead of 1063 and 2617 °C as reported in [80Bre]. The eutectic composition was predicted to be 2.1

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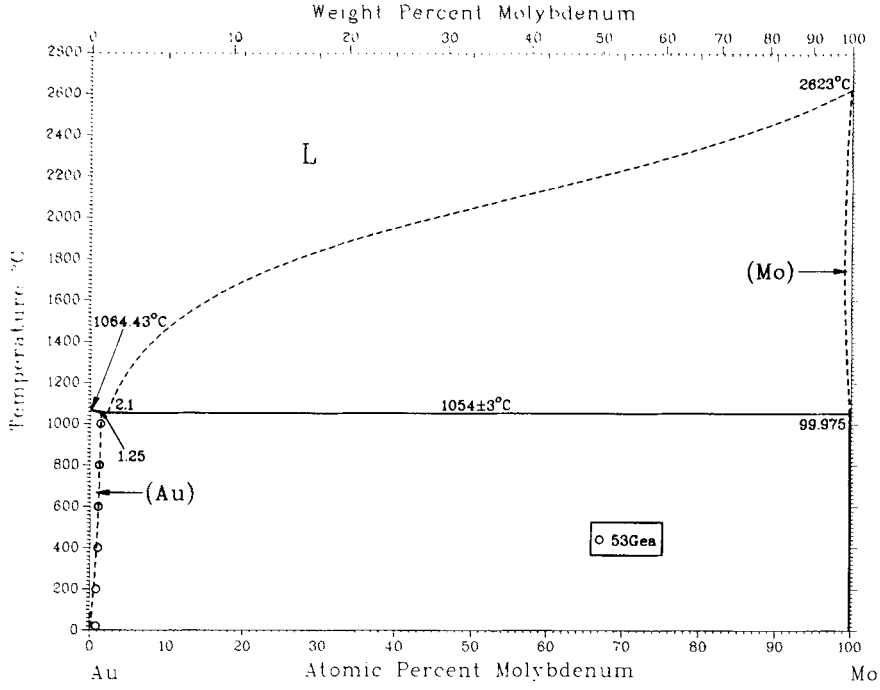
Fig. 1 Assessed Au-Mo Phase Diagram



From [80Bre].

T.B. Massalski, H. Okamoto, and L. Brewer, 1986.

Table 1 (Au)/[(Au) + (Mo)] Solvus Boundary, at.% Mo

Temperature, °C	Experimental [53Gea] High-temperature camera	Experimental [53Gea] Quenched specimen	Experimental [53Gea] Values based on presently re-estimated data	Calculated [80Bre]
1055	...	...	...	1.11
1000	...	1.2	...	1.07
800	1.1	1.05	2.5 ± 2.5	0.90
600	0.9	0.95	1.2 ± 0.4	0.70
400	0.9	...	1.2 ± 0.4	0.47
200	0.7	...	1.0 ± 0.2	0.22
20	0.7	...	0.8 ± 0.3	0.05

Table 2 Phase Boundaries

Boundary	Expression
L/[L + (Au)]	$X_{Mo} = 2.289 \times 10^{-3}(1337.58 - T) \pm 0.0002$
L/[L + (Mo)]	$T = [5150 + 2450(1 - X_{Mo})^2]/[1.778 - \ln X_{Mo}]$
[L + (Au)]/(Au)	$X_{Mo} = 1.34 \times 10^{-3}(1337.58 - T) \pm 1 \times 10^{-4}$
[L + (Mo)]/(Mo)	$\ln X_{Au} = \ln(2897 - T) - 9460/T - 9.686 + 9.86 \times 10^{-4} T - 9.27 \times 10^{-8} T^2 \pm 0.5$
(Au)/[(Au) + (Mo)]	$\ln X_{Mo} = -3.6 - 1190/T \pm 0.2$

Estimated by [80Bre], T in K and X in atomic fraction.

at.% Mo at the eutectic temperature taken at 1055 ± 3 °C (1054 ± 3 °C in [80Bre]). The compositions of the (Au) and (Mo), phases at this temperature are 1.25 at.% Mo and 99.975 at.% Mo, respectively [80Bre]. The calculated (Mo) solidus is retrograde, with a maximum solubility of 0.38 at.% Au at 2156 °C.

