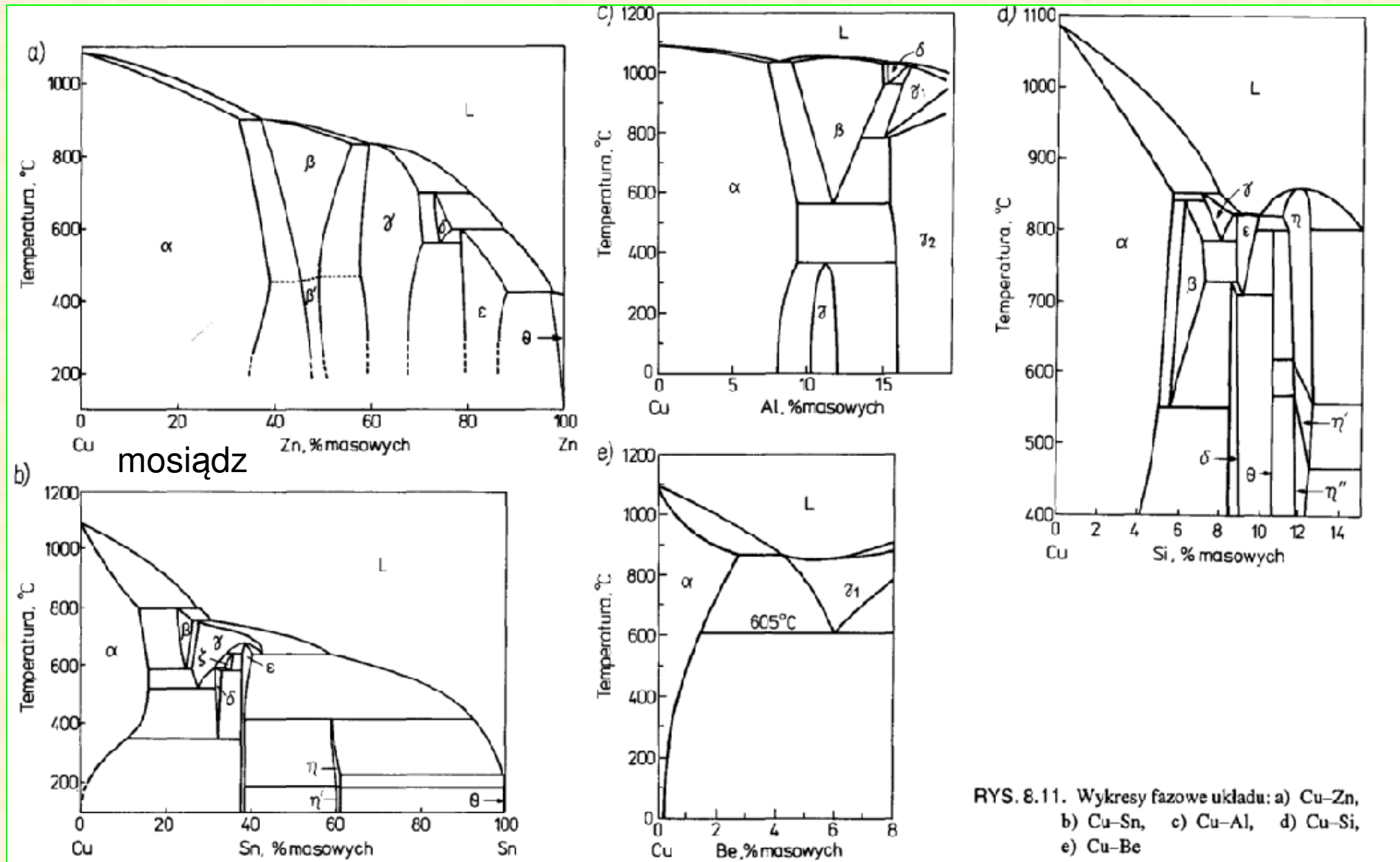


Wykład 10:

