Solidificación de aleaciones de aluminio y diagramas de fase

0185 Metalurgia de aleaciones coladas base aluminio

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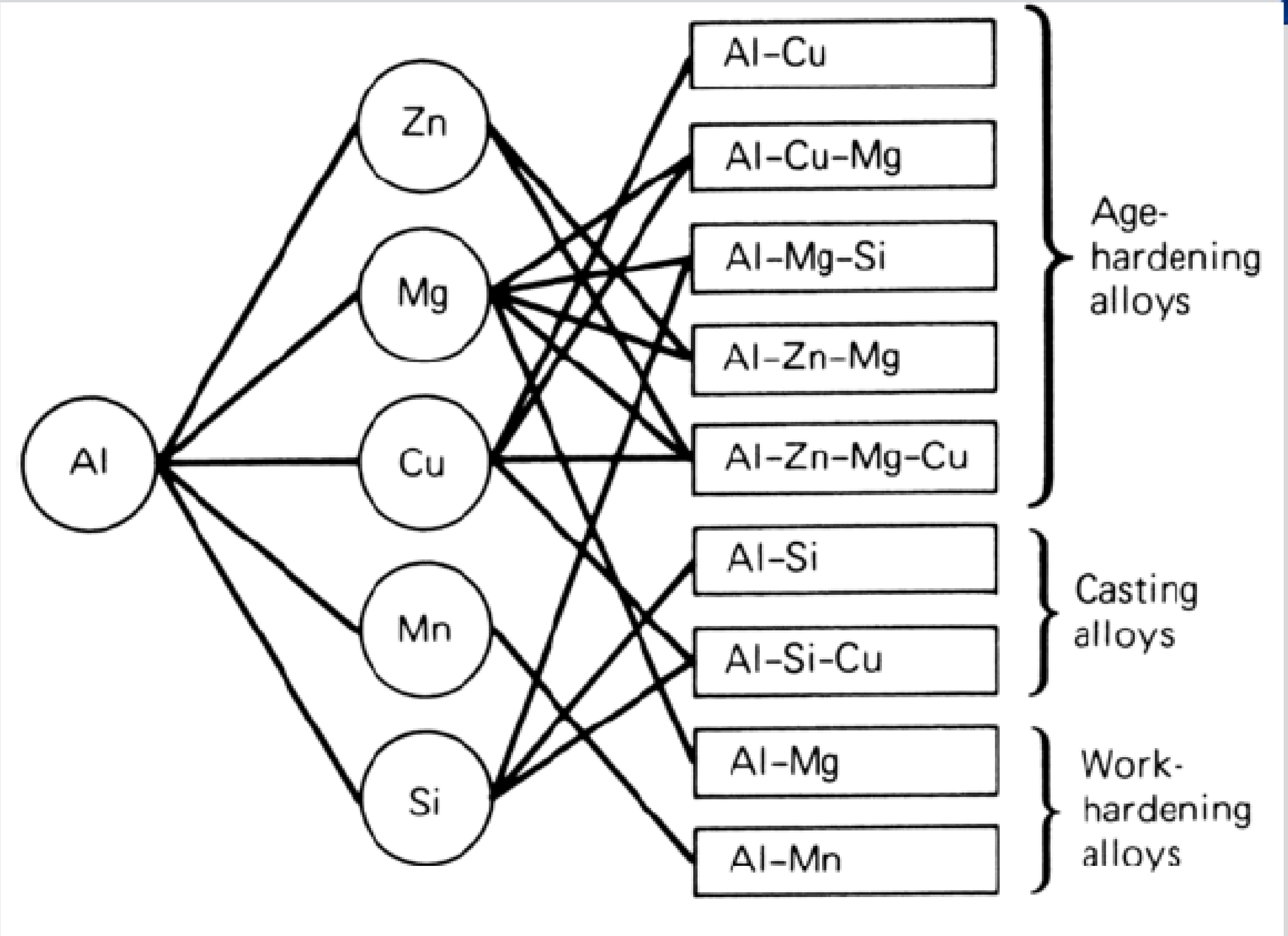
Principal elemento de aleación	Serie
Aluminio con mínimo 99.00% de pureza	1XXX
Cobre	2XXX
Manganeso	3XXX
Silicio	4XXX
Magnesio	5XXX
Magnesio y Silicio	6XXX
Zinc	7XXX
Otros elementos	8XXX
En desuso	9XXX

Aluminum Wrougth Alloys (AWA)

Aluminum Cast Alloys (ACA)

Principal elemento de aleación	Serie
Aluminio con mínimo 99.00% de pureza	1XX.X
Cobre	2XX.X
Silicio con Cu y/o Mg	3XX.X
Silicio	4XX.X
Magnesio	5XX.X
En desuso	6XX.X
Zinc	7XX.X
Estaño	8XX.X
Otros elementos	9XX.X


Al
Zn
Mg
Cu
Mn
Si
Al–Cu
Al–Cu–Mg
Al–Mg–Si
Al–Zn–Mg
Al–Zn–Mg–Cu
Al–Si
Al–Si–Cu
Al–Mg
Al–Mn
Age-hardening alloys
Casting alloys
Work-hardening alloys

Aluminum Wrougth Alloys (AWA)

Alloy group	Nominal chemical composition[(a)], wt%									
	Mg	**Si**	**Ti**	**Cr**	**Mn**	**Fe**	**Ni**	**Cu**	**Zn**	**Zr**	**Other**
Wrought alloys											
1xxx (Al > 99.00%)	0.006–0.25	0.006–0.7	0.002–0.06	0.01–0.03	0.002–0.05	0.006–0.6	...	0.006–0.35	0.006–0.05	...	...
2xxx (Cu)	0.02–0.8	0.10–1.3	0.02–0.3	0.05–0.2	0.05–1.3	0.12–1.3	0.05–2.3	0.8–6.8	0.10–0.80	0.05–0.5	...
3xxx (Mn)	0.05–1.3	0.3–1.8	0.05–0.10	0.05–0.40	0.05–1.8	0.1–1.0	0.05	0.05–0.50	0.05–1.0	0.1–0.5	...
4xxx (Si)	0.05–2.0	0.8–13.5	0.04–0.30	0.05–0.25	0.03–1.5	0.20–1.0	0.15–1.3	0.05–1.5	0.05–0.25	...	...
5xxx (Mg)	0.2–5.6	0.08–0.7	0.05–0.20	0.05–0.35	0.03–1.4	0.10–0.7	0.03–0.05	0.03–0.35	0.05–2.8	...	...
6xxx (Mg + Si)	0.05–1.5	0.20–1.8	0.08–0.20	0.03–0.035	0.03–1.0	0.08–1.0	0.2	0.10–1.2	0.05–2.4	0.05–0.20	...
7xxx (Zn)	0.10–3.7	0.10–0.50	0.03–0.15	0.04–0.35	0.02–1.5	0.10–0.70	0.10	0.05–2.6	0.8–8.7	0.05–0.18	...
8xxx (other element)	0.02–1.4	0.10–1.0	0.08–0.2	0.01–0.2	0.02–1.0	0.10–2.0	0.2–1.3	0.03–2.2	0.03–1.8	0.04–0.16	Li, B, Sn, Ga

Aluminum Cast Alloys (ACA)

Cast alloys											
1*xx.x* (Al > 99.00%)	…	0.10–0.15	0.15–0.35	…	…	0.25–0.8	…	0.05–0.10	0.05	…	…
2*xx.x* (Cu)	0.03–2.3	0.05–3.5	0.06–0.35	0.15–0.40	0.05–0.7	0.04–1.5	0.03–2.3	3.5–10.7	0.05–2.5	…	…
3*xx.x* (Si + Cu/Mg)	0.03–1.5	4.5–23.0	0.04–0.25	0.05–0.35	0.03–0.8	0.06–1.5	0.10–3.0	0.03–5.0	0.03–4.5	…	…
4*xx.x* (Si)	0.05–0.10	3.3–13	0.20–0.25	0.25	0.05–0.5	0.12–1.3	0.05–0.5	0.05–1.0	0.05–0.5	…	…
5*xx.x* (Mg)	1.4–10.6	0.10–2.2	0.10–0.25	0.25	0.05–0.6	0.10–1.3	0.05–0.4	0.05–0.30	0.05–0.20	…	…
7*xx.x* (Zn)	0.2–2.4	0.10–0.30	0.10–0.25	0.06–0.6	0.05–0.6	0.10–1.4	0.15	0.1–1.0	2.0–7.8	…	…
8*xx.x* (Sn)	0.1–0.9	0.4–6.5	0.2	…	0.1–0.5	0.5–0.7	0.3–1.5	0.7–4.0	Sn, 5.5–7.0	…	…

Aluminum Wrougth Alloys (AWA)

Alloy	Phase constituents [a]	
	Rough state	**Treated state**
Wrought alloys		
1xxx (Al > 99.00%), Al-Fe-Si, Al-Cu	Al_3Fe, α-Al(FeSi)	Al_6Mn, α-Al(FeSi)
2xxx (Cu), Al-Si-Cu-Mn-Mg, Al-Si-Cu-Mn, Al-Cu-Mg, Al-Cu-Mg-Ni, Al-Cu-Mn-Ti-V-Zr, Al-Cu-Mg-Ni-Fe-Ti	Al_2Cu, Al_2CuMg, $Al_{20}Cu_2Mn_3$, α-Al(FeMnSi), Al_3FeMn, Al_6MnFe, Al_7Cu_2Fe, Mg_2Si, $Al_5Cu_2Mg_8Si_6$	Al_2Cu, Al_2CuMg, $Al_{20}Cu_2Mn_3$, α-Al(FeMnSi), Al_7Cu_2Fe, $Al_{12}Mn_3Si$
3xxx (Mn), Al-Cu-Mn, Al-Fe-Si-Mg-Mn, Al-Si-Mn- Fe	α-Al(FeMnSi), Al_6MnFe	α-Al(FeMnSi), Al_6MnFe
4xxx (Si)	β-AlFeSi	…
5xxx (Mg), Al-Mn-Mg-Cr, Al-Mn-Mg-Cr, Al-Mn-Mg, Al-Mg	Mg_2Si, $Al_{18}Mg_3Cr_2$, Al_6Mn	Mg_2Si, Al_3Ni
6xxx (Mg, Si), Al-Si-Cu-Mg-Cr, Al-Si-Mg, Al-Si-Mg-Cr, Al-Si-Mn-Mg	β-AlFeSi, Mg_2Si, α-Al(FeSi)	Mg_2Si
7xxx (Zn), Al-Mn-Mg-Zn-Zr, Al-Mn-Mg-Cr-Zn, Al-Zn, Al-Cu-Mg-Cr-Zn, Al-Cu-Mn-Mg-Cr-Zn, Al-Cu-Mg-Cr-Zn	α-Al(FeCrSi), $Al_2CuMgZn$, Al_7Cu_2Fe	Al_2CuMg, Mg_2Si, Al_7Cu_2Fe, α-Al(FeCrSi), $Al_{18}Mg_3Cr_2$
8xxx (other element), Al-Li-Mg-Cu	…	…

(a) α-Al(other) = solid solution.

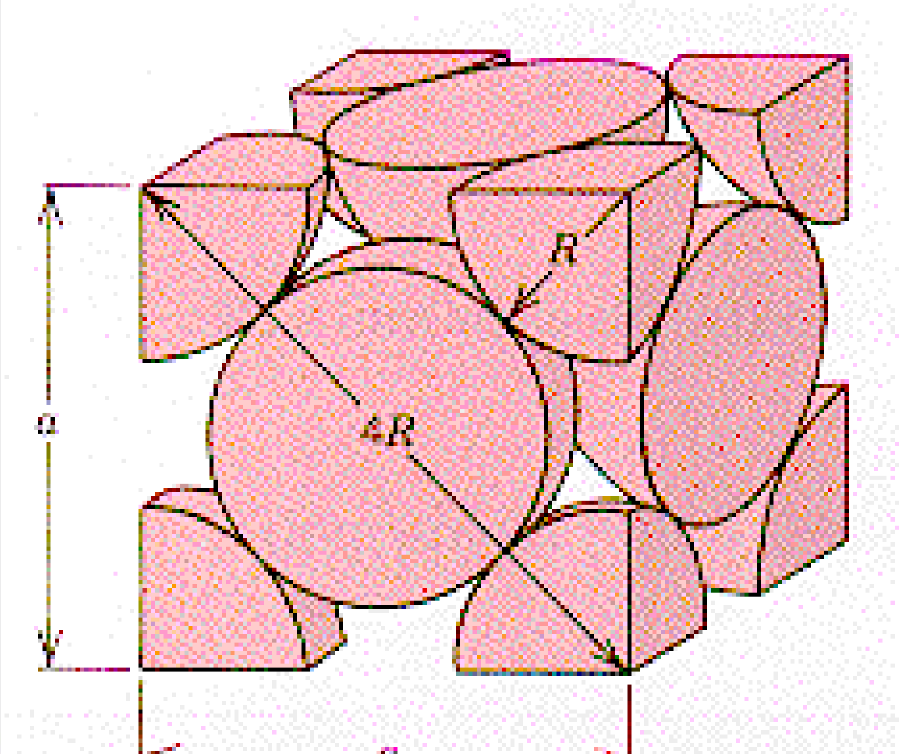
Aluminum Cast Alloys (ACA)

Cast alloys		
1xx.x (Al > 99.00%), 7xxx(Zn)	Si, β-AlFeSi, α-Al(FeSi)	…
2xx.x (Cu), Al-Cu-Mg, Al-Cu-Mn, Al-Cu-Si-Mg, Al-Cu-Mn-Mg-Ni, Al-Cu-Mg-Ni, Al-Cu-Si	Si, Al_2Cu, Al_2CuMg, Al_7Cu_2Fe, $Al_5Cu_2Mg_8Si_6$, β-AlFeSi α-Al(FeMnSi), AlCuFeNi, Al_6Cu_3Ni	Al_2Cu, Al_2CuMg, $Al_{20}Cu_2Mn_3$, Al_7Cu_2Fe, AlCuFeNi, Al_6Cu_3Ni, Al_3Ni
3xx.x (Si + Cu/Mg), Al-Cu-Si, Al-Si-Cu-Mg-Ni, Al-Si-Cu-Mg, Al-Si-Mg, Al-Si-Mg-Fe, Al-Si-Mg-Ti, Al-Si-Mn-Mg-Cu	Si, Al_2Cu, Al_2CuMg, Al_7Cu_2Fe, $Al_5Cu_2Mg_8Si_6$, β-AlFeSi α-Al(FeMnSi), AlCuFeNi, Al_6Cu_3Ni, Mg_2Si, Al_3Ni, Al_9NiFe, $Al_8Mg_3FeSi_2$	Si, Al_2Cu, Al_2CuMg, Al_7Cu_2Fe, AlCuFeNi, Al_6Cu_3Ni, $Al_{20}Cu_2Mn_3$, Al_3Ni, $Al_8Mg_3FeSi_2$, $Al_5Cu_2Mg_8Si_6$, β-AlFeSi, α-Al(FeMnSi)
4xx.x (Si), Al-Si, Al-Si-Cu, Al-Si-Fe	Si, Al_2Cu, β-AlFeSi, α-Al(FeMnSi)	Si, Al_2Cu, β-AlFeSi, α-Al(FeMnSi)
5xx.x (Mg), Al-Mg	Mg_2Si, $Al_6(FeMn)$, Al_3Mg_2, $Al_{18}Mg_3Cr_2$	Mg_2Si, $Al_6(FeMn)$, Al_3Mg_2, $Al_{18}Mg_3Cr_2$
7xx.x (Zn)	$Al_{18}Mg_3Cr_2$, Al_3Fe, Al_7FeCr, $MgZn_2$	…
8xx.x (Sn)	Si, Sn, Cu_6Sn_5, Al_3Ni	Si, Sn, Cu_6Sn_5, Al_3Ni, Al_6Cu_3Ni

(a) α-Al(other) = solid solution.

Al puro
1XX.X
1XXX

La temperatura de fusión del Al puro es 660°C aproximadamente



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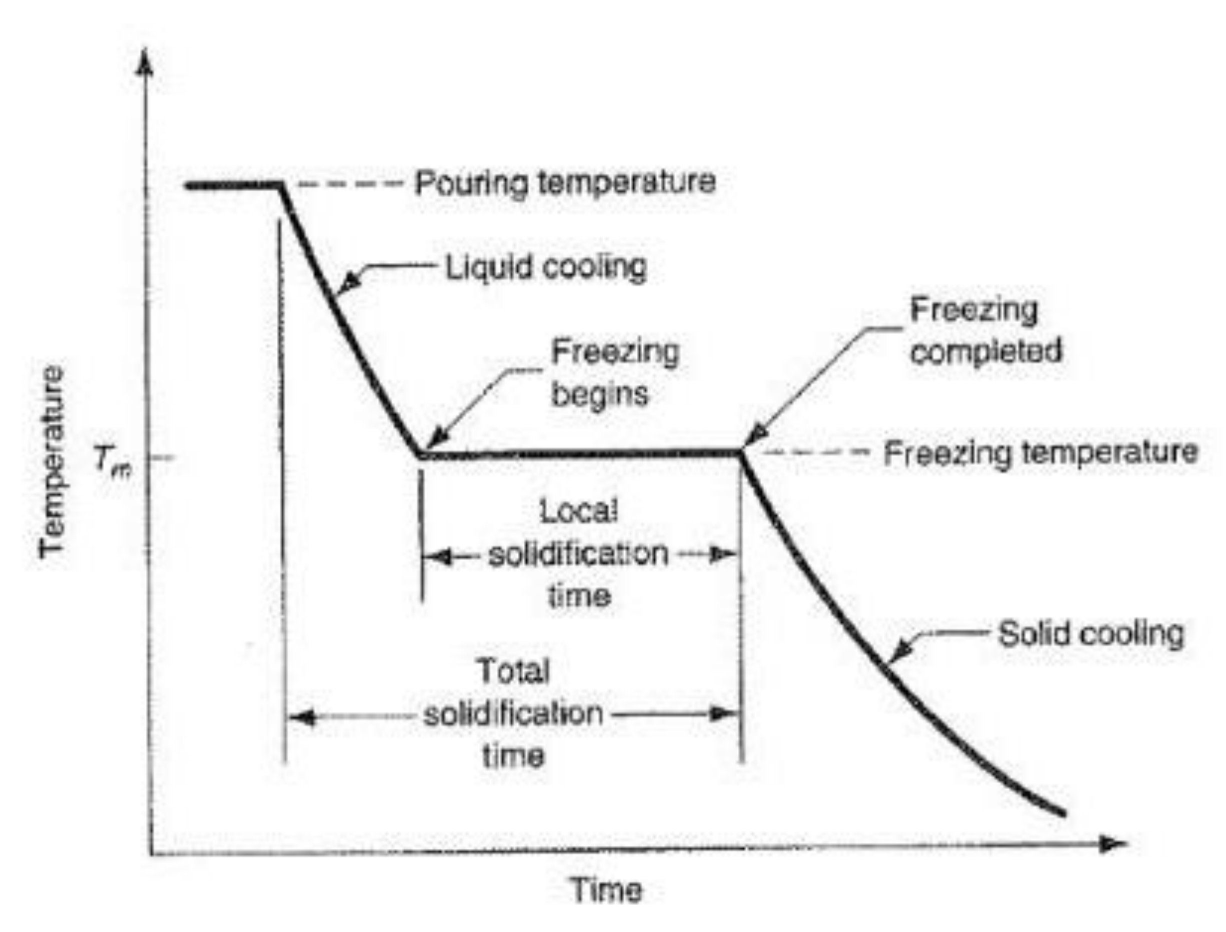