Metastable Phases

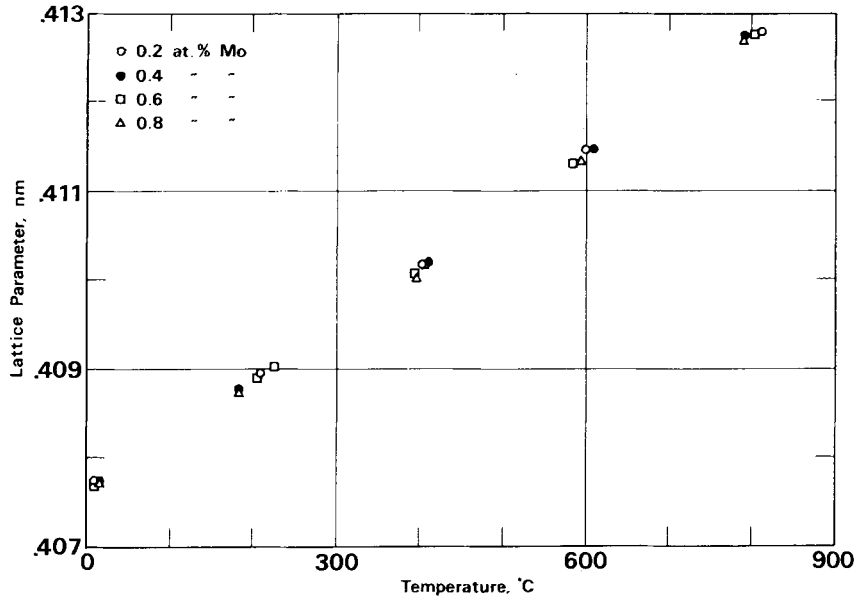
Thin films of single-phase alloys having amorphous, fcc, or bcc structures can be prepared by vapor quenching [74Pil]; the observed structures appear to depend on the quality of vacuum and the substrate temperature.

Crystal Structures

The crystal structures occurring in this system are listed in Table 3.

Lattice parameters of the (Au) alloys were measured by [53Gea], as shown in Fig. 2 (a misprint in the original table is corrected). To determine the (Au)/[(Au) + (Mo)] phase boundary, [53Gea] derived lattice parameters at temperatures of 20, 200, 400, 600, and 800 °C from nearby data points and plotted against composition. Table 4 gives the presently re-estimated lattice parameters at these temperatures. The thermal expansion coefficient was assumed here to be composition-independent

Fig. 2 Lattice Parameter as a Function of Temperature for (Au) Alloys [53Gea]



T.B. Massalski, H. Okamoto, and L. Brewer, 1986.

Table 3 Au-Mo Crystal Structure and Lattice Parameter Data

Phase	Homogeneity, at.% Mo	Pearson symbol	Space group	Structur-bericht designation	Proto-type	Lattice parameter, nm
(Au)	0 to 1.25	*cF*4	*Fm*3*m*	*A*1	Cu	0.40784(a)
(Mo)	99.6 to 100	*cI*2	*Im*3*m*	*A*2	W	0.31470

From [King1]. (a) Composition and temperature dependence in Table 4 and Fig. 2.

Table 4 Lattice Parameter Data of [53Gea] Reduced to 20, 200, 400, 600, and 800 °C

Composition, at.% Mo	Temperature, °C				
	20	200	400	600	800
0.2	0.40781	0.40889	0.41016	0.41145	0.41271
0.4	0.40779	0.40888	0.41010	0.41141	0.41281
0.6	0.40774	0.40886	0.41012	0.41141	0.41274
0.8	0.40776	0.40884	0.41003	0.41137	0.41275
1.2	0.40773	···	0.41001	0.41137	0.41279
1.6	0.40774	0.40883	···	0.41133	0.41277
3.1	0.40774	0.40883	0.41004	0.41136	0.41279
5.0	0.40774	0.40883	0.41004	0.41135	0.41281