Stopy nieżelazne

Grzegorz Karwasz

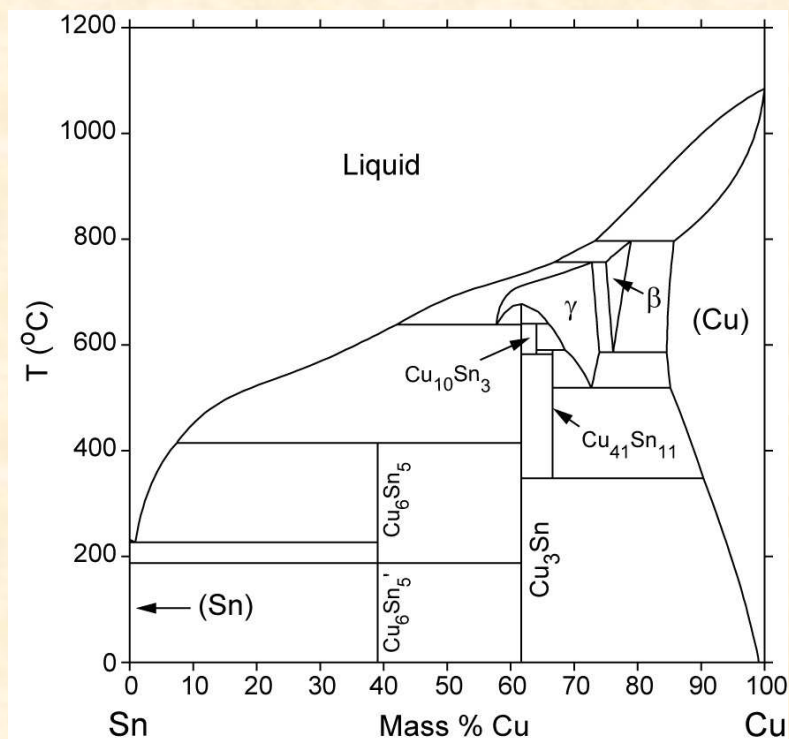
Stopy miedzi



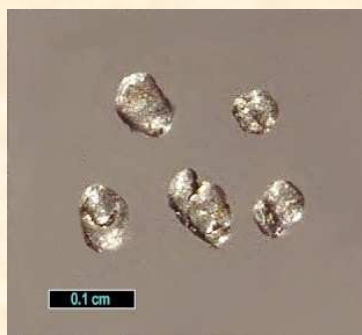
RYS. 8.11. Wykresy fazowe układu: a) Cu-Zn, b) Cu-Sn, c) Cu-Al, d) Cu-Si, e) Cu-Be

brąz

Epoka brązu 3300-1300 p.n.e



Miedz rodzima, Michigan, USA



Cyna rodzima, NSW, Australia.

<http://www.metallurgy.nist.gov/phase/solder/cusn.html>
http://en.wikipedia.org/wiki/Bronze_Age
http://www.coloradogem.com/images/3507_big.jpg
<http://webmineral.com/specimens/picshow.php?id=2469>
http://it.wikipedia.org/wiki/File:Marek_Aureliusz_Kapitol.jpg
<http://www.exceptionalminerals.com/exceptionalroom6.htm>

Brązy na odlewy artystyczne

Lega n°	Cu	Sn	Zn	Pb	Si	Ni	Bi	Fe	Mn	Al
1	85,7	4,8	4,4	4,7		0,3		0,1		
2	65,5	0,5	30,9	1,4	0,9	0,5		0,4		
3	86,9	10,8	2,1	0,1		0,1				
4	86,4 + 88,4	8,2 + 10,2		2,4 + 4,4						
5	87,8 + 89,8	6,6 + 8,6	0,0 + 1,3	0,0 + 1,4	1,8 + 3,8	0,0 + 1,1		0,0 + 1,1		
6	84,3 + 86,3	8,3 + 10,3	1,1 + 3,1	0,0 + 1,1		2,2 + 4,2		0,0 + 1,0	0,0 + 1,0	
7	85,0 + 87,0	7,0 + 9,0	0,0 + 1,3	0,0 + 1,3	1,7 + 3,7	0,0 + 1,1		0,0 + 1,0		
8	83,5 + 85,5	6,8 + 8,8	1,1 + 3,1	0,0 + 1,3	1,9 + 3,9	0,0 + 1,0	1,4 + 3,4	0,0 + 1,1		
9	85,7 + 87,7	3,4 + 5,4	1,9 + 3,9	2,3 + 4,3	0,0 + 1,7	0,2 + 2,2		0,0 + 1,2		
11	85,6 + 87,6	4,2 + 6,2	5,4 + 7,4	0,0 + 1,8		0,0 + 2,0		0,0 + 1,1		
12	83,8 + 85,8	9,4 + 11,4	1,0 + 3,0	0,0 + 1,8		1,0 + 3,0				
13	85,6 + 87,6	9,0 + 11,0	1,4 + 3,4	0,0 + 2,0						