Al puro
1XX.X
1XXX

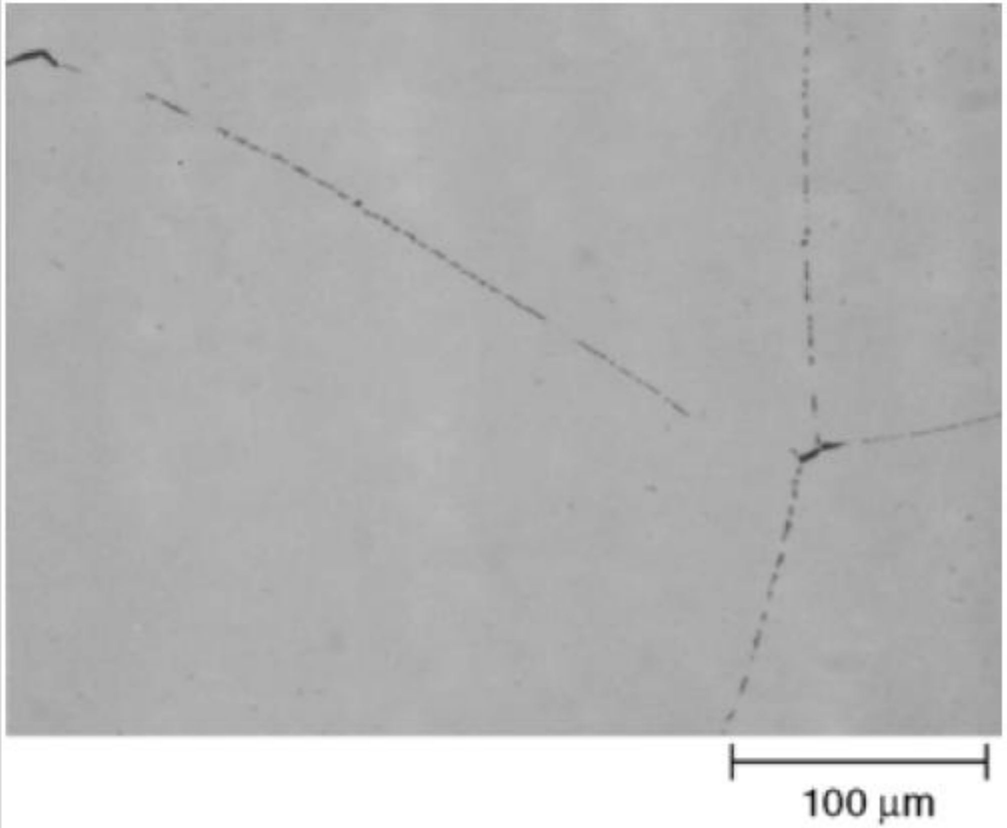
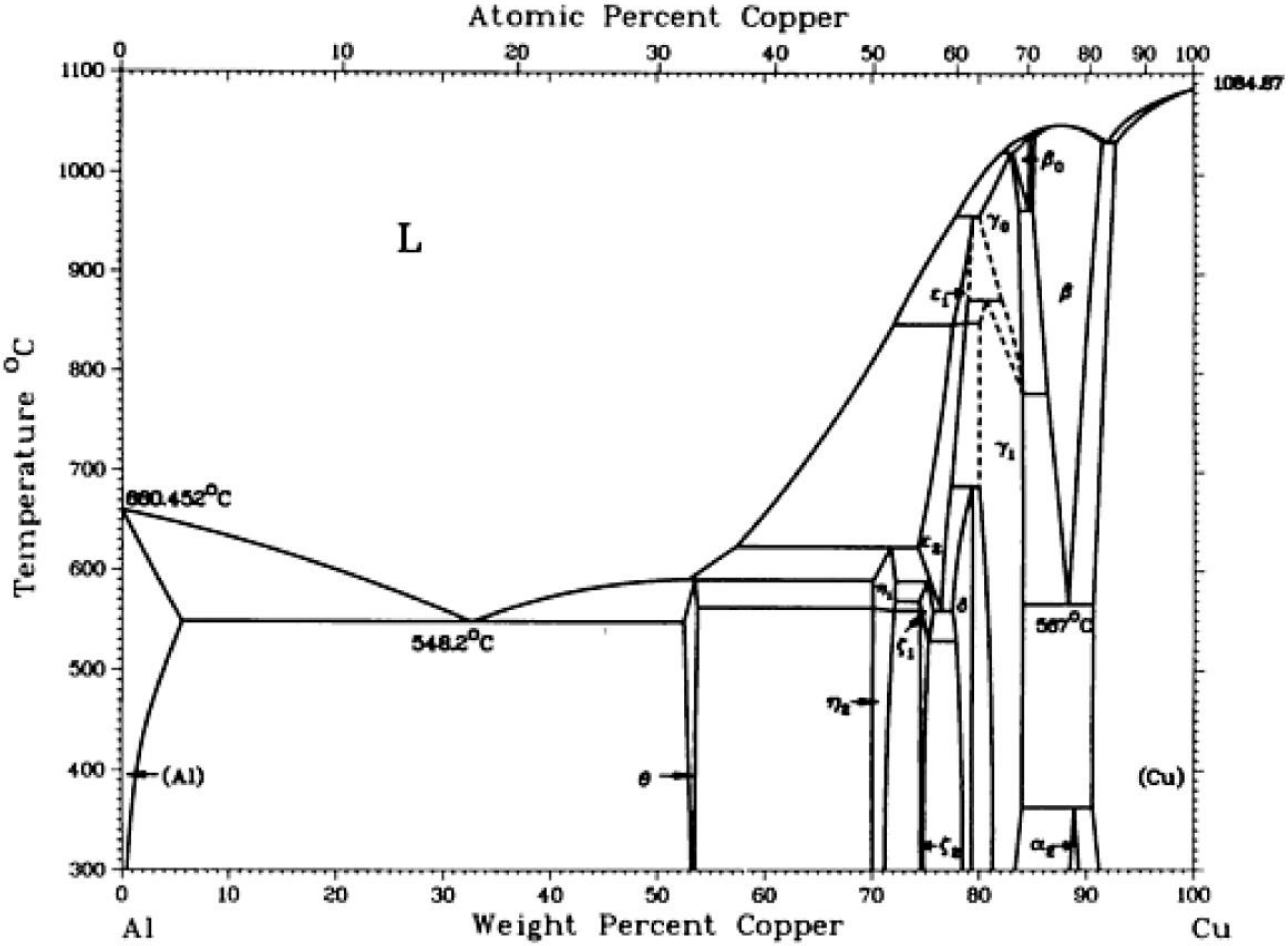


Fig. 4 Monophase structure of etched commercially pure aluminum (1*xx.x*) at 200× magnification. HF

Al – Cu
2XX.X
2XXX



Al – Cu
2XX.X
2XXX

Al-Cu crystallographic data

Phase	Composition, wt% Cu	Pearson symbol	Space group
(Al)	0 to 5.65	*cF*4	$Fm\bar{3}m$
θ	52.5 to 53.7	*tI*12	*I*4/*mcm*
η_1	70.0 to 72.2	*oP*16 or *oC*16	*Pban* or *Cmmm*
η_2	70.0 to 72.1	*mC*20	*C*2/*m*
ζ_1	74.4 to 77.8	*hP*42	*P*6/*mmm*
ζ_2	74.4 to 75.2	(a)	. . .
ε_1	77.5 to 79.4	(b)	. . .
ε_2	72.2 to 78.7	*hP*4	$P6_3/mmc$
δ	77.4 to 78.3	(c)	$R\bar{3}m$
γ_0	77.8 to 84	(d)	. . .
γ_1	79.7 to 84	*cP*52	$P\bar{4}3m$
β_0	83.1 to 84.7	(d)	. . .
β	85.0 to 91.5	*cI*2	$Im\bar{3}m$
α_2	88.5 to 89	(e)	. . .
(Cu)	90.6 to 100	*cF*4	$Fm\bar{3}m$

Metastable phases			
θ'	. . .	*tP*6	. . .
β'	. . .	*cF*16	$Fm\bar{3}m$
Al_3Cu_2	61 to 70	*hP*5	$P\bar{3}m1$

(a) Monoclinic?

(b) Cubic?

(c) Rhombohedral.

(d) Unknown.

(e) $D0_{22}$-type long-period superlattice

Al – Cu
2XX.X
2XXX

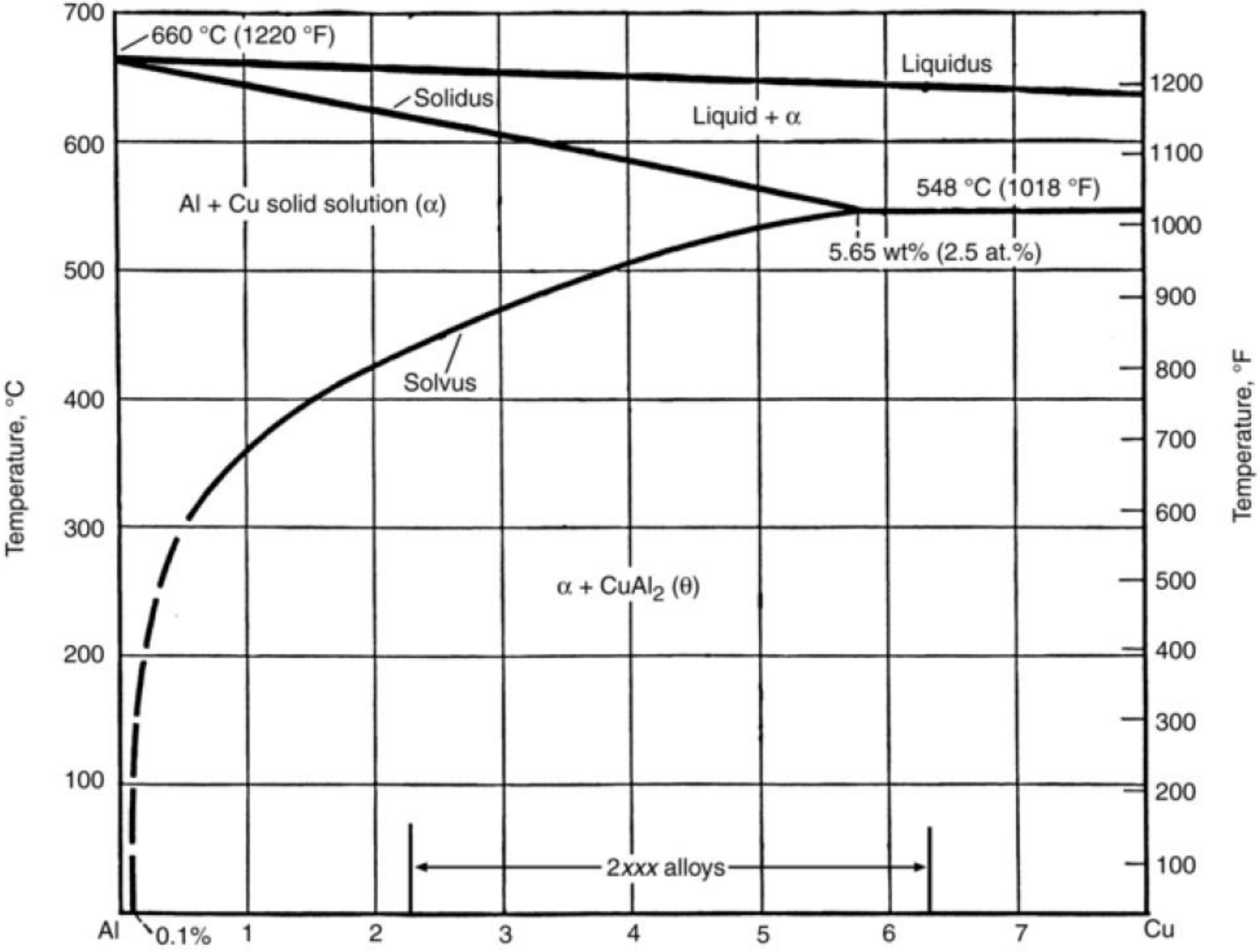


Fig. 3 Aluminum corner of the aluminum-copper phase diagram. Eutectic composition (not shown) is at 33 wt% (17 at.%) Cu.

Al – Cu
2XX.X
2XXX

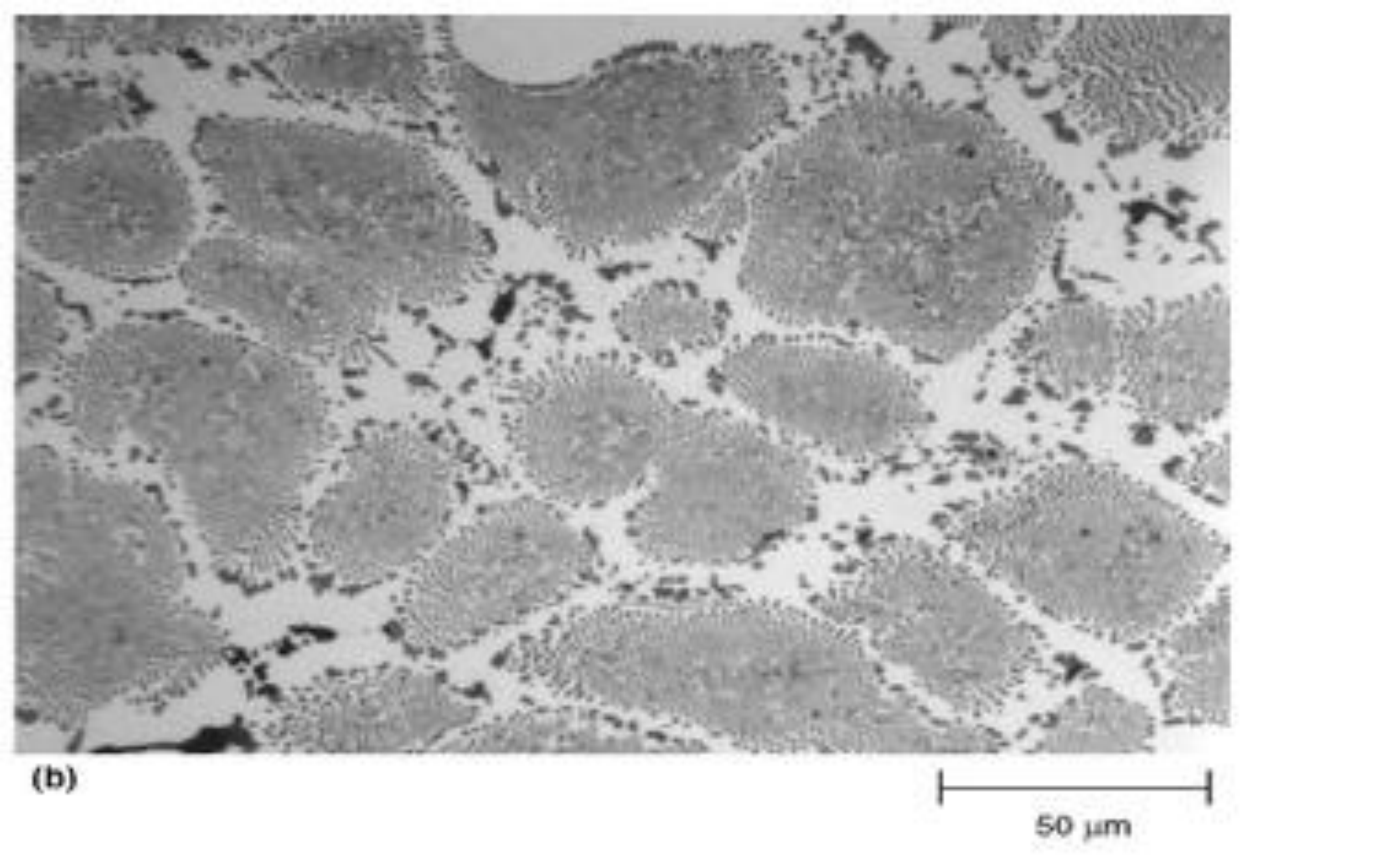


Fig. 8 Dispersed phase and networklike morphology of second-phase structure in two eutectic alloys. (a) As-cast 413 alloy at 750×. (b) As-cast aluminum-copper alloy at 400×. Both etched with 0.5% HF (5m in Table 4)

Al – Cu
2XX.X
2XXX

Otros precipitados en aleaciones base Al

Element	Temperature [a]		Liquid solubility		Solid solubility	
	°C	°F	wt%	at.%	wt%	at.%
Ag	570	1060	72.0	60.9	55.6	23.8
Au	640	1180	5	0.7	0.36	0.049
B	660	1220	0.022	0.054	<0.001	<0.002
Be	645	1190	0.87	2.56	0.063	0.188
Bi	660[b]	1220[b]	3.4	0.45	<0.1	<0.01
Ca	620	1150	7.6	5.25	<0.1	<0.05
Cd	650[b]	1200[b]	6.7	1.69	0.47	0.11
Co	660	1220	1.0	0.46	<0.02	<0.01
Cr	660[c]	1220[c]	0.41	0.21	0.77	0.40
Cu	550	1020	33.15	17.39	5.67	2.48
Fe	655	1210	1.87	0.91	0.052	0.025
Ga	30	80	98.9	97.2	20.0	8.82
Gd	640	1180	11.5	2.18	<0.1	<0.01
Ge	425	800	53.0	29.5	6.0	2.30
Hf	660[c]	1220[c]	0.49	0.074	1.22	0.186
In	640	1180	17.5	4.65	0.17	0.04
Li	600	1110	9.9	30.0	4.0	13.9
Mg	450	840	35.0	37.34	14.9	16.26
Mn	660	1220	1.95	0.97	1.25	0.62
Mo	660[c]	1220[c]	0.1	0.03	0.25	0.056

Otros precipitados en aleaciones base Al

Element	Temperature (a)		Liquid solubility		Solid solubility	
	°C	°F	wt%	at.%	wt%	at.%
Na	660(b)	1220(b)	0.18	0.21	<0.003	<0.003
Nb	660(c)	1220(c)	0.01	0.003	0.22	0.064
Ni	640	1180	6.12	2.91	0.05	0.023
Pb	660	1220	1.52	0.20	0.15	0.02
Pd	615	1140	24.2	7.5	<0.1	<0.02
Rh	660	1220	1.09	0.29	<0.1	<0.02
Ru	660	1220	0.69	0.185	<0.1	<0.02
Sb	660	1220	1.1	0.25	<0.1	<0.02
Sc	660	1220	0.52	0.31	0.38	0.23
Si	580	1080	12.6	12.16	1.65	1.59
Sn	230	450	99.5	97.83	<0.01	<0.002
Sr	655	1210	...	...	...	...
Th	635	1180	25.0	3.73	<0.1	<0.01
Ti	665(c)	1230(c)	0.15	0.084	1.00	0.57
Tm	645	1190	10.0	1.74	<0.1	<0.01
U	640	1180	13.0	1.67	<0.1	<0.01
V	665(c)	1230(c)	0.25	0.133	0.6	0.32
Y	645	1190	7.7	2.47	<0.1	<0.03
Zn	380	720	95.0	88.7	82.8	66.4
Zr	660(c)	1220(c)	0.11	0.033	0.28	0.085

(a) Eutectic reactions unless designated otherwise.
(b) Monotectic reaction.
(c) Peritectic reaction.

Otros precipitados en aleaciones base Al

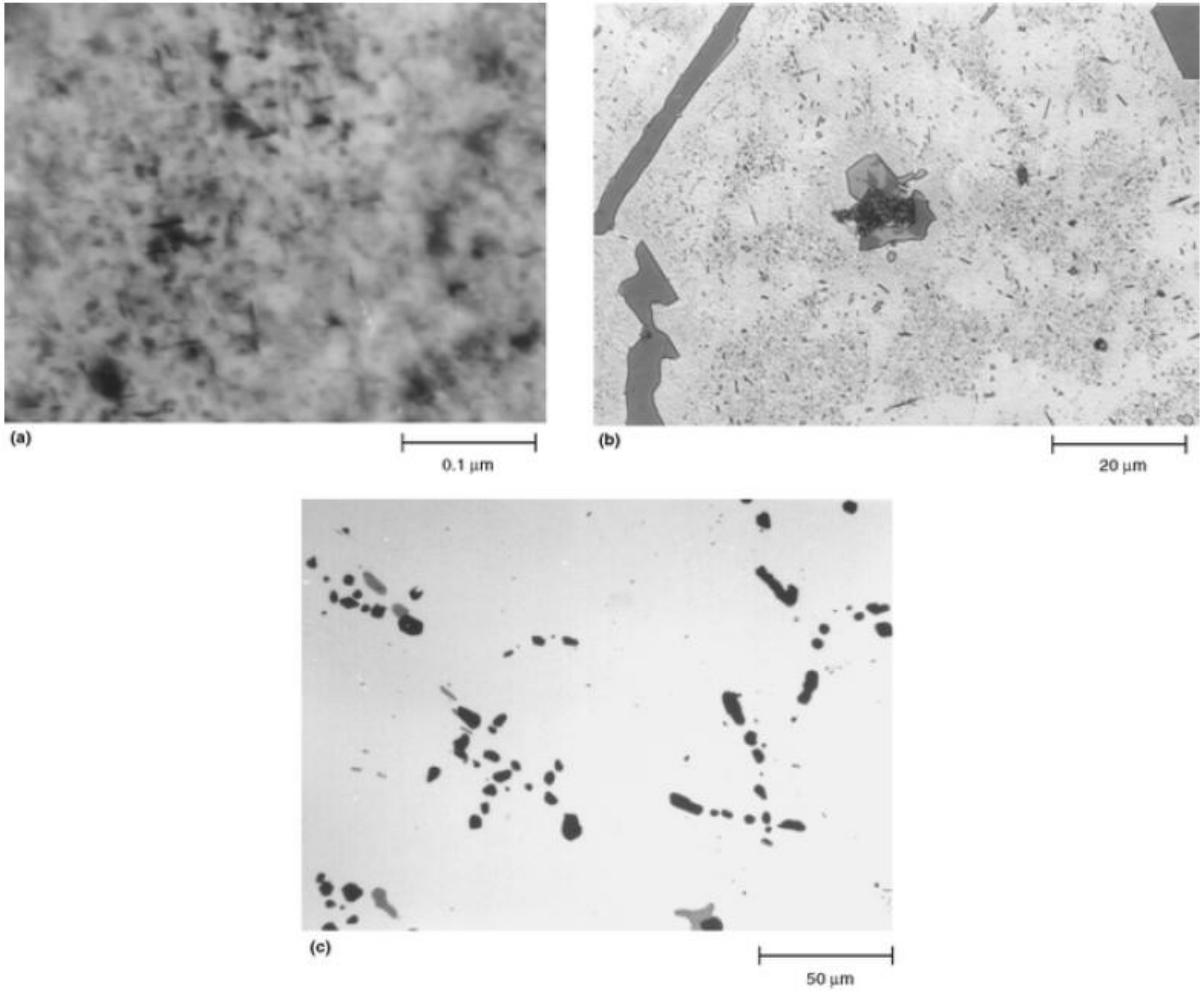
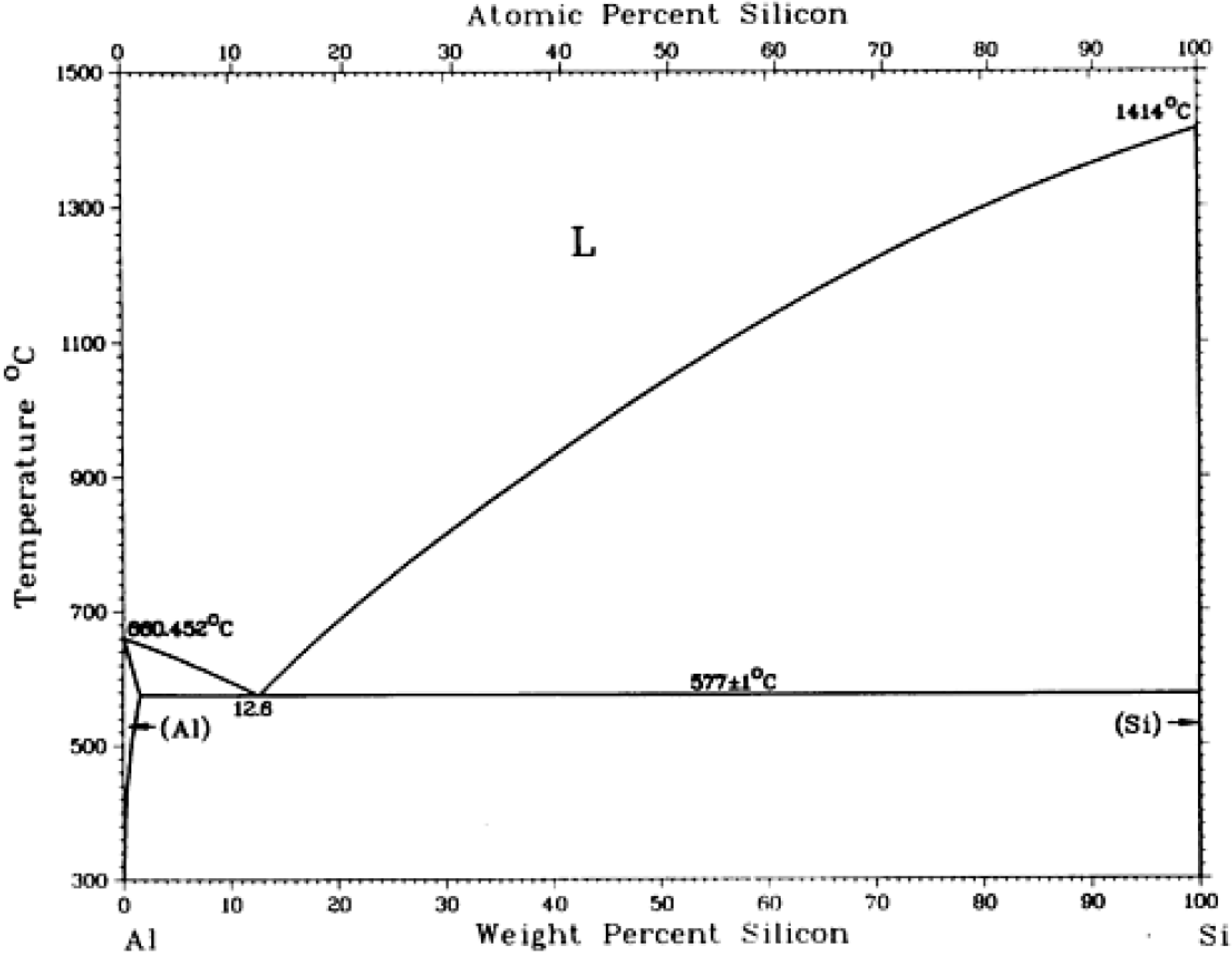