Note: A factor 0.100202 was used to convert the unit from kX to nm. Assumed thermal expansion coefficient is $dL/dT = 1.19334 \times 10^{-9}T + 5.89064 \times 10^{-6}$ nm/°C.

and was derived from quadratic regression of the data shown in Fig. 2 ($dL/dT = 1.19334 \times 10^{-9}T + 5.89064 \times 10^{-6}$ nm/°C, where L is the lattice parameter and T is in °C). The recalculated lattice parameters (Table 4) seem to indicate that the solvus compositions cannot be determined (Table 1) as accurately as they appeared on the original lattice parameter-composition diagram given by [53Gea].

Thermodynamics

No experimental thermodynamic data are available on the Au-Mo system. [80Bre] estimated the thermodynamic properties (Table 5) from the limited experimental phase diagram data. The analytical expressions of phase boundaries given in Table 2, however, are not the direct result of calculations based on these thermodynamic

Table 5 Thermodynamic Properties of the Au-Mo Alloys

$G^0(\text{Mo, fcc}) - G^0(\text{Mo, bcc}) = (1190 + 3.6T)R$
$-(G^0(\text{Mo, bcc}) - \Delta H^0_{298})/RT = 1.933 - 3.30 \times 10^{-5}T + 3.15 \times 10^{-8}T^2 - 1.068 \times 10^{-11}T^3 (\Delta H/R = 4\,298$ K at the melting point, $\Delta H/R = 5\,326$ K at 627 °C)

$G^{ex}_{Au} = 11\,000RX^2_{Mo}$ (infinitely dilute solute standard state of Mo in fcc Au)

$G^{ex}_{Mo} = 2450RX^2_{Au}$ (infinitely dilute solute standard state of Au in liquid Mo)

From [80Bre].
Note: R is the gas constant 8.314 J/mol · K.

parameters, but are reported as simplified or approximated by [80Bre]. These boundaries are accepted in Fig. 1 as a good representation of the equilibrium diagram. Further experimental studies on both thermodynamic properties and phase boundaries are needed for confirmation.

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*Indicates key paper.
#Indicates presence of a phase diagram.

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The Au-Sr (Gold-Strontium) System

196.9665 87.62

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Equilibrium Diagram

The assessed phase diagram for the Au-Sr system (Fig. 1) is essentially the same as that of [Elliott], which is based on the work of Feller-Kniepmeier and Heumann [60Fel]. The equilibrium phases are: (1) the liquid, L; (2) the terminal fcc solid solution, (Au), with very small solubility of Sr; (3) the terminal bcc solid solution, (βSr)—designated (γSr) in [Pearson2]—with unknown solubility of Au; (4) the terminal fcc solid solution, (αSr), with very small solubility of Au and stable below 547 °C; and (5) several intermetallic phases—Au_5Sr, Au_2Sr, $AuSr_3$, $AuSr_9$, (AuSr)—and phases denoted by [60Fel] as β and γ.

Alloys were prepared by [60Fel] in corundum crucibles in an argon atmosphere (up to 20 atm for high-Sr alloys) from 99.99% Au and Sr that was redistilled several times (Sr initially contained 1.2% Ca). The compositions of the alloys were determined by chemical analysis. The phase boundaries were studied mainly by thermal analysis. Other methods were also used—density measurements (for six alloys), specific resistance (<31 at.% Sr), microhardness (15 to 19.5 at.% Sr), microstructure observation, and X-ray analysis.

Special points in the assessed phase diagram are summarized in Table 1. Additional information on each phase follows.

(Au) Terminal Solid Solution. The melting point of pure Au is 1064.43 °C [Melt]. The liquidus from the position of the melting point of Au in the diagram of [60Fel] goes down to the eutectic point (890 °C and 7 at.% Sr) almost as a straight line with a slope of about −25 °C/at.%. Assuming immiscibility of Sr in (Au) and using 13 000 J/mol for the heat of fusion of Au [83Cha], the initial slope of the liquidus is −11.7 °C/at.%.

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