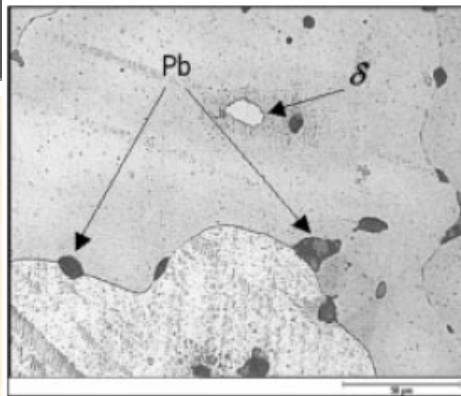


Fig. 1. La solubilità dello Sn diminuisce al diminuire della temperatura. A questo fa seguito la formazione della fase δ in misura variabile a seconda della velocità di raffreddamento, usualmente presente come eutettoide $\alpha+\delta$ (FeCl3 in alcool etilico)

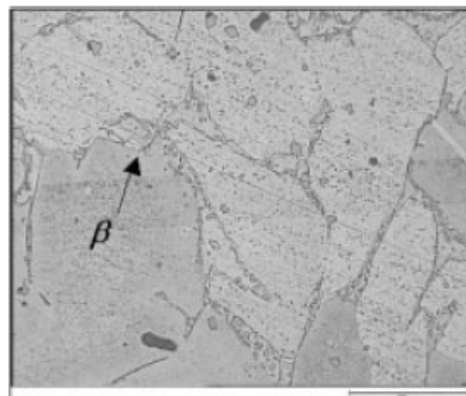


Fig.2 Con Zn aumenta la durezza e diminuisce la temperatura di fusione. La presenza di dendriti di fase α e di una piccola quantità di fase β interdendritica, formatasi in seguito a fenomeni di segregazione.

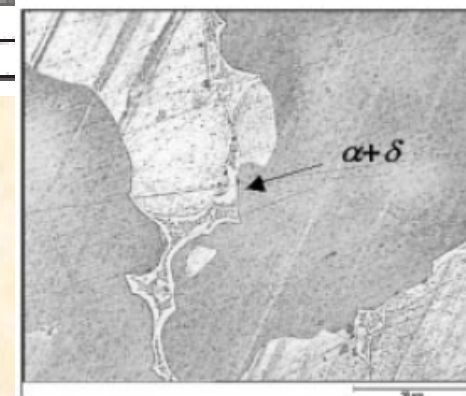


Fig. 3. Sn assicura un ampliamento dell'intervallo di solidificazione, e promuove l'insorgere di fenomeni segregativi. E' possibile notare la presenza di fase eutettoidica $\alpha+\delta$, ricca in Sn, segregata a bordo grano. .