Fig. 5 Examples of dispersed precipitates shown at various magnifications. (a) Transmission electron microscopy image (at 200,000×) of η′ phase in thin foil of 7050-T6 alloy. (b) Micrograph (at 1000×) of heat treated (T6) 418 alloy etched with 0.5% HF (etchant 5m in Table 4). (c) Micrograph (at 400×) of heat treated 7050-T6 alloy etched with 0.5% HF (etchant 5m in Table 4)

Al – Si
4XX.X
4XXX

Al-Si crystallographic data

Phase	Composition, wt% Si	Pearson symbol	Space group
(Si)	99.985 to 100	$cF8$	$Fd\bar{3}m$



Al – Si
4XX.X
4XXX

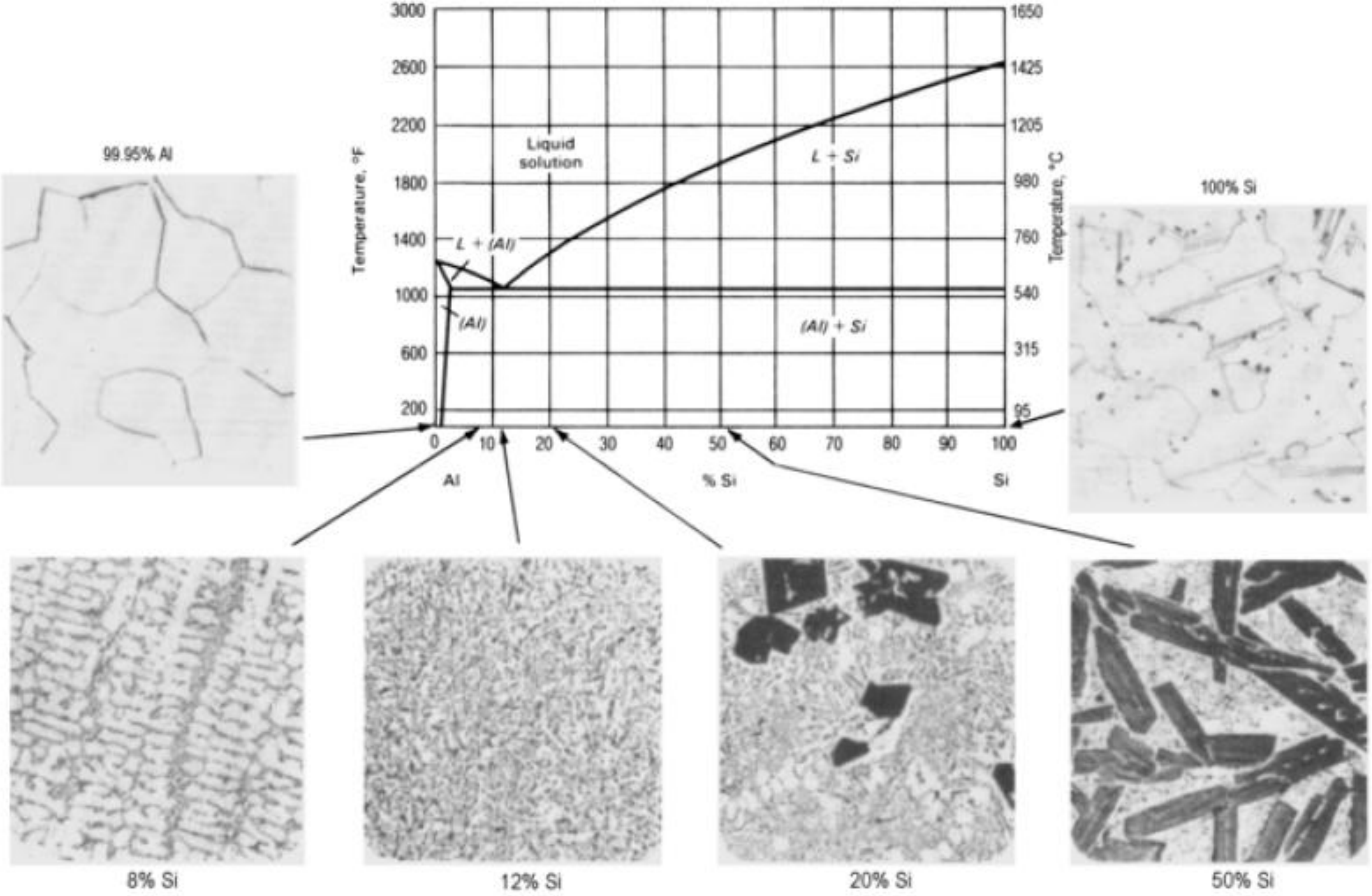


Fig. 6 Aluminum-silicon phase diagram and cast microstructures of hypoeutectic compositions (<12% Si), hypereutectic compositions (>12% Si), and one close to the eutectic composition of 12% Si

Al – Si
4XX.X
4XXX

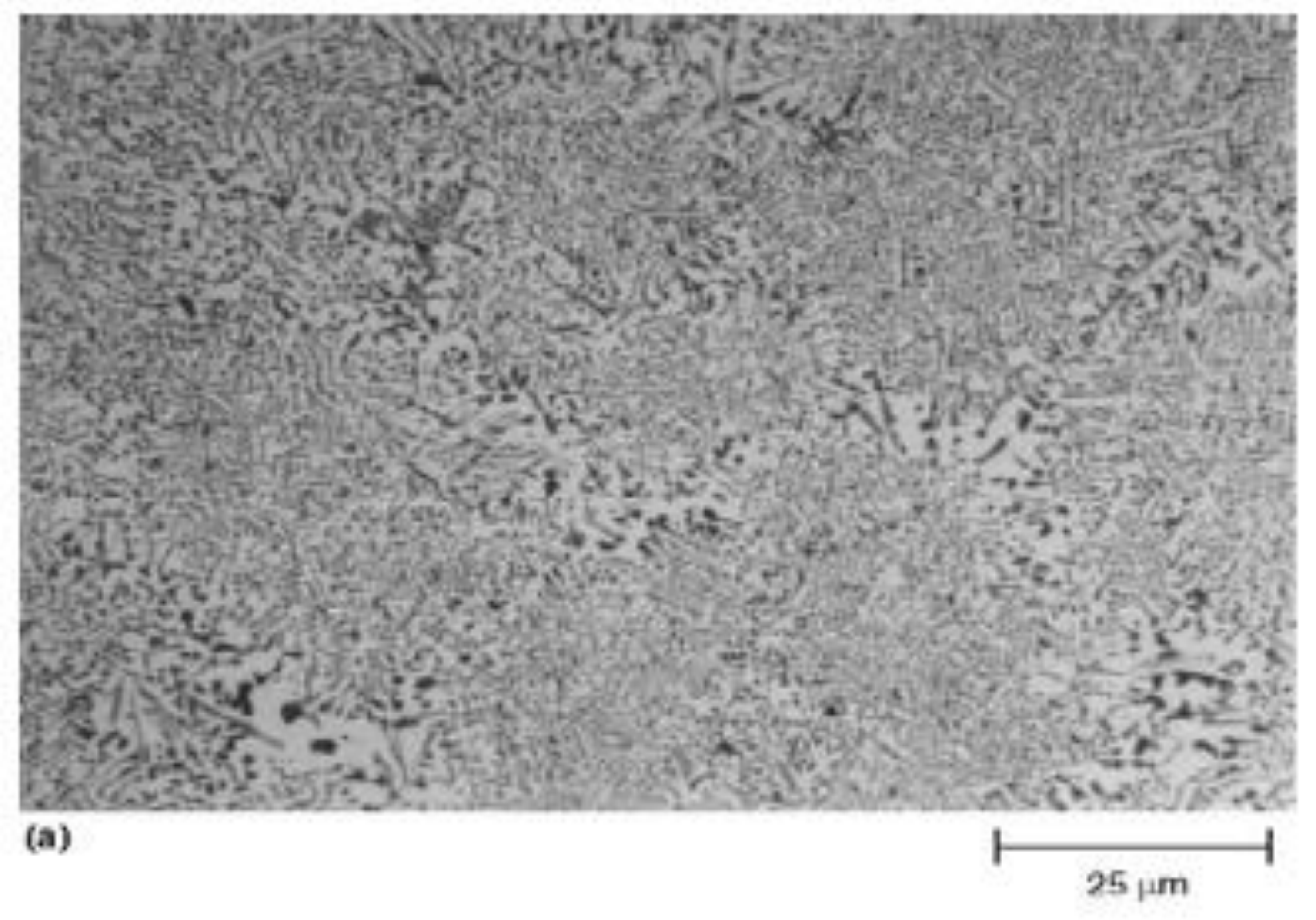


Fig. 8 Dispersed phase and networklike morphology of second-phase structure in two eutectic alloys. (a) As-cast 413 alloy at 750×. (b) As-cast aluminum-copper alloy at 400×. Both etched with 0.5% HF (5m in Table 4)

Al – Si
4XX.X
4XXX

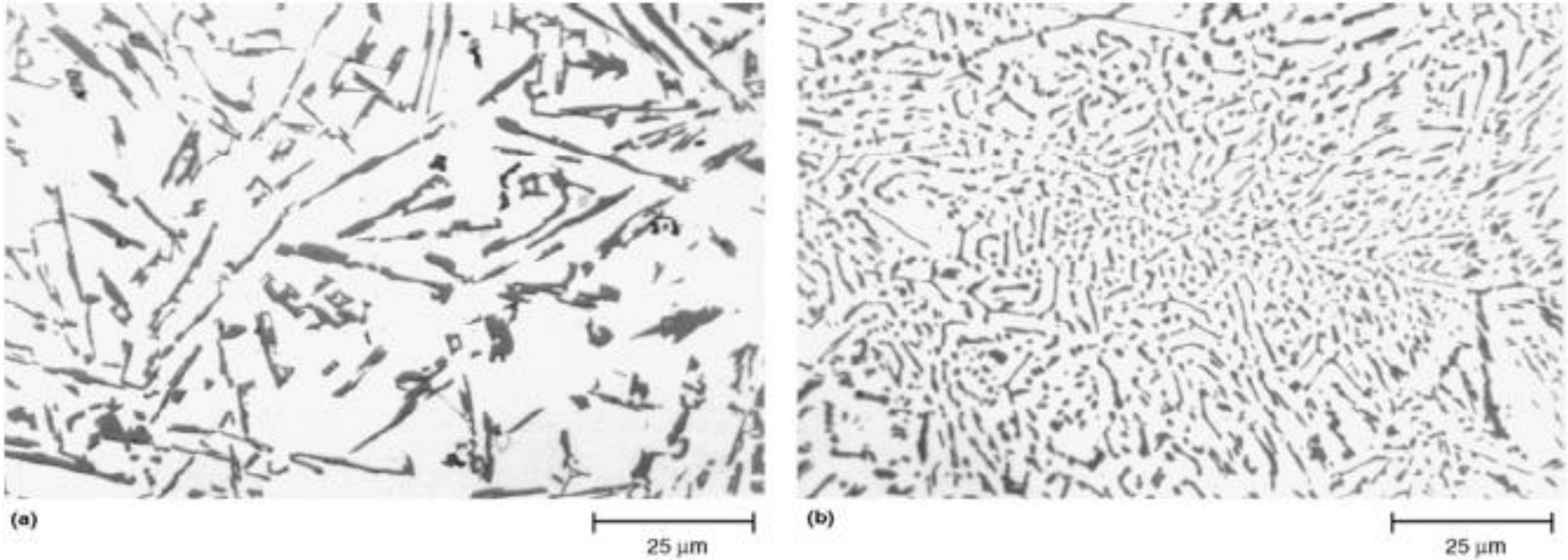


Fig. 10 As-cast morphologies in a eutectic aluminum-silicon alloy. (a) Unmodified alloy with coarse silicon precipitates formed during solidification. (b) Modified alloy with solidification of finer silicon precipitates. Both etched with 0.5% HF (5m in Table 4) and magnified by 750×

Al – Si
4XX.X
4XXX

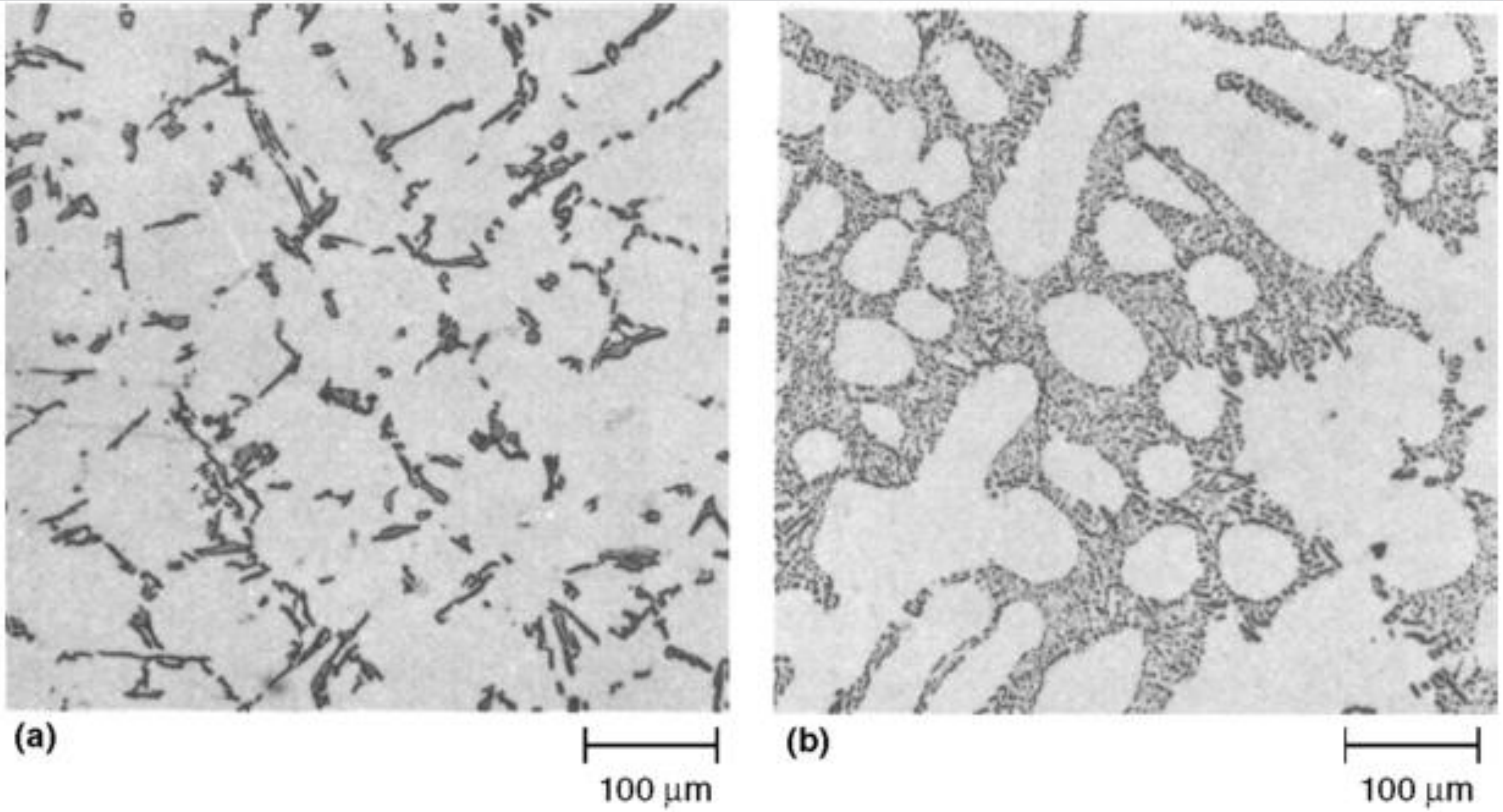


Fig. 16 Effect of sodium modification on microstructure of sand-cast aluminum-silicon hypoeutectic alloy 356-F. Both specimens were etched in 0.5% hydrofluoric acid and are shown at 100×. (a) As-cast structure in unmodified alloy consists of a network of silicon particles (sharp gray), which formed in the interdendritic aluminum-silicon eutectic. (b) Modified alloy by addition of 0.025% Na to the melt. Constituents are the same as in (a), but the particles of silicon are smaller and less angular

Al – Si
4XX.X
4XXX

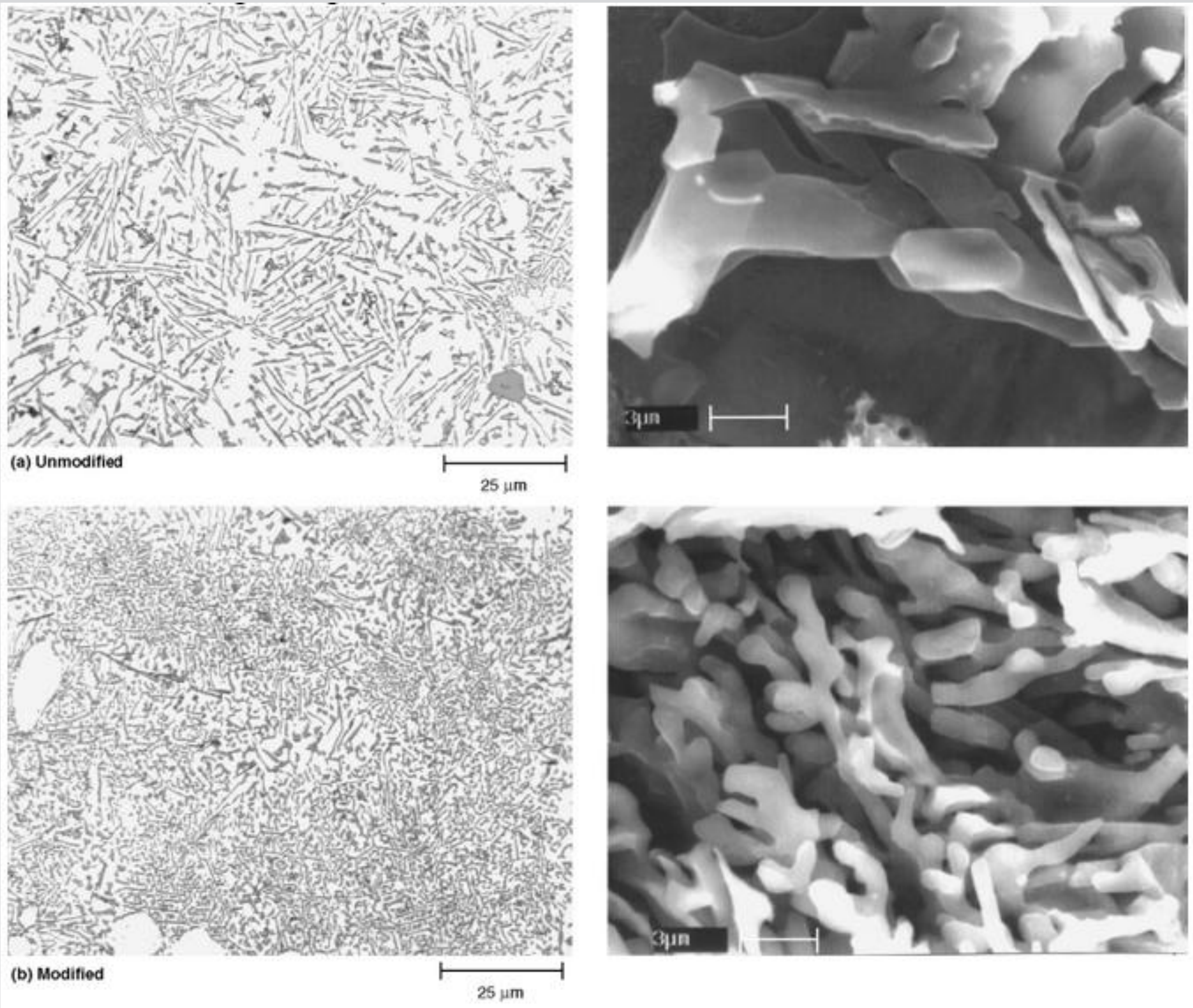


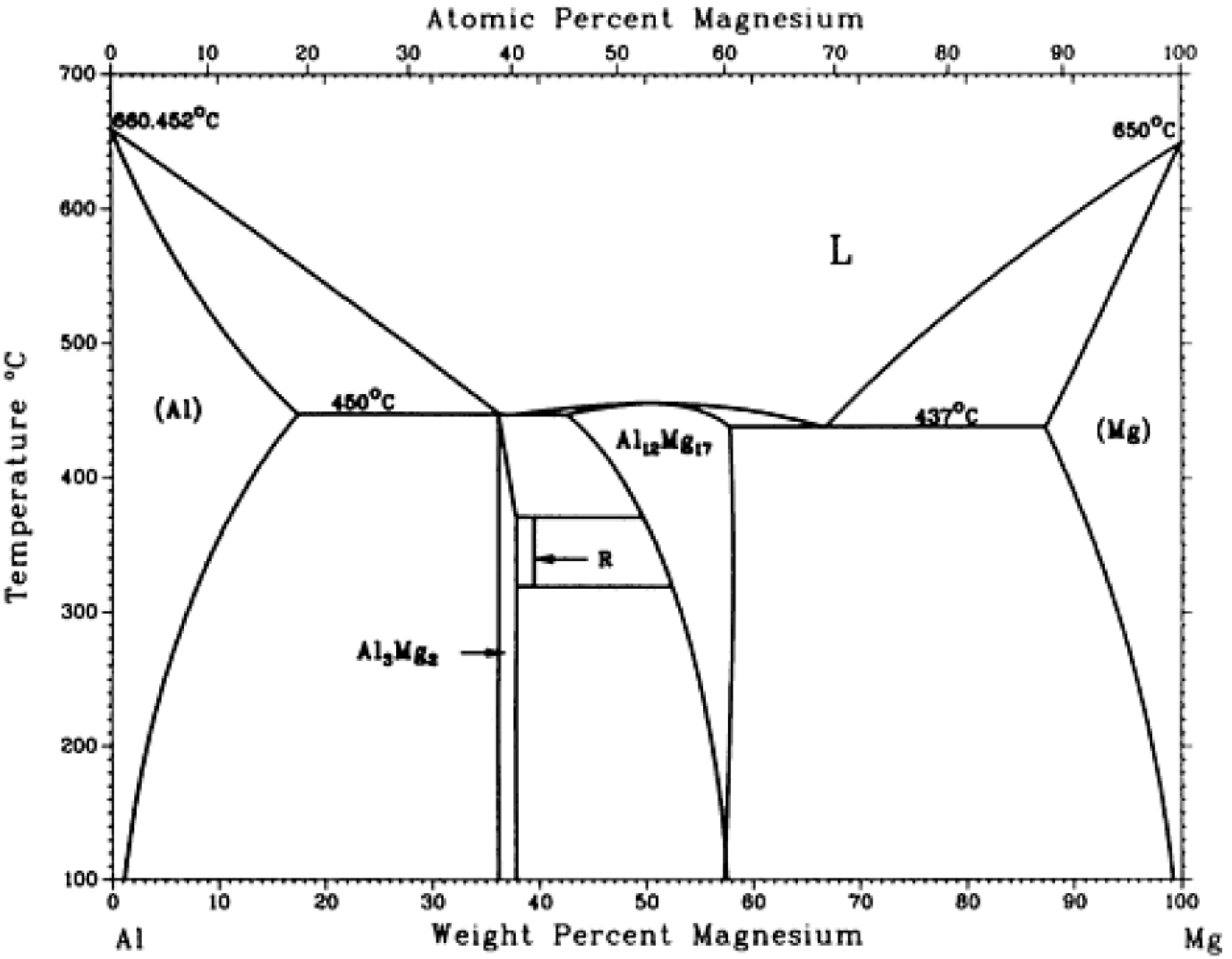
Fig. 51 Modified and unmodified phase morphology of a eutectic aluminum-silicon alloy from examination by light microscopy (left, at 750×) of etched specimens (0.5% HF) and by SEM imaging (right, at 4000×) of specimens deep etched with procedure 2s in Table 22 [Solution A (Flick's reagent) + Solution B]. (a) Unmodified alloy. (b) Modified alloy

Al – Mg
5XX.X
5XXX

Al-Mg crystallographic data

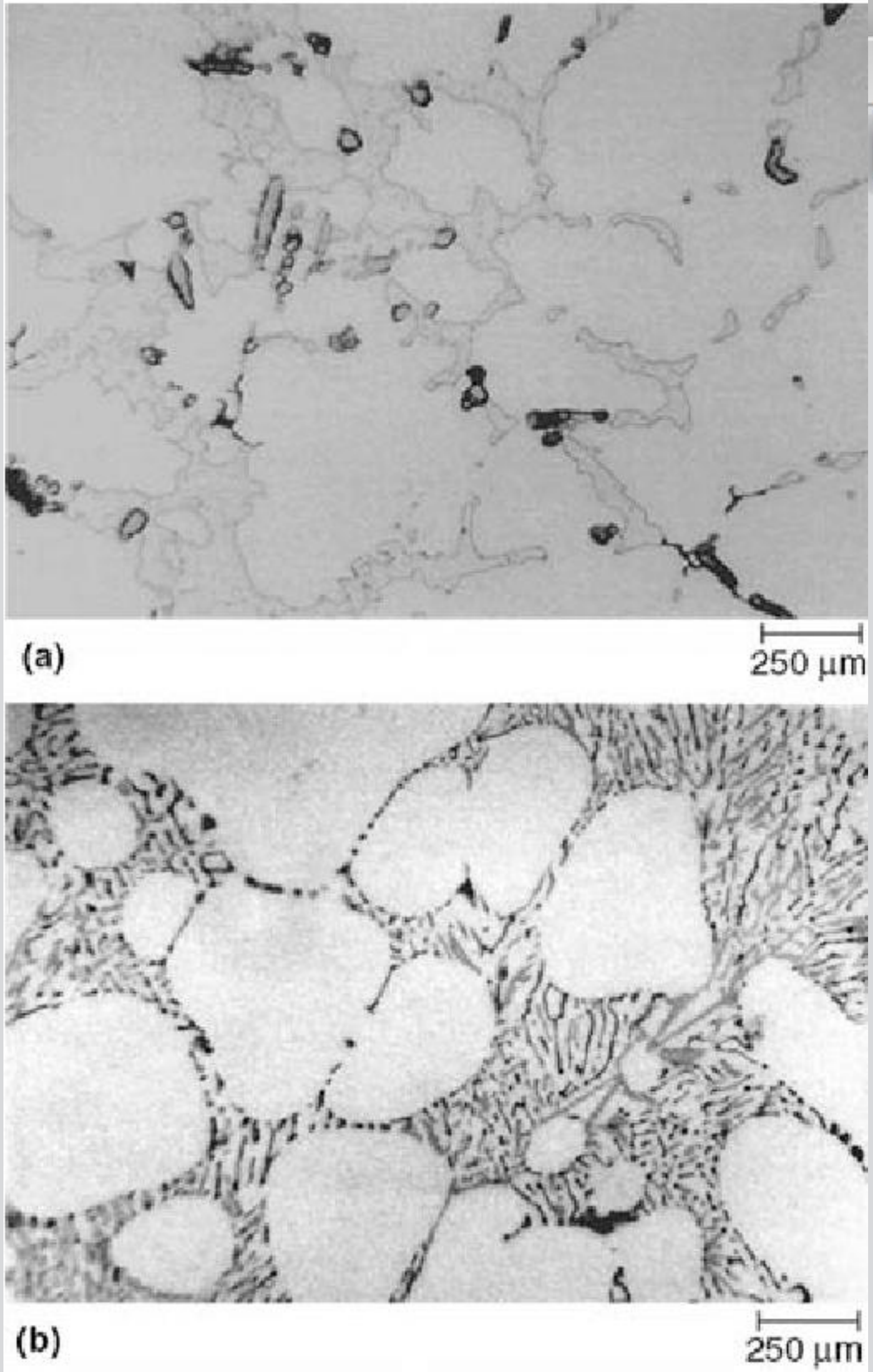
Phase	Composition, wt% Mg	Pearson symbol	Space group
(Al)	0 to 17.1	$cF4$	$Fm\bar{3}m$
$\beta(Al_3Mg_2)$	36.1 to 37.8	$cF1168$	$Fd\bar{3}m$
R	39	$hR53$	$R\bar{3}$
$\gamma(Al_{12}Mg_{17})$	42 to 58.0	$cI58$	$I\bar{4}3m$
(Mg)	87.1 to 100	$hP2$	$P6_3/mmc$
Metastable phases			
Al_2Mg	31.0	$tI24$	$I4_1/amd$
γ'	**38 to 56.2**	(a)	. . .

(a) Tetragonal



Al – Mg
5XX.X
5XXX

Typical examples of aluminum-magnesium commercial alloys. (a) Microstructure showing Al3Fe (gray) and Mg2Si (black) in-aluminum solid-solution matrix (alloy type A518 with 7.6% Mg). Etchant: 0.5% HF. Original magnification 560. (b) Microstructure showing ternary eutectic and-aluminum solid-solution dendrites matrix (alloy type A512 with 4Mg-1.8Si). Etchant: 0.5% HF. Original magnification 560

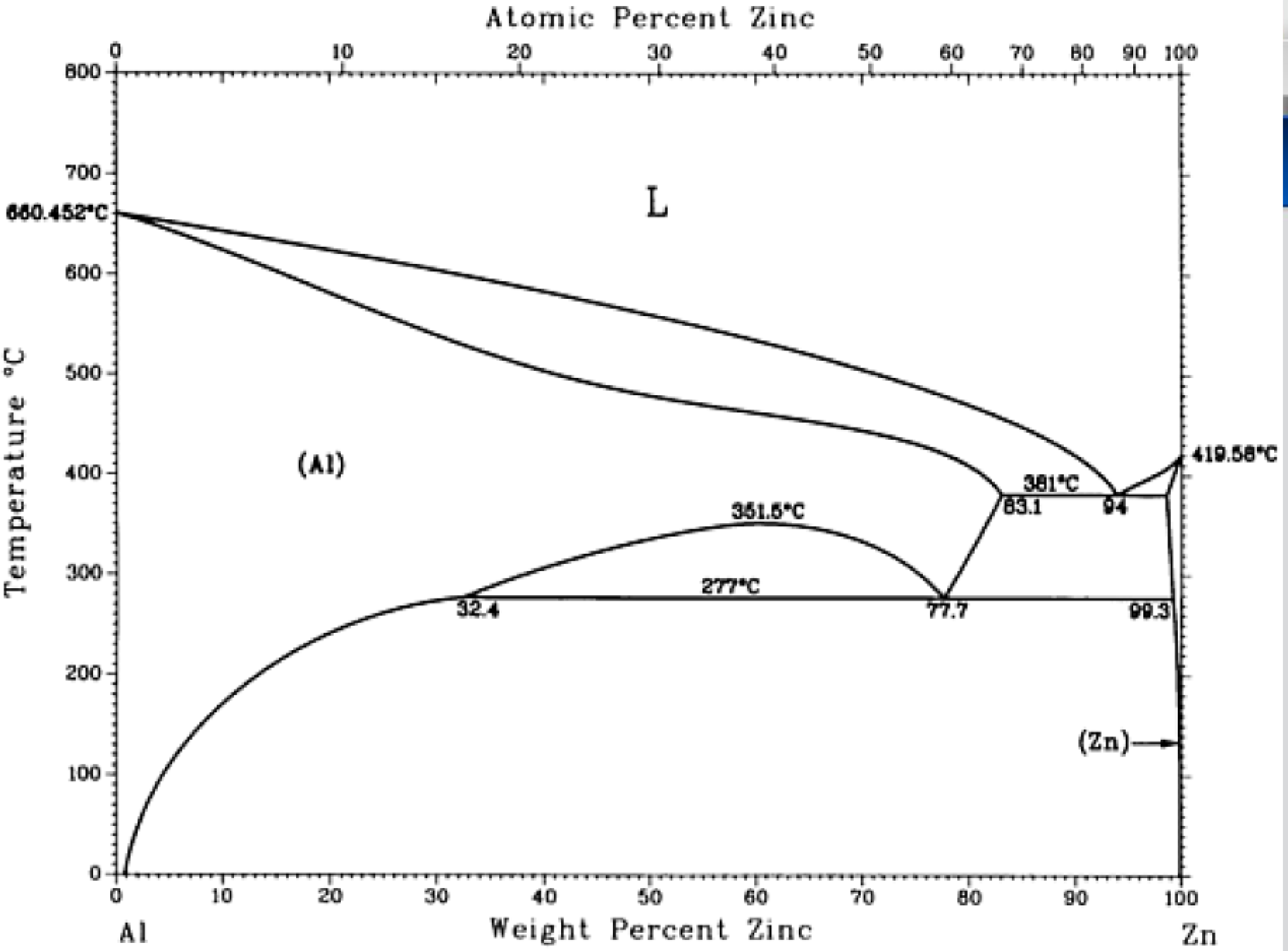


Al – Zn
7XX.X
7XXX

Al-Zn crystallographic data

Phase	Composition, wt% Zn	Pearson symbol	Space group
(Al)	0 to 83.1	*cF*4	$Fm\bar{3}m$
(Zn)	98.8 to 100	*hP*2	$P6_3/mmc$
Metastable phases			
$(\alpha'Al)_R$	78 to ∼85	...	$R\bar{3}m$
"*R*"	(a)	...	...
Y	...	...	...

(a) Coherent precipitate



Al – Zn
7XX.X
7XXX

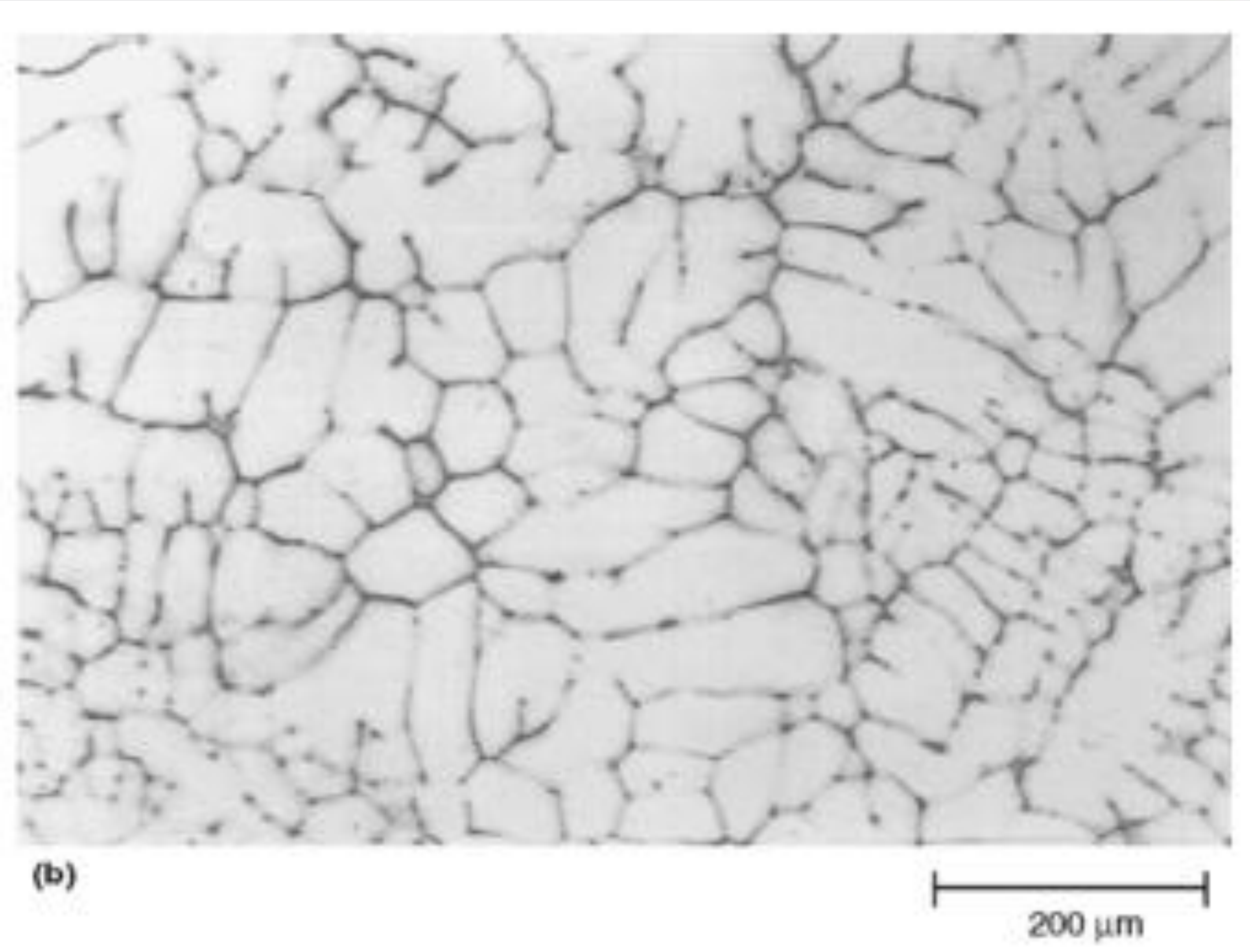


Fig. 7 Networklike morphology of second-phase structure in two hypoeutectic alloys. (a) As-cast 356 alloy. (b) As-cast 7050 alloy. Both etched with 0.5% HF (5m in Table 4) and magnified by 100×

Al – Zn
7XX.X
7XXX

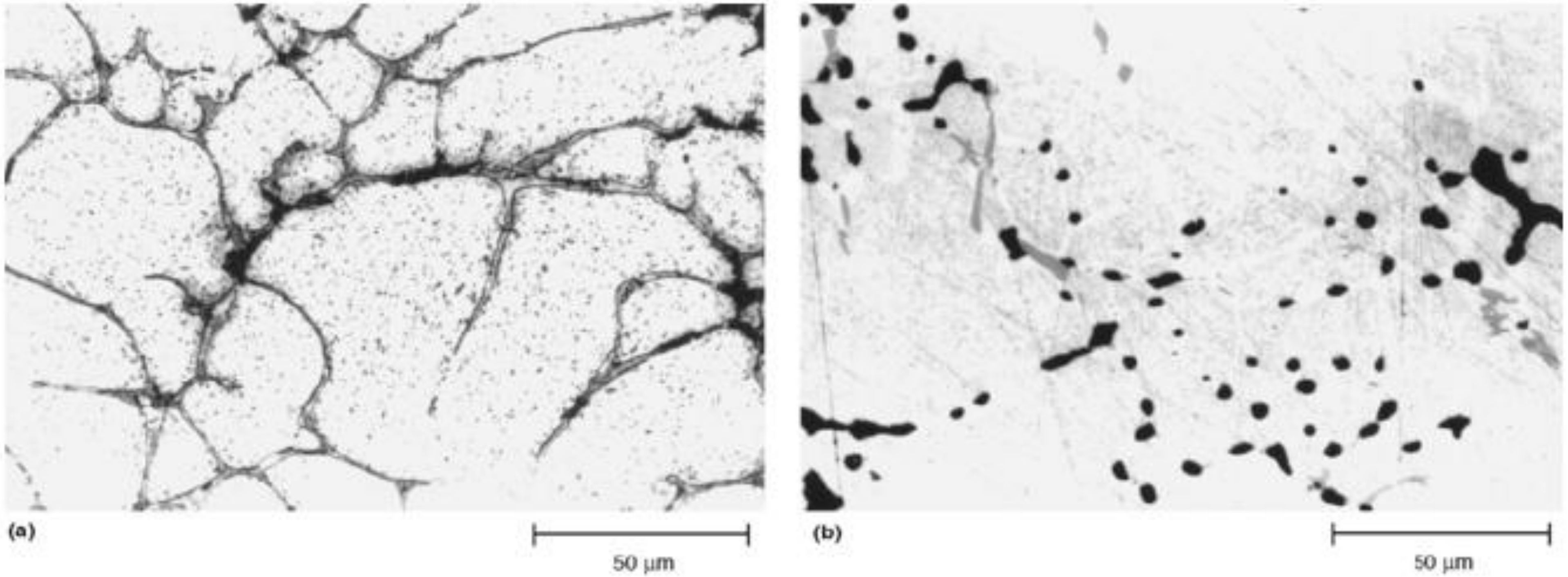
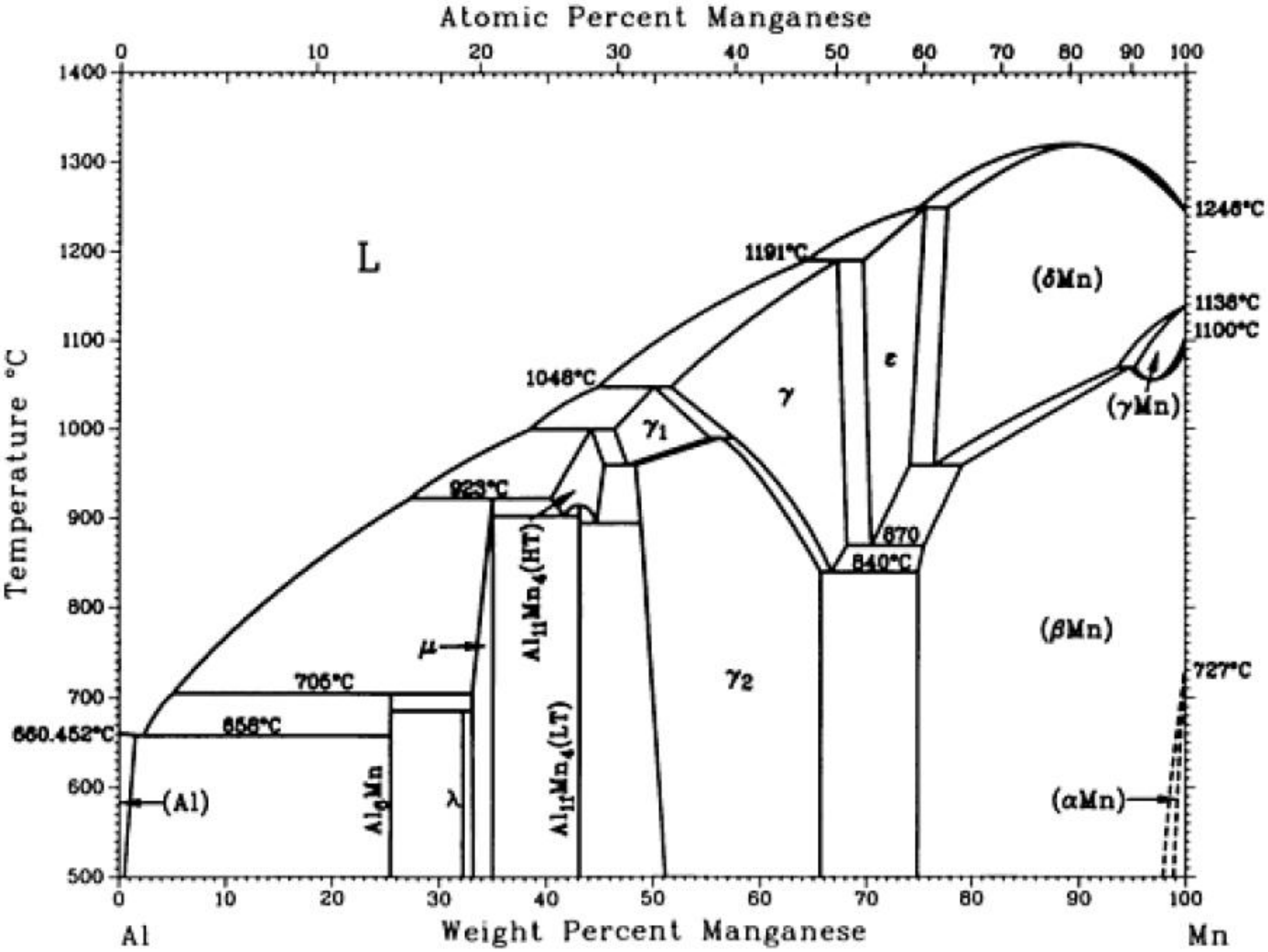


Fig. 12 Effect of heat treatment on phase morphology in alloy 7050. (a) As-cast structure with network of Al + M($MgZn_2$) eutectic and $Al_2Mg_3Zn_3$(T) precipitates. (b) Heat treated (T6) condition with globular morphology of M($MgZn_2$) eutectic and $Al_2Mg_3Zn_3$(T) precipitates. Both etched with 0.5% HF (5m in Table 4) and magnified by 500×

Al – Mn
3XXX



Atomic Percent Manganese
Weight Percent Manganese
Temperature °C
L
1191°C
1246°C
1138°C
1100°C
1048°C
923°C
870
840°C
706°C
658°C
660.452°C
727°C
(δMn)
(γMn)
(βMn)
(αMn)
(Al)
ε
γ
γ1
γ2
μ
λ
Al6Mn
Al11Mn4(HT)
Al11Mn4(LT)
Al
Mn

Al – Mn
3XXX

Al-Mn crystallographic data

Phase	Composition, wt% Mn	Pearson symbol	Space group
(Al)	0 to 1.25	$cF4$	$Fm\bar{3}m$
G[(a)]	(b)	$cI26$	$Im\bar{3}m$
Al_6Mn	25.2	$oC28$	$Cmcm$
λ("Al_4Mn")[(c)]	~29.4 to ~32	(d)	...
μ	~32 to 34.8	(d)	...
$Al_{10}Mn_3$(ϕ)	(b)	$hP28$	$P6_3/mmc$
$Al_{11}Mn_4$(LT)[(e)]	43	$aP30$	$P\bar{1}$
$Al_{11}Mn_4$(HT)[(e)]	40 to 45.0	$oP160$	$Pnma$
γ_1	47 to 55.7	(f)	...
γ_2[(g)]	48.2 to 64	$hR26$	$R\bar{3}m$
γ	51.8 to 68.2	(f)	...
ε	69.8 to 75	$hP2$	$P6_3/mmc$
τ	(b)	$tP2$	$P4/mmm$
(δMn)	76.5 to 100	$cI2$	$Im\bar{3}m$
(γMn)	95.3 to 100	$cF4$	$Fm\bar{3}m$
(βMn)	75.0 to 100	$cP20$	$P4_132$
(αMn)	~99 to 100	$cI58$	$I\bar{4}3m$

(a) Several other structures have been ascribed to the G phase or variants of the G phase (G', G").

(b) Metastable phase.

(c) A simple orthorhombic structure was reported in an alloy described as "Al_4Mn."

(d) Hexagonal.

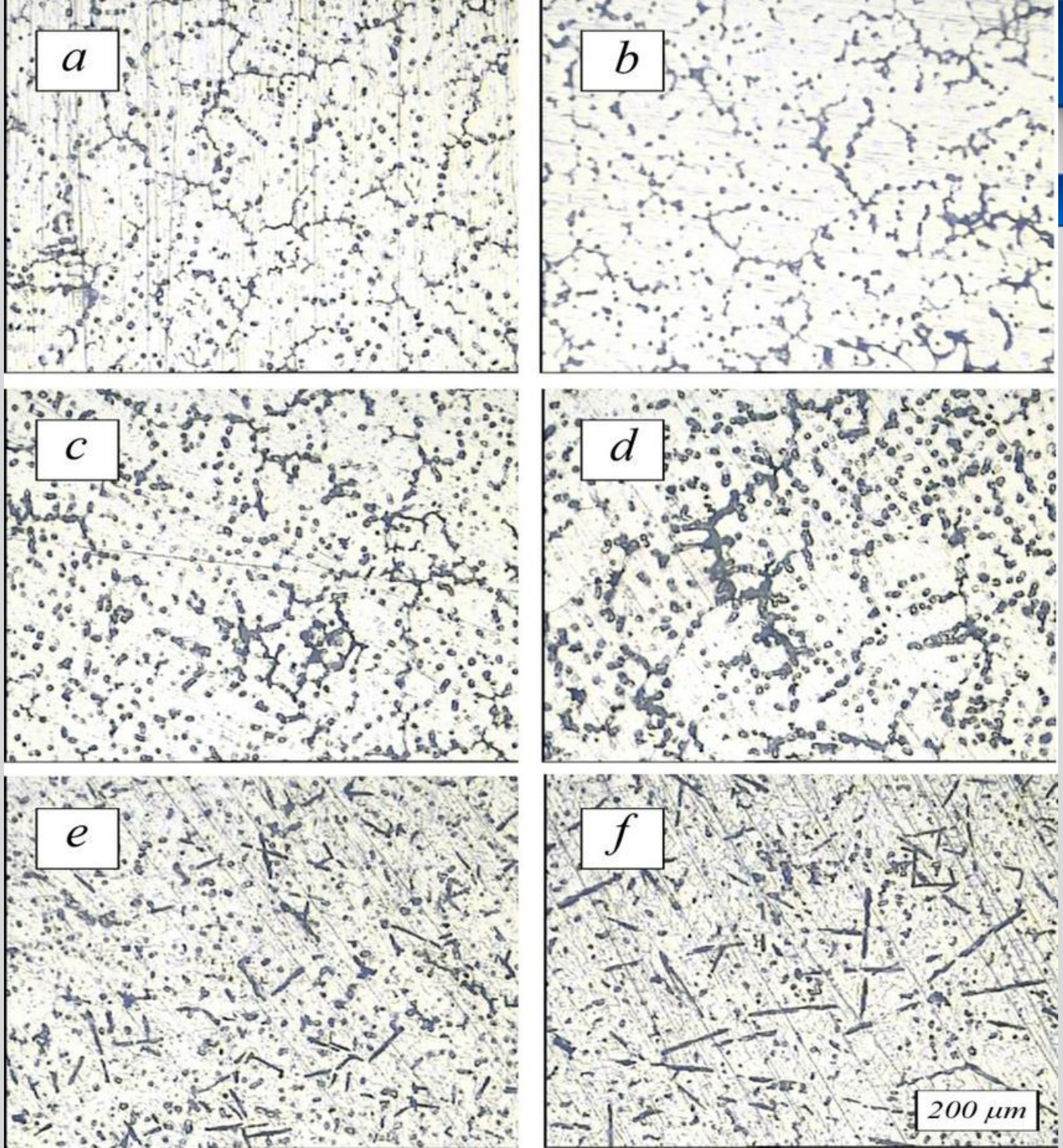
(e) Variants of this structure are described as complex stacking sequences along the *b* axis.

(f) Unknown.

(g) The structure has been described as distorted γ-brass type, cubic (bcc or fcc), and rhombohedral.

Al – Mn
3XXX

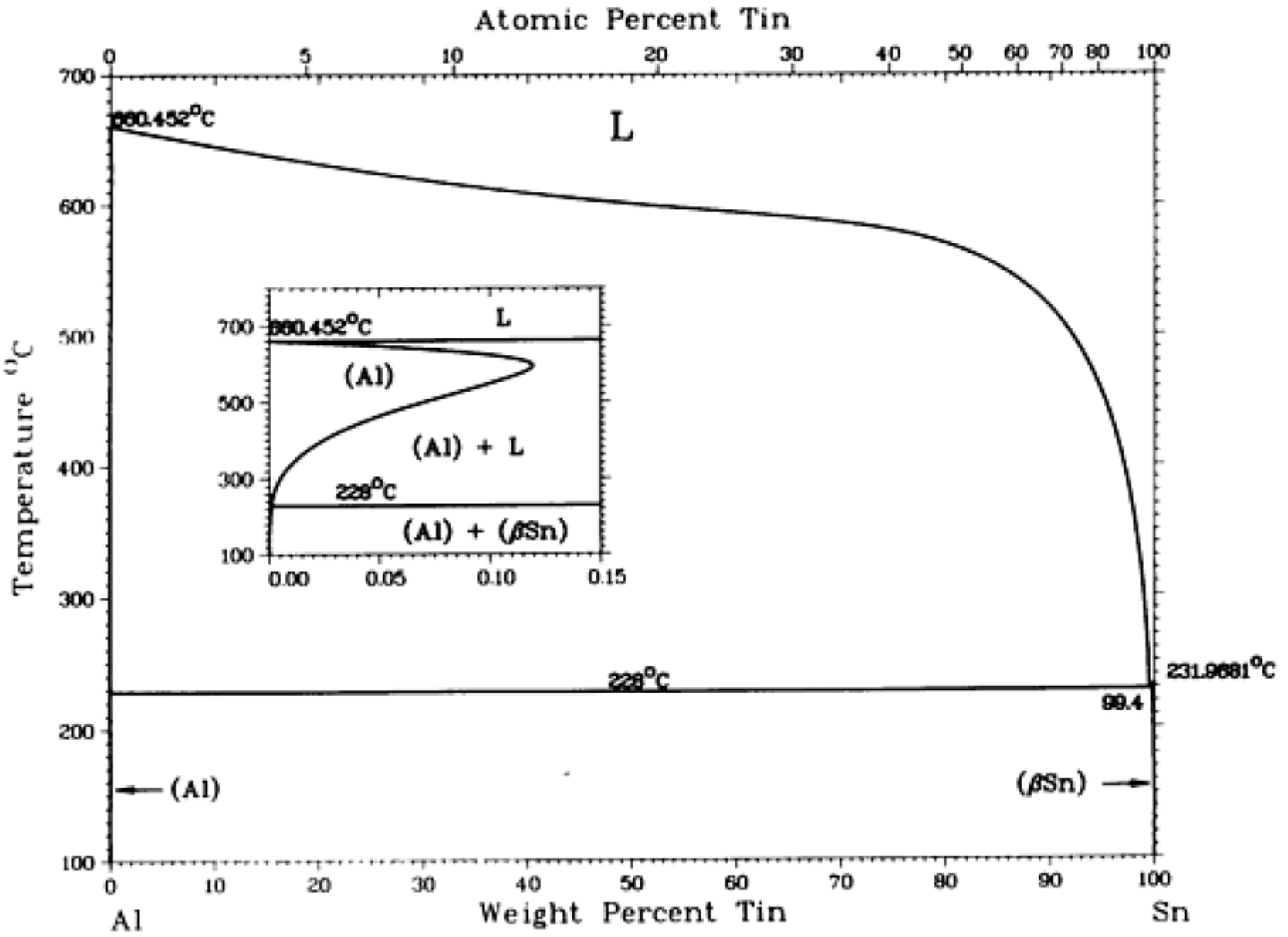
Optical microstructure of Al-6%Mg alloy as a function of Mn content (a) 0% (b) 0.03% (c) 0.3% (d) 1% (e)3% (f) 5%. In order to understand the effect of Mn content on the phase formation in the Al-6%Mg- X%Mn alloy, a cross section of equilibrium phase diagram with different levels of Mn content is



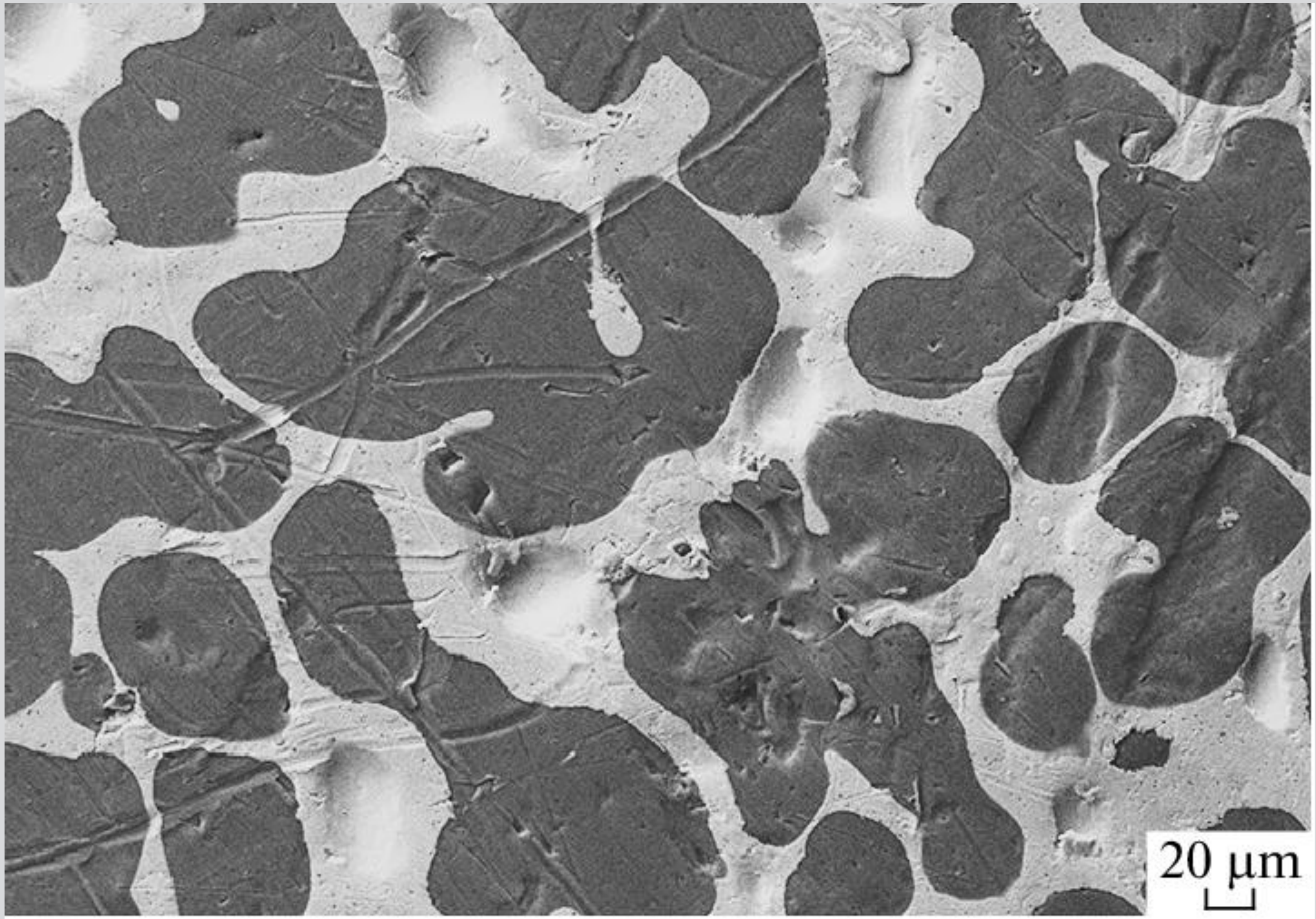
Al – Sn
8XX.X

Al-Sn crystallographic data

Phase	Composition, wt% Sn	Pearson symbol	Space group
(Al)	0	*cF*4	$Fm\bar{3}m$
(βSn)	100	*tI*4	$I4_1/amd$
(αSn)	100	*cF*8	$Fd\bar{3}m$
Metastable phase			
Γ	>81.5	*hP*1	*P6/mmm*

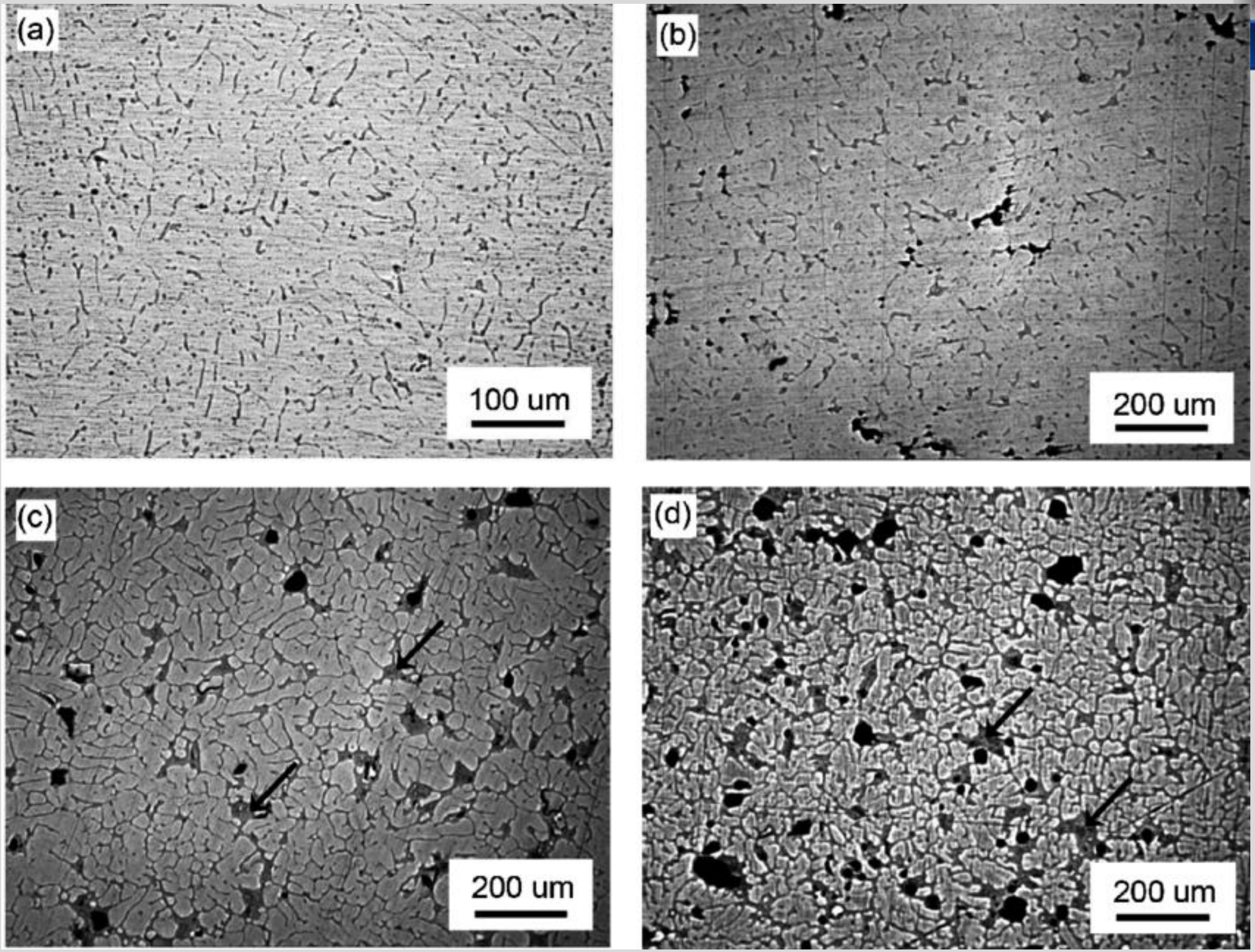


Al – Sn
8XX.X



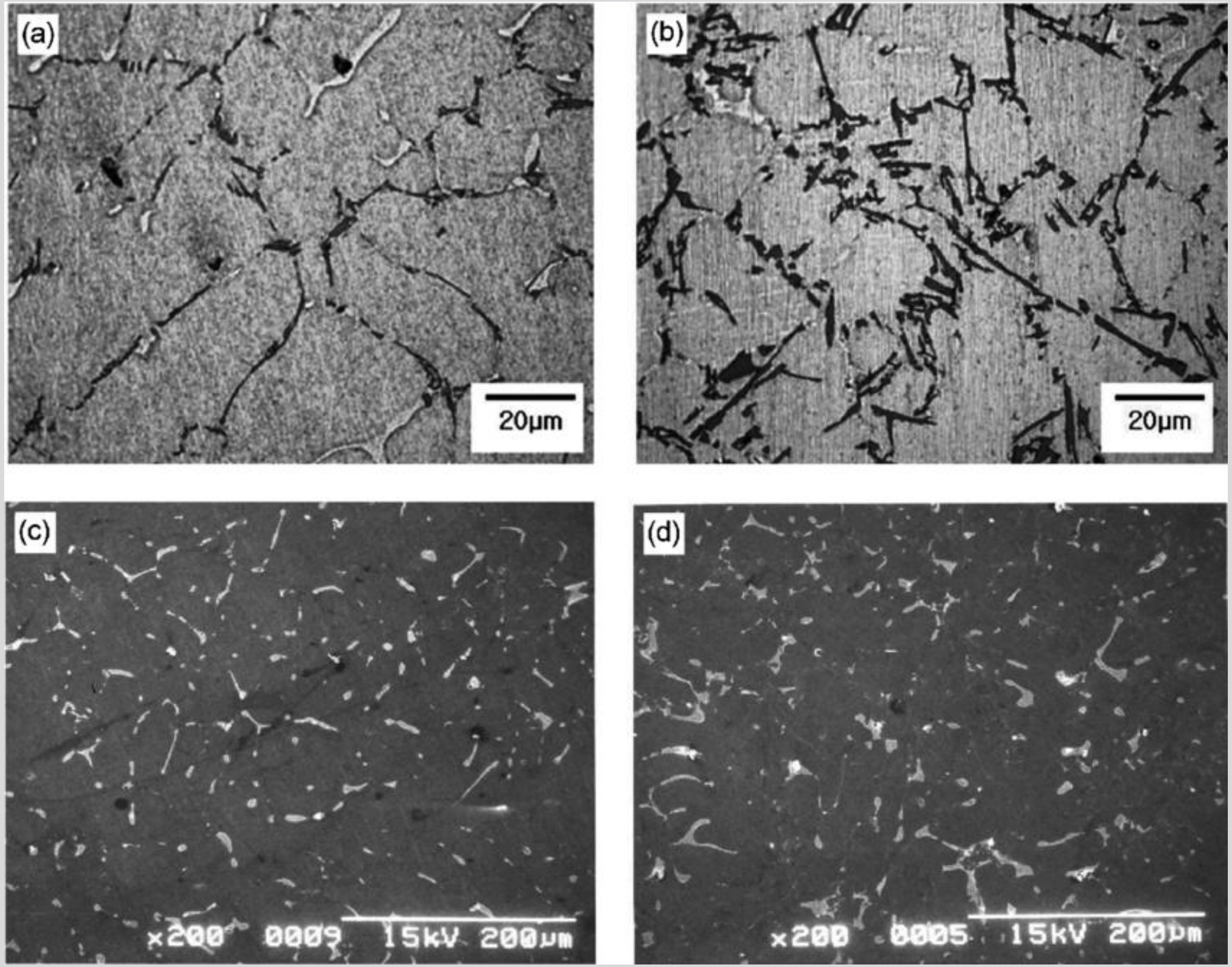
Microstructure of the Al-50 wt % Sn alloy.

Al – Sn
8XX.X



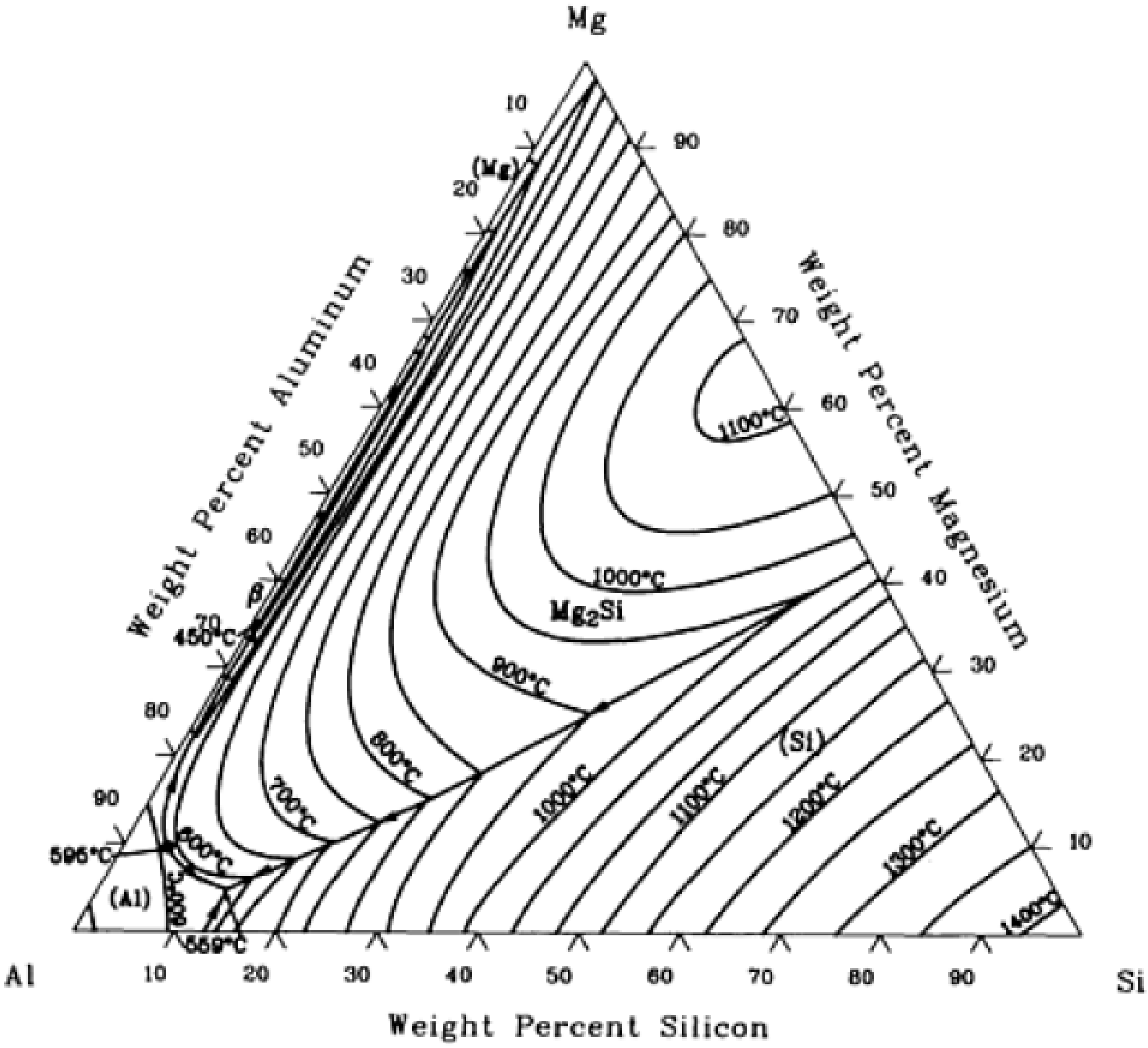
Microstructure of Al-Sn alloy with addition of Cu: arrows indicate coarsened Sn particles: (a) Al-10%Sn; (b) Al-10%Sn-1%Cu; (c) Al-30%Sn-1%Cu; (d) Al-40%Sn-1%Cu.

Al – Sn
8XX.X



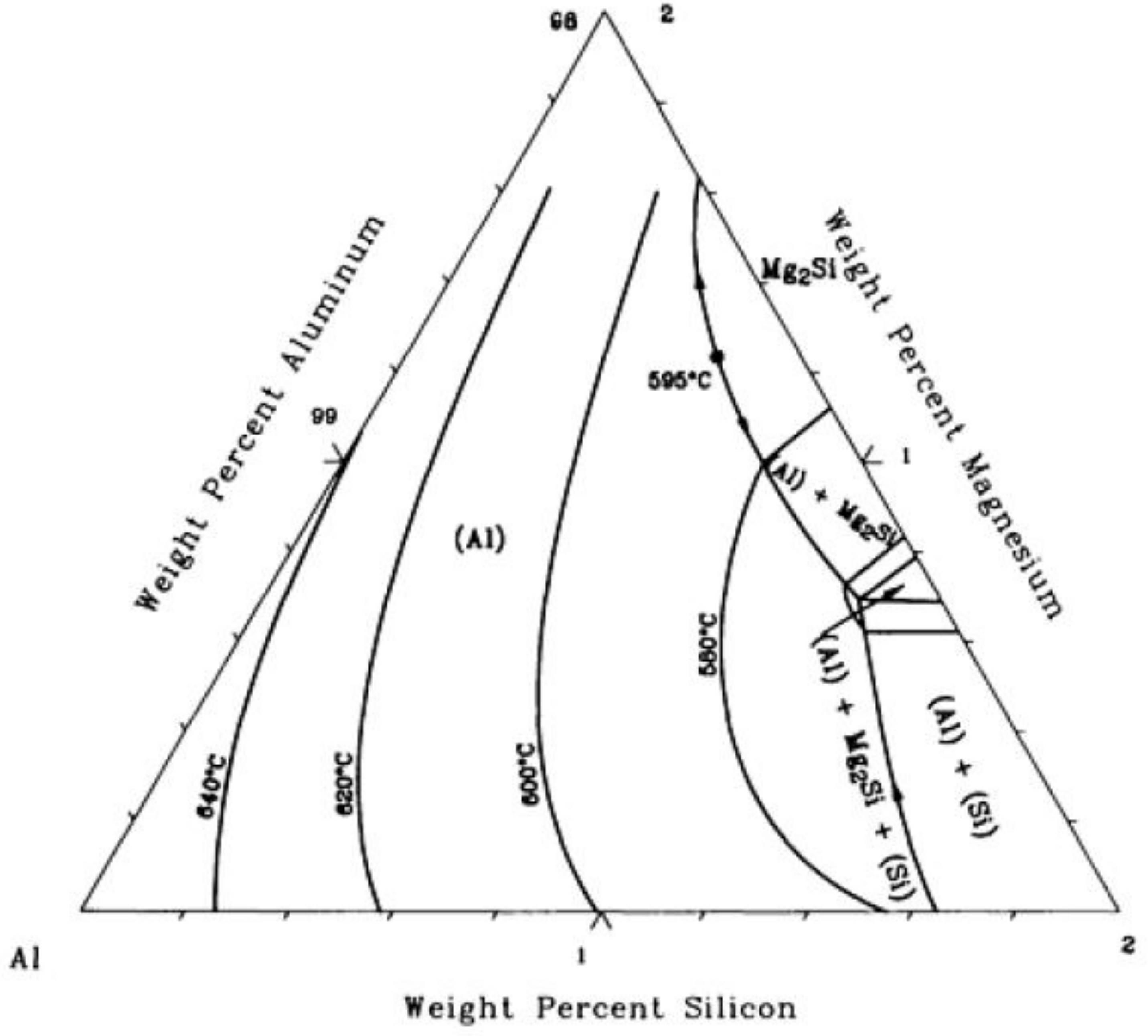
Microstructure of Al-Sn alloy with addition of Si: (a), (c) Al-10Sn-2Si, (b), (d)Al-10Sn-7Si.

Al – Si – Mg
3XX.X
6XXX



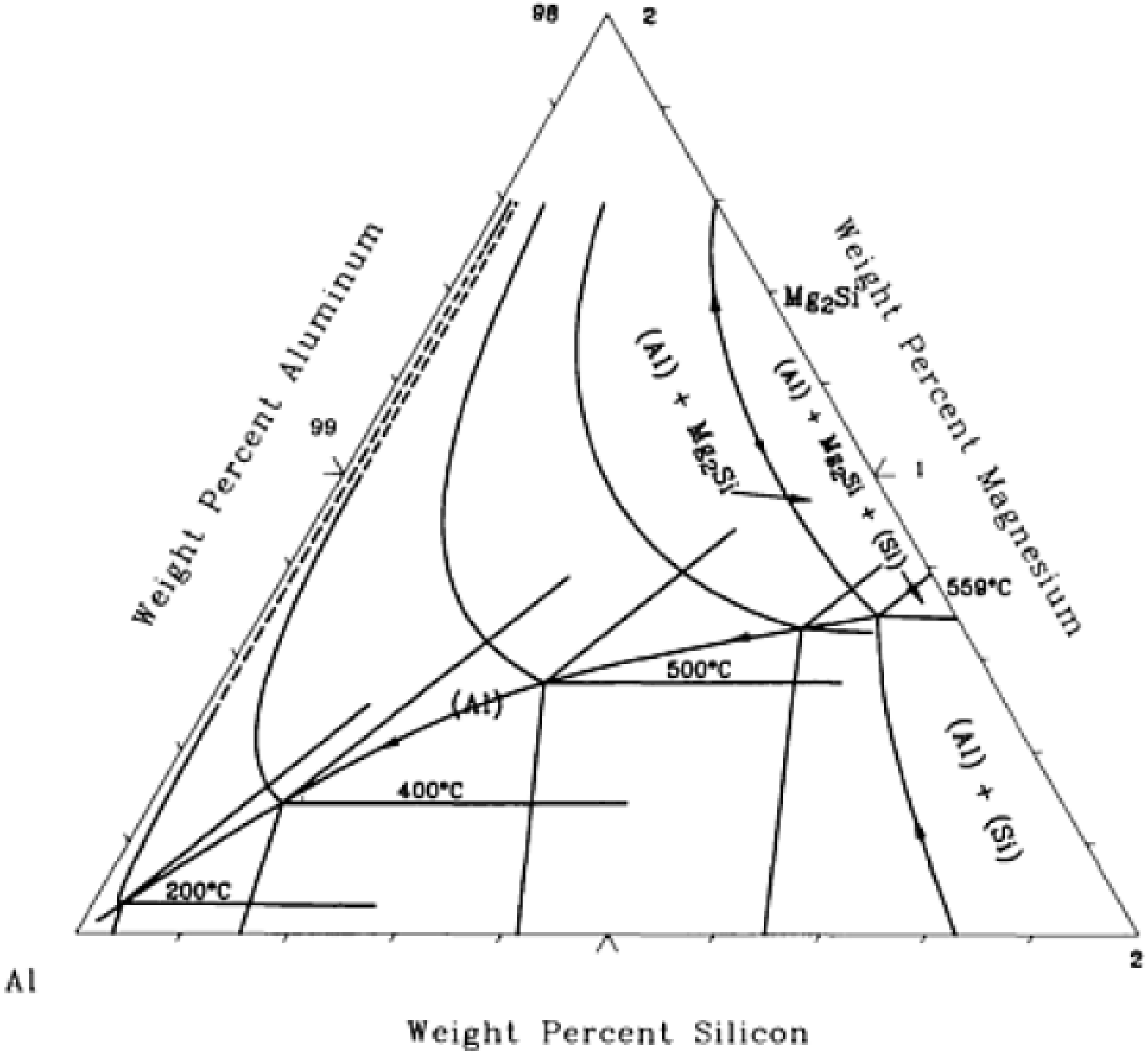
Al-Mg-Si liquidus projection [73Wil 34].

Al – Si – Mg
3XX.X
6XXX



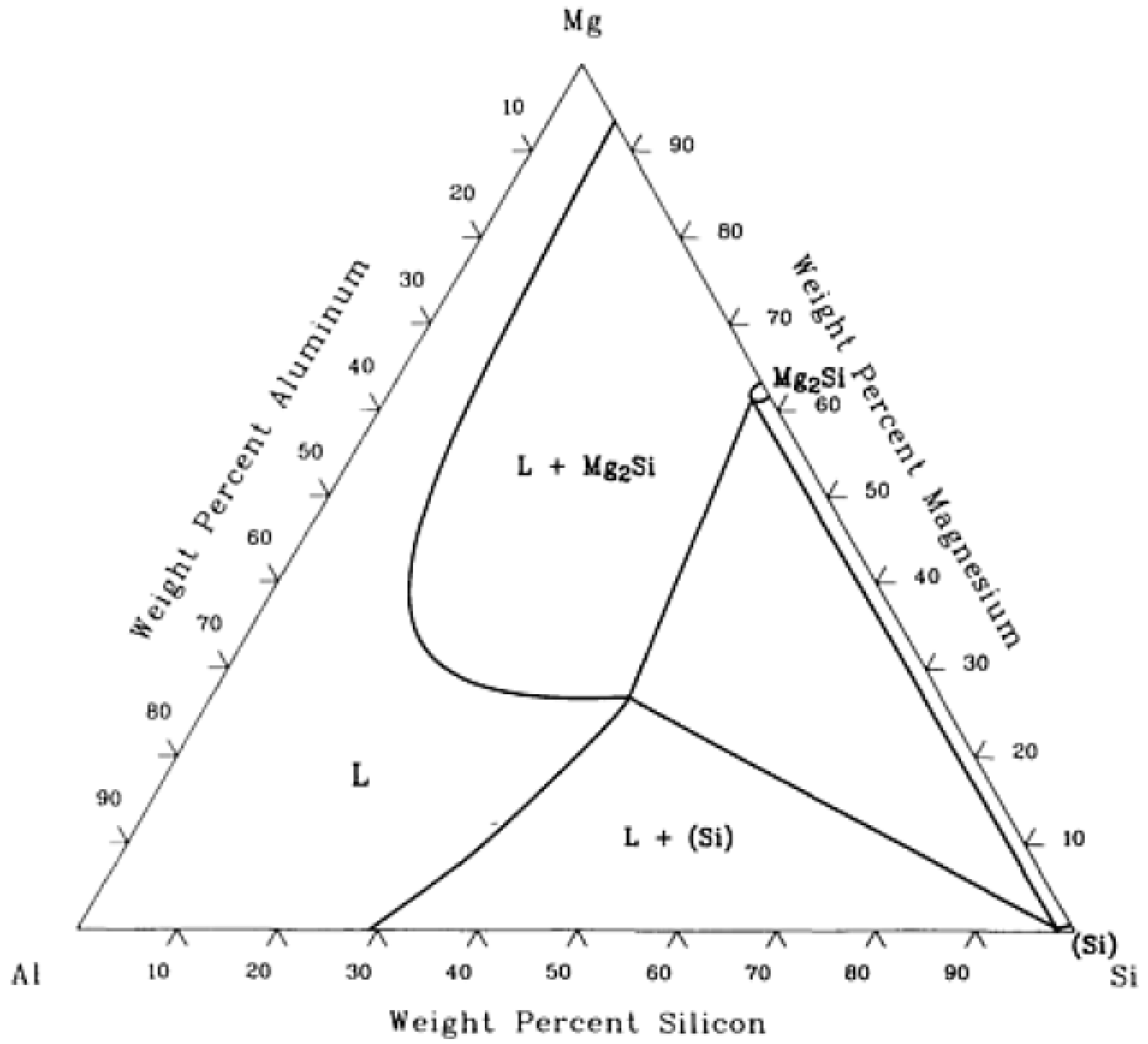
Al-Mg-Si solidus projection [73Wil 34].

Al – Si – Mg
3XX.X
6XXX



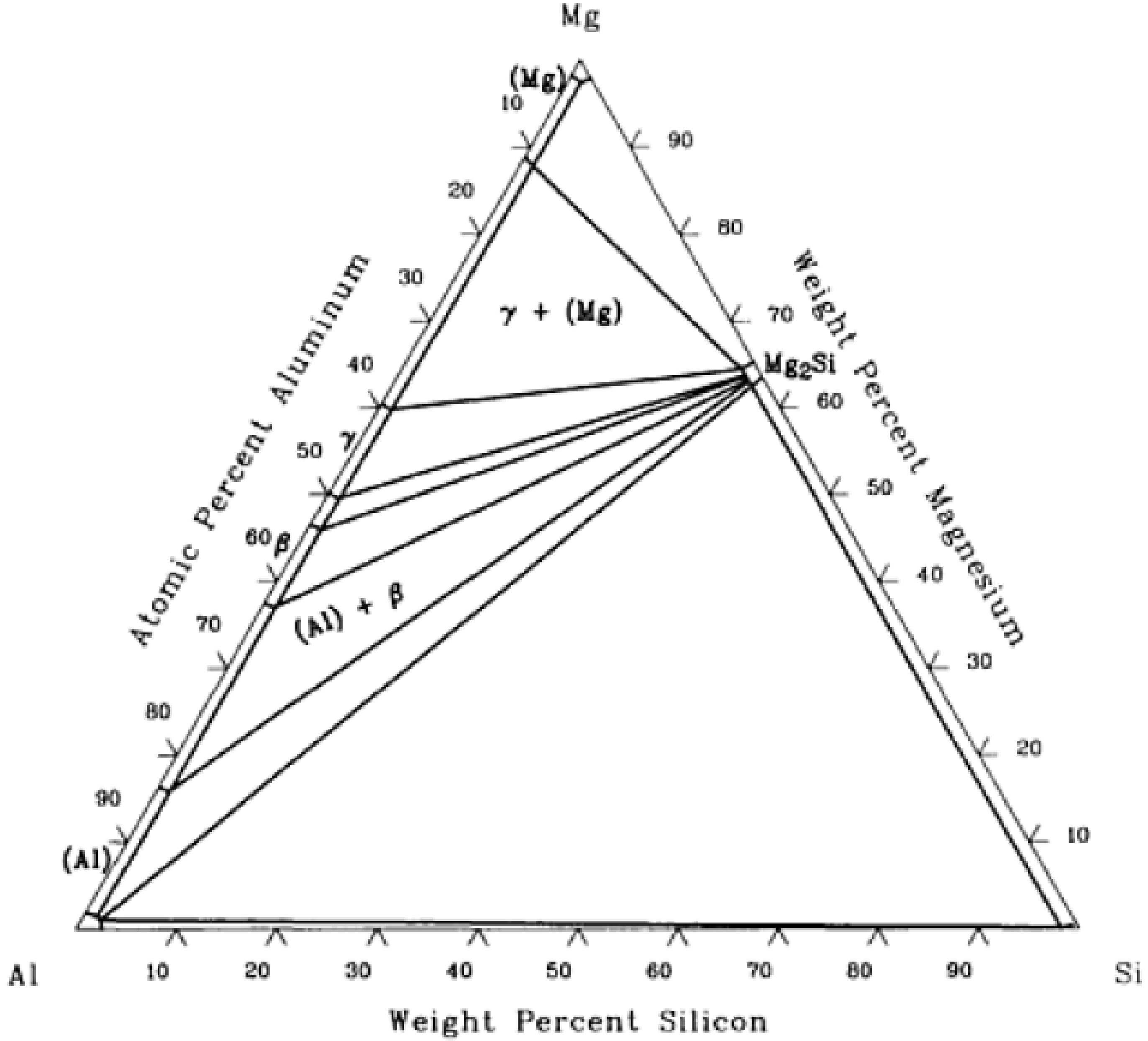
Al-Mg-Si solvus projection [73Wil 34].

Al – Si – Mg
3XX.X
6XXX



Al-Mg-Si isothermal section at 800 °C [88Rok 61].

Al – Si – Mg
3XX.X
6XXX



Al-Mg-Si isothermal section at 430 °C [88Rok 61].

Al – Si – Mg
3XX.X
6XXX

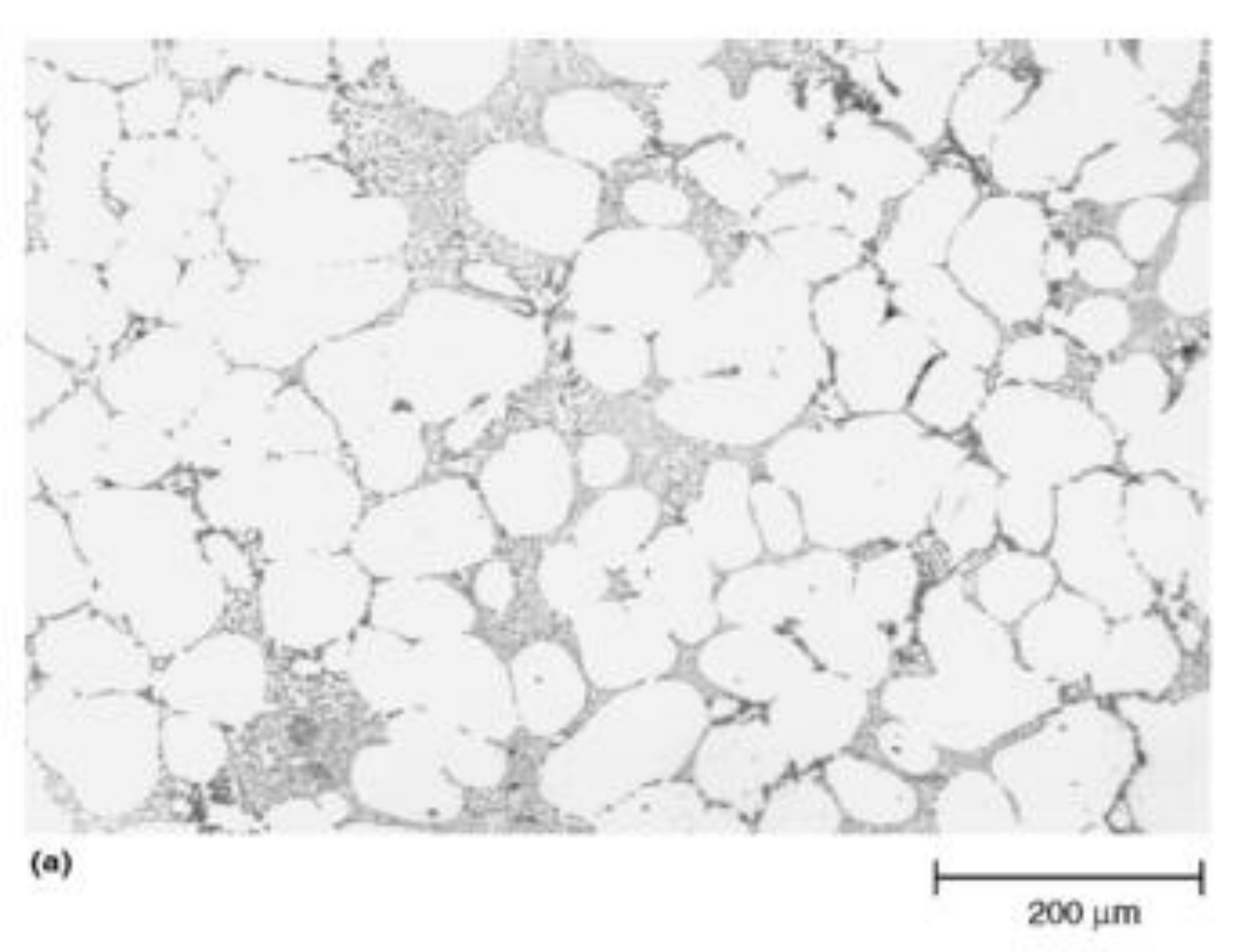
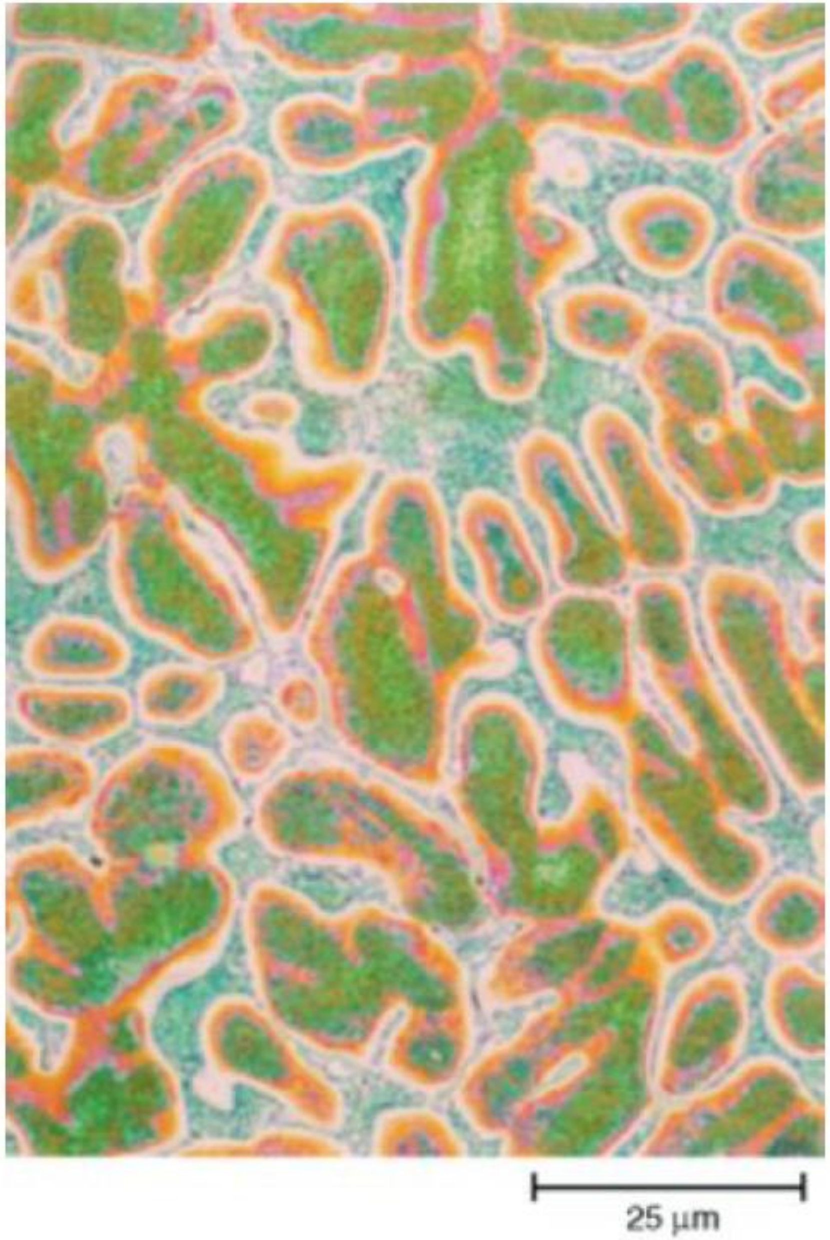


Fig. 7 Networklike morphology of second-phase structure in two hypoeutectic alloys. (a) As-cast 356 alloy. (b) As-cast 7050 alloy. Both etched with 0.5% HF (5m in Table 4) and magnified by 100×

Al – Si – Mg
3XX.X
6XXX

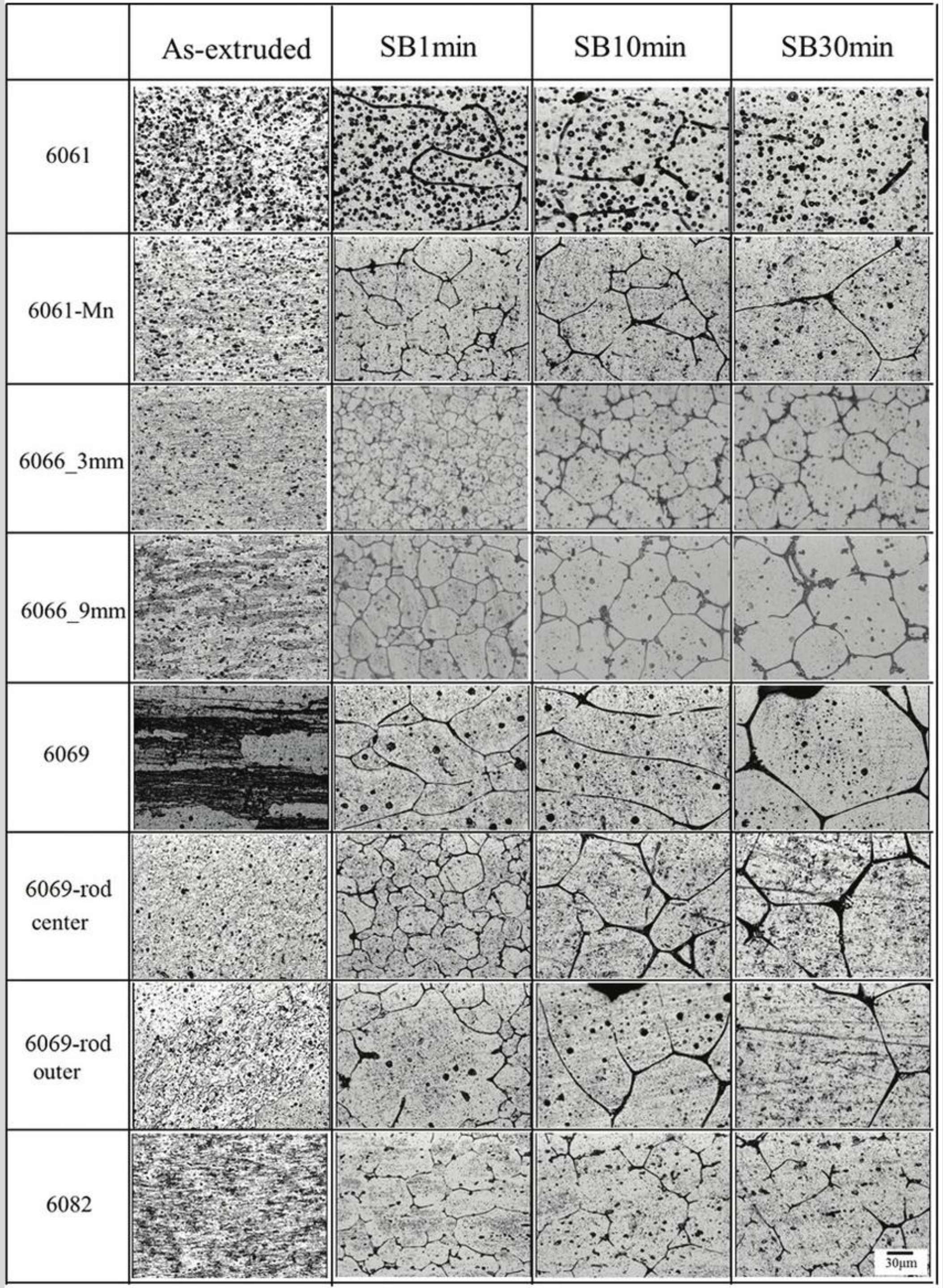
Fig. 37 Phase constituent identification in alloy 356.0 with reagent 13m (Table 4). Time of attack: 5 s. Orange-green fields are primary dendritic microsegregation regions with α-Al (solid solution). Blue fields are interdendritic eutectic (α-Al + Si). 800×. Compare with Table 18. (Małgorzata Warmuzek, Foundry Research Institute, Kraków, Poland)



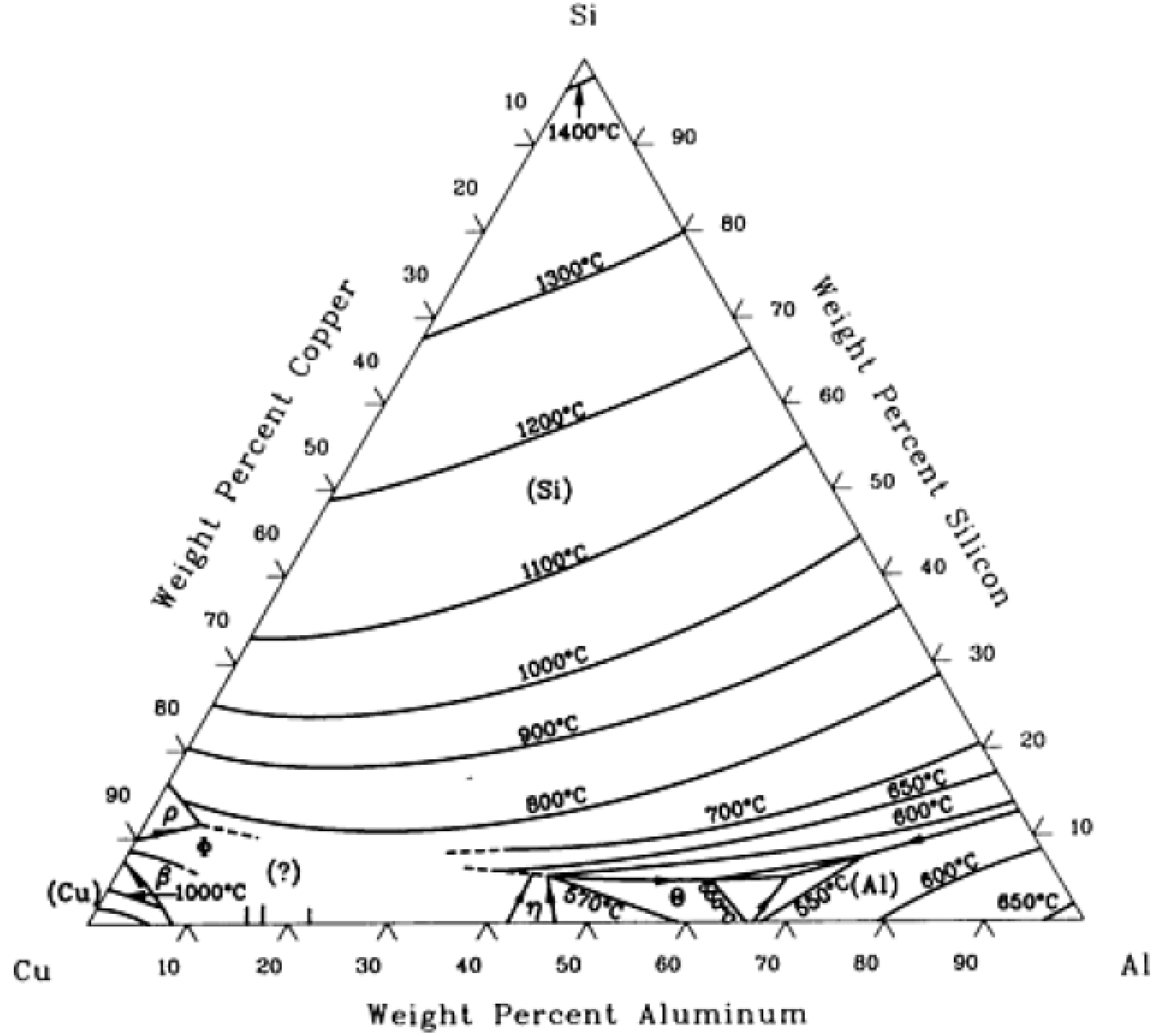
Magnification: 800×
Alloy: 356.00
Primary dendritic microsegregation: primary α-Al, orange-green fields; interdendritic eutectic α-Al + Si, blue fields
Time of attack: 5 s

Al – Si – Mg
3XX.X
6XXX

Microstructure evolution of Al-Mg-Si alloys via salt bath.

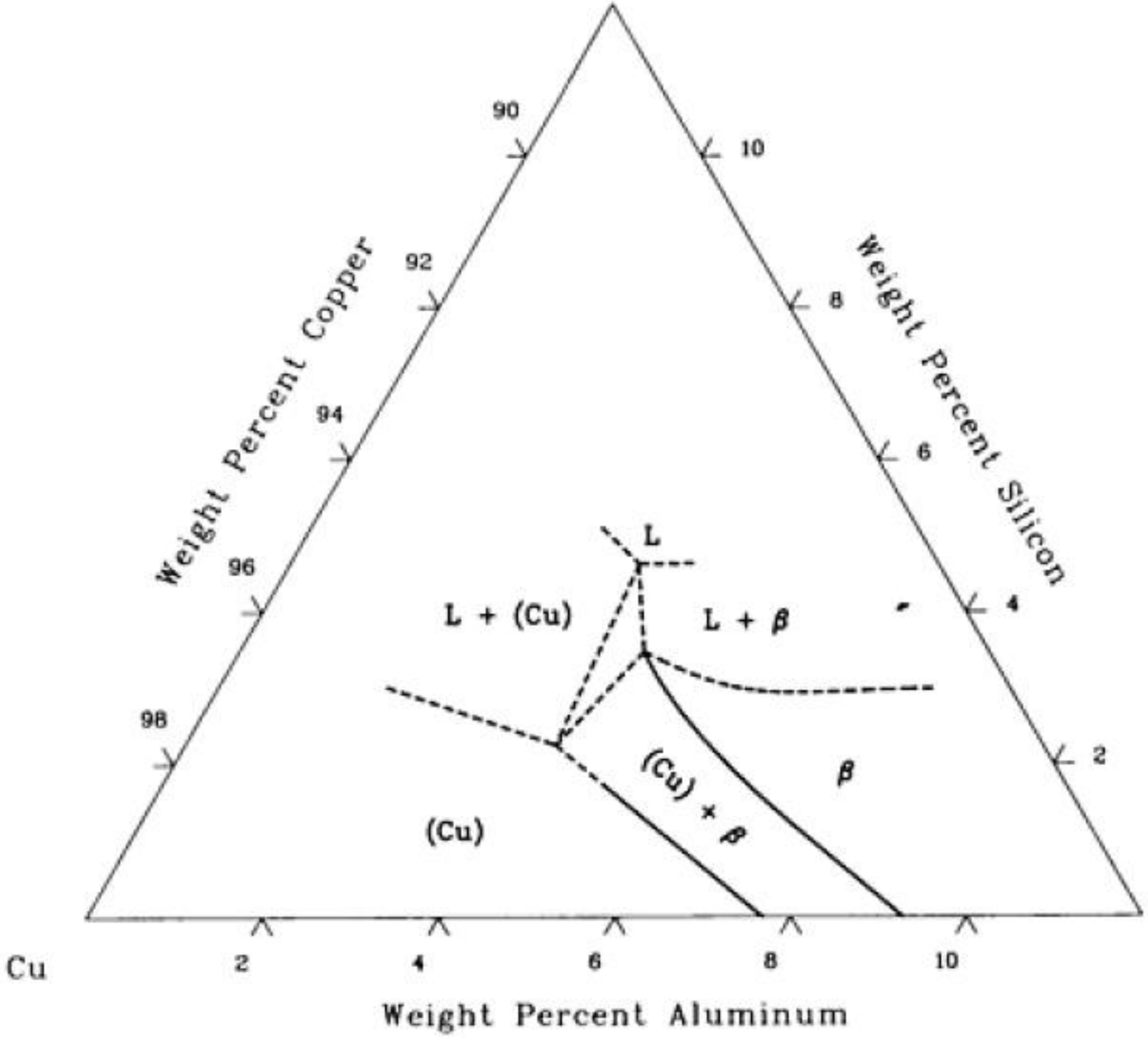


Al – Si – Cu
3XX.X



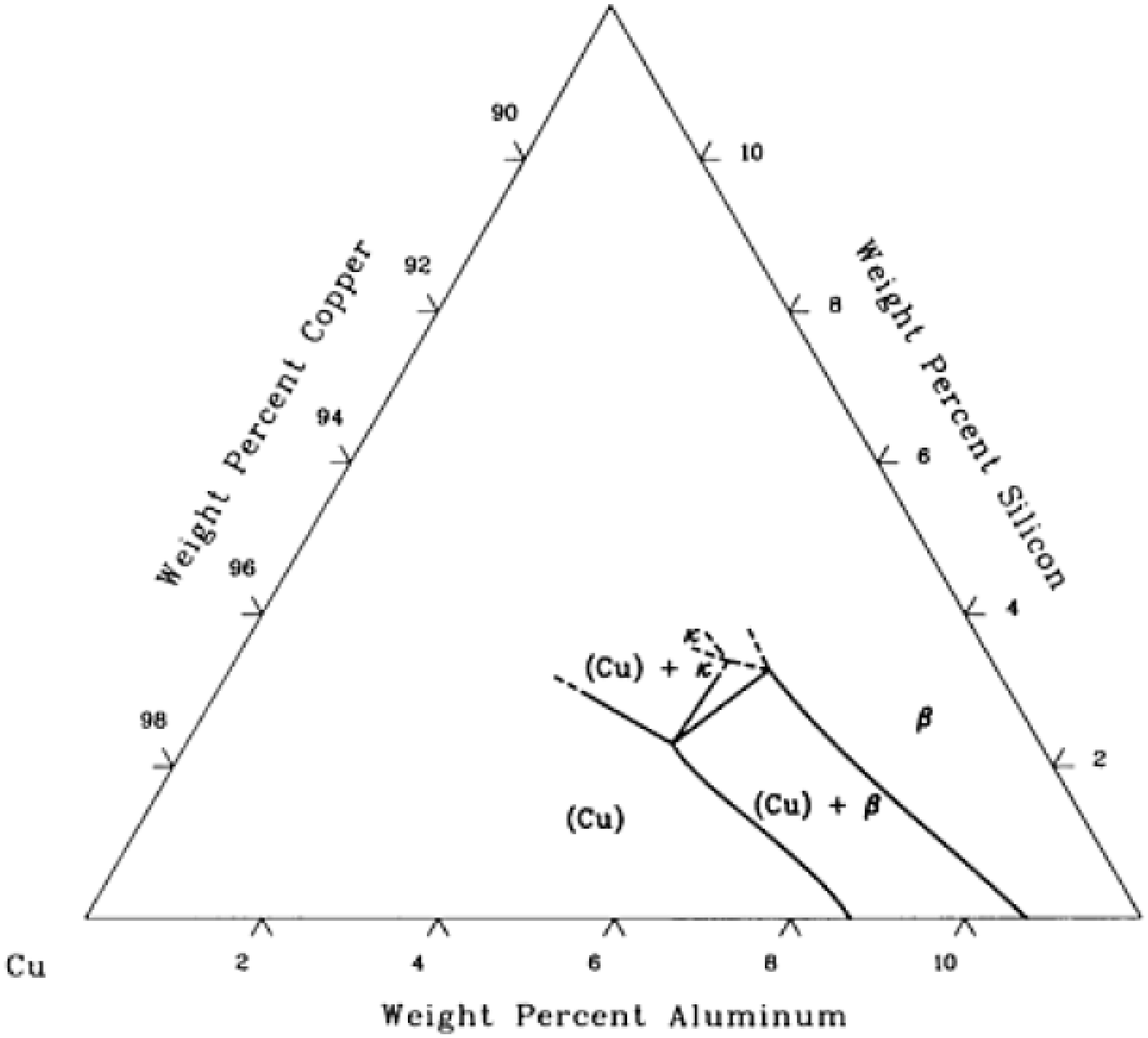
Al-Cu-Si liquidus projection [79Cha 38].

Al – Si – Cu
3XX.X



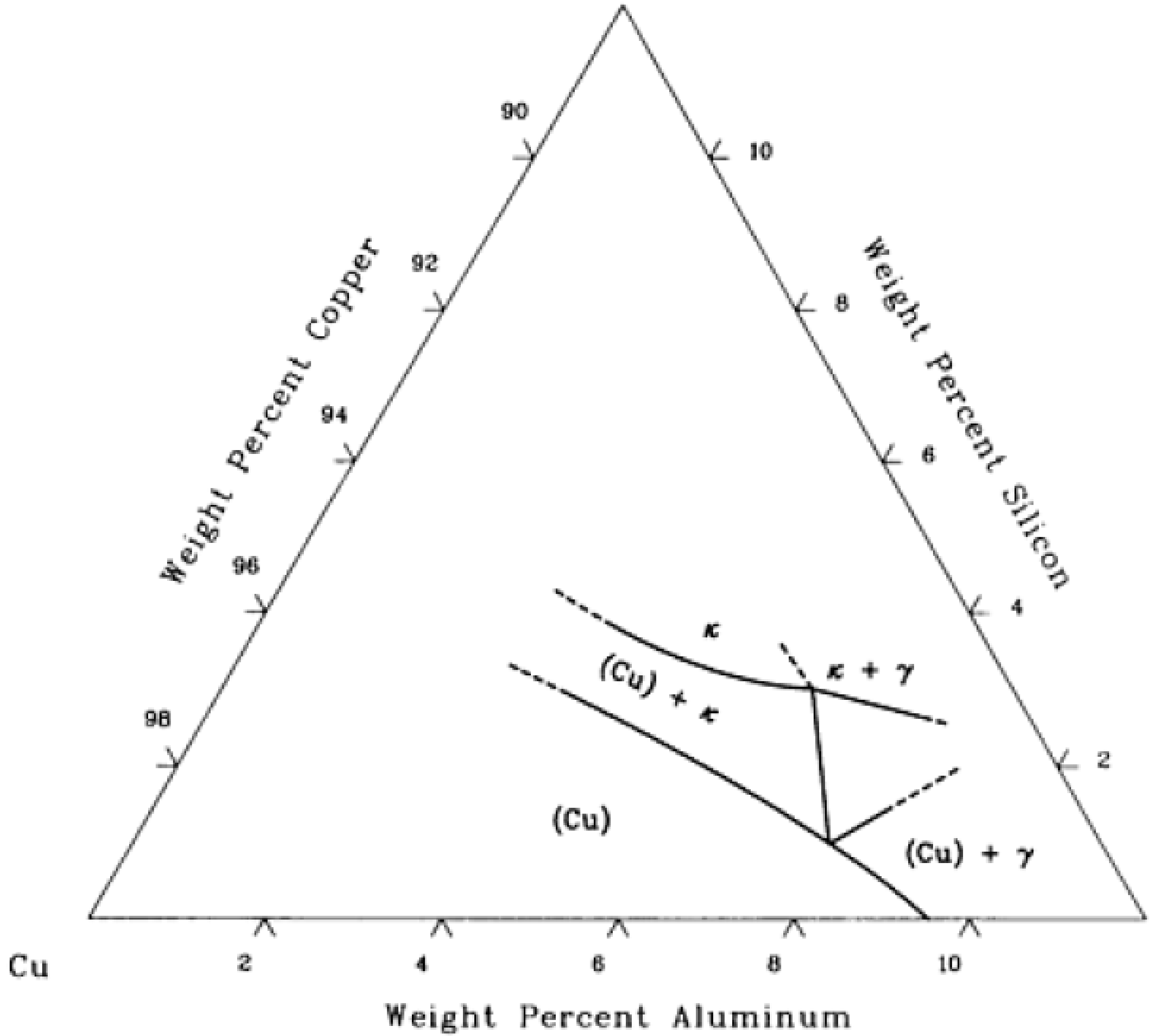
Al-Cu-Si isothermal section at 955 °C [48Wil 5].

Al – Si – Cu
3XX.X



Al-Cu-Si isothermal section at 750 °C [48Wil 5].

Al – Si – Cu 3XX.X



Al-Cu-Si isothermal section at 400 °C [48Wil 5].

Al – Si – Cu
3XX.X

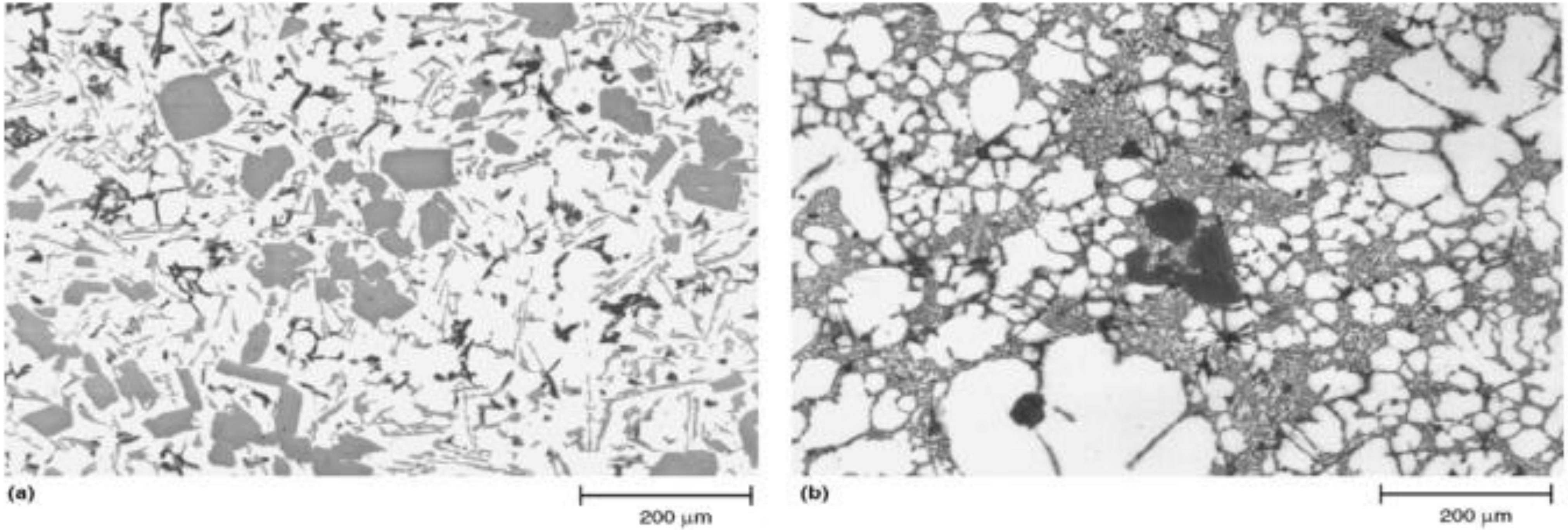


Fig. 9 Dispersed phase and networklike morphology of second-phase structure in two hypereutectic alloys. (a) As-cast 390 alloy with primary precipitates of silicon (light gray). (b) As-cast 384.0 alloy with primary precipitates of Al-Fe-Si. Both etched with 0.5% HF (5m in Table 4) and magnified by 100×

Al – Si – Cu
3XX.X

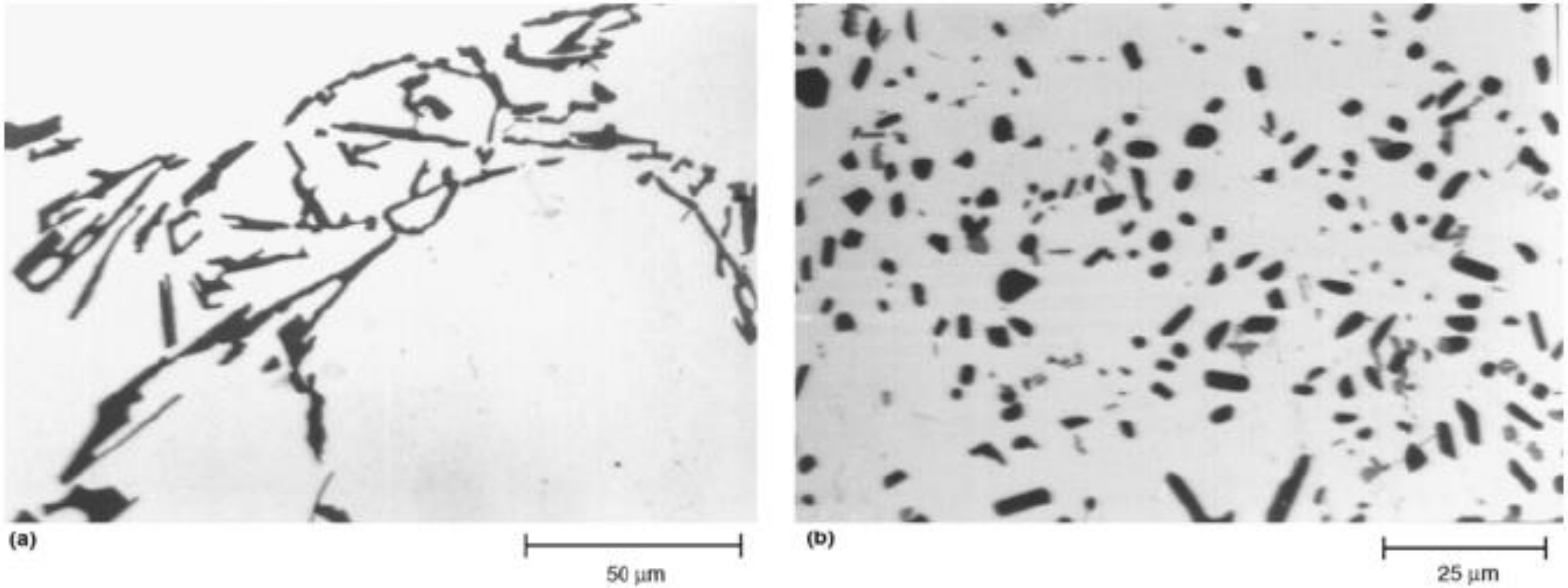
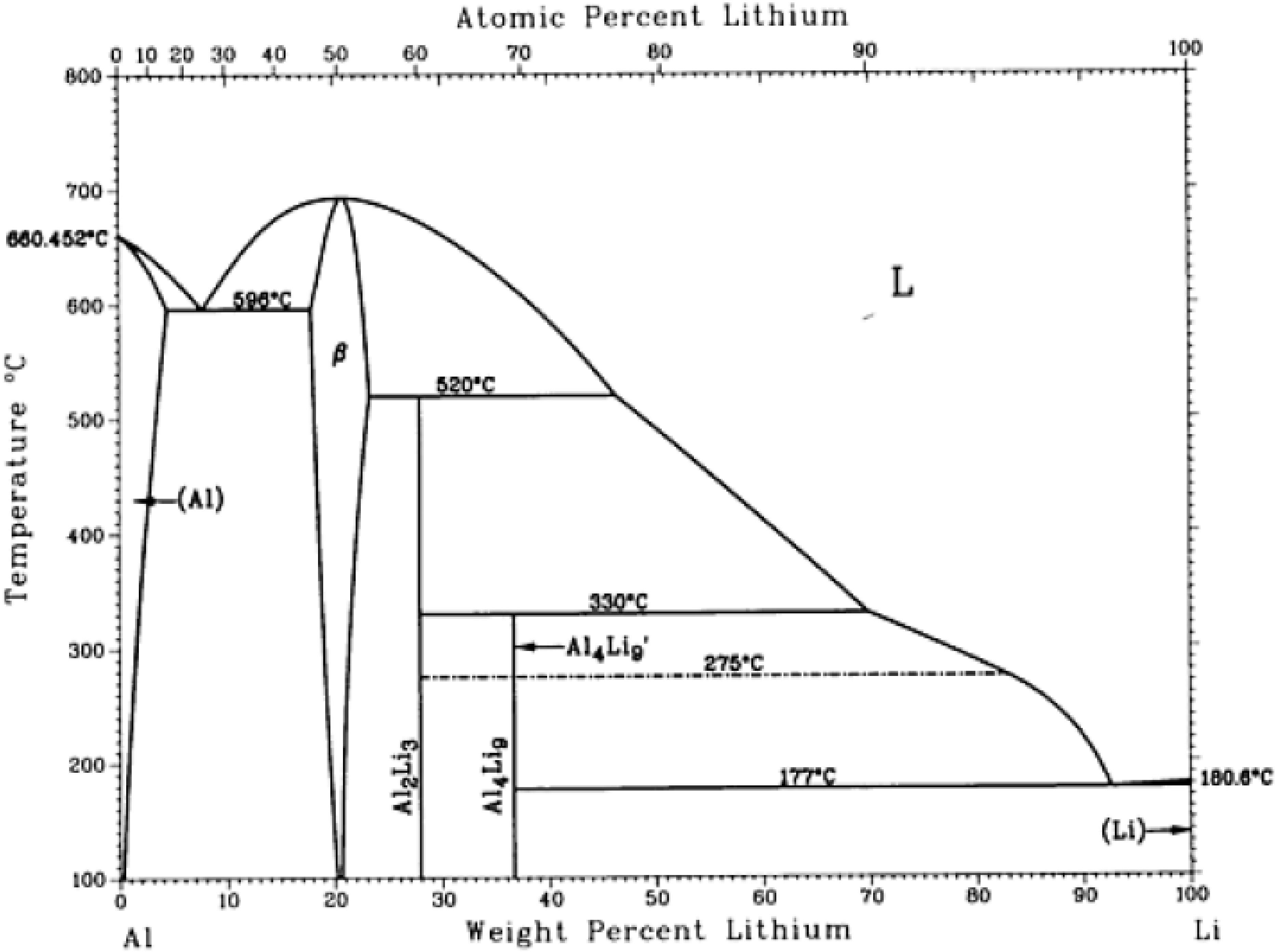


Fig. 11 Effect of heat treatment on phase morphology in a hypoeutectic alloy (alloy 355). (a) As-cast structure (at 500× magnification) with a continuous network of interdendritic precipitates of eutectic silicon. (b) Heat treated condition (T6) of same alloy with globular eutectic silicon precipitates shown at 750×. Both etched with 0.5% HF (5m in Table 4)

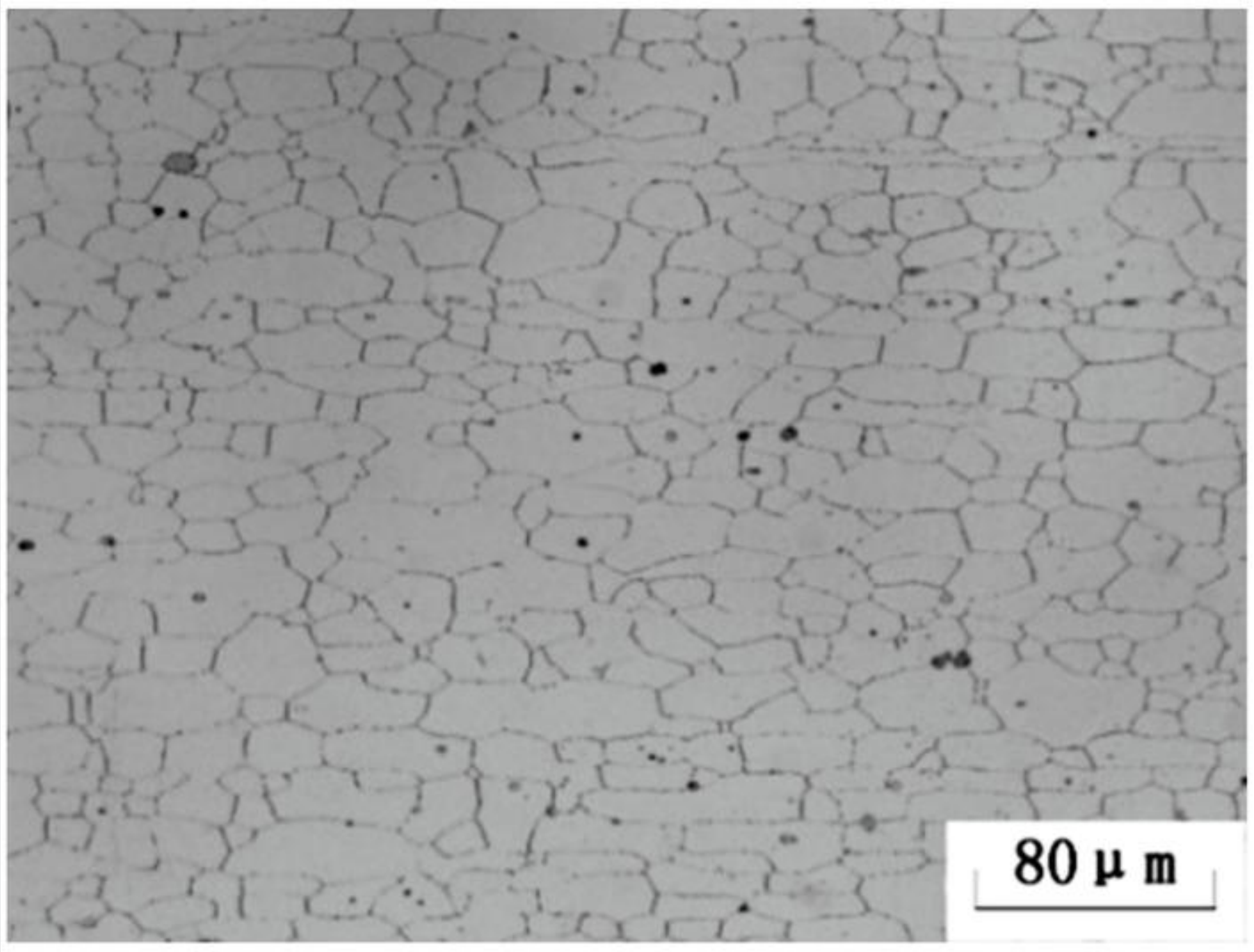
Al – Li
9XX.X
8XXX

Al-Li crystallographic data

Phase	Composition, wt% Li	Pearson symbol	Space group
(Al)	0 to 4	*cF*4	$Fm\bar{3}m$
β	17 to 24	*cF*16	$Fd\bar{3}m$
Al_2Li_3	28 to 29	*hR*15	$R\bar{3}m$
Al_4Li_9	36.6	*mC*26	*C*2/*m*
Al_4Li_9'	36.6	...	...
(βLi)	100	*cI*2	$Im\bar{3}m$
(αLi)	100	*hP*2	$P6_3/mmc$
Metastable phases			
Al_3Li	...	*cP*4	$Pm\bar{3}m$



Al – Li
9XX.X
8XXX



Microstructure of 1420 Al-Li alloy.