Brązy fosforowe



Phosphor bronze [propeller](#) salvaged from 1940s American warship



[Bauhaus Walstein tenor saxophone](#)
manufactured in 2008 from phosphor bronze



[Acoustic guitar](#) string wrapped with phosphor bronze

Mosiądze (+ Pb), zastosowania

Lega	Applicazione
P- CuZn20Pb P-CuZn35Pb2	<i>Meccanica:</i> Particolari tranciati a freddo, chiavi . klucze <i>Edilizia:</i> Accessori idrosanitari, rubinetteria.
P-CuZn36Pb3	<i>Meccanica:</i> Ingranaggi, pignoni e tutti i particolari a forme complesse che richiedono una impegnativa lavorazione alle macchine utensili ad asportazione di truciolo ad altissima velocità. Tryby, przekładnie ślimakowe
P-CuZn36Pb2As	<i>Edilizia:</i> Rubinetteria e raccorderia a contatto con acque potenzialmente atte a determinare il fenomeno della dezincificazione negli ottoni al piombo comuni. krany do wody (kwaśnej)
P-CuZn37Pb2	<i>Meccanica:</i> Bilancieri e casse per orologi, parti per orologeria, ingranaggi, ruotismi. kółka zamachowe zegarków
P-CuZn37Pb2Sn	<i>Meccanica:</i> Steli di valvole, viti, dadi e bulloni, particolari per impieghi marini. Śruby na statkach, wkładki zaworów do wody
P-CuZn38Pb2	<i>Meccanica:</i> Spine, bulloneria, viteria, spilli, occhielli, gancetti, articoli per uso domestico, minuteria metallica, lucchetti, serrature. Kłódki, zamki <i>Edilizia:</i> Rubinetteria cromata, miscelatori termostatici, valvole a sfera, a farfalla, a saracinesca, termostatiche, a quattro vie, organi di intercettazione, regolazione e controllo, valvole per gas. krany chromowane, zawory do gazu
P-CuZn38Pb4	<i>Meccanica:</i> Piastre, arpionismi e parti metalliche in genere per orologeria.
P-CuZn39Pb1	<i>Meccanica:</i> Viteria e bulloneria ottenute su macchine utensili ad alta velocità.

Stopy mennicze

Monety polskie:

- 1, 2, 5 gr - $\text{Cu}_{59}\text{Zn}_{40}\text{Mn}_1$
- 10, 20, 50 gr i 1 zł - $\text{Cu}_{75}\text{Ni}_{25}$
- 2 zł : $\text{Cu}_{92}\text{Al}_6\text{Ni}_2$ - zewn., $\text{Cu}_{75}\text{Ni}_{25}$ - wewn.

Euro:

-  stalowe, pokryte Cu
- 
- 10, 20, 50 cents $\text{Cu}_{89}\text{Al}_5\text{Zn}_5\text{Sn}_1$ (nordic gold – szwedzkie złoto)
-  inner: $\text{Cu}_{75}\text{Ni}_{25}$ outer $\text{Cu}_{75}\text{Zn}_{20}\text{Ni}_5$

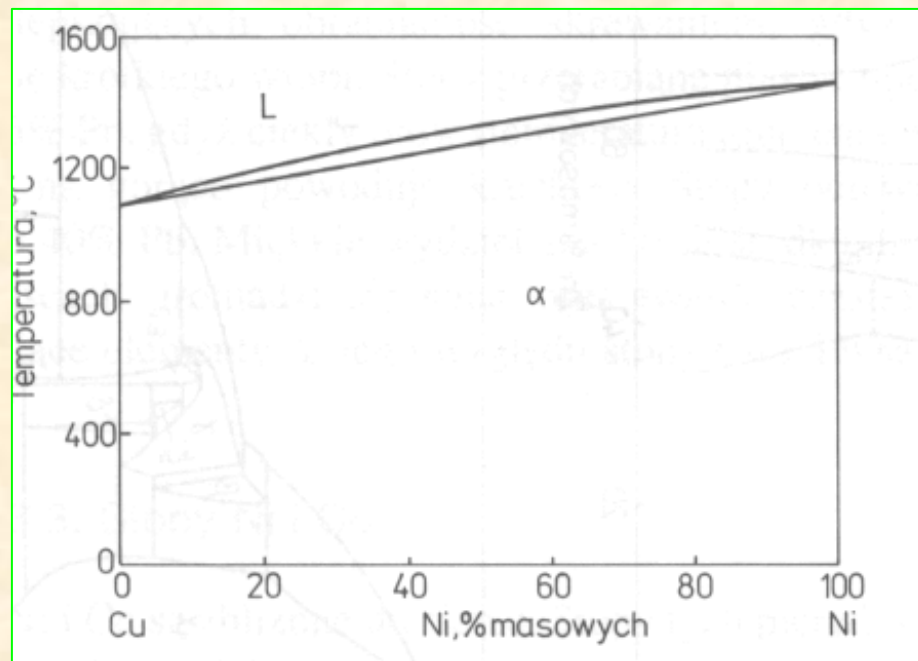
Stopy miedzi

TABLICA 8.8. Własności mechaniczne typowych stopów miedzi (*Metals Handbook, tom 2, wyd 10, ASM International 1990*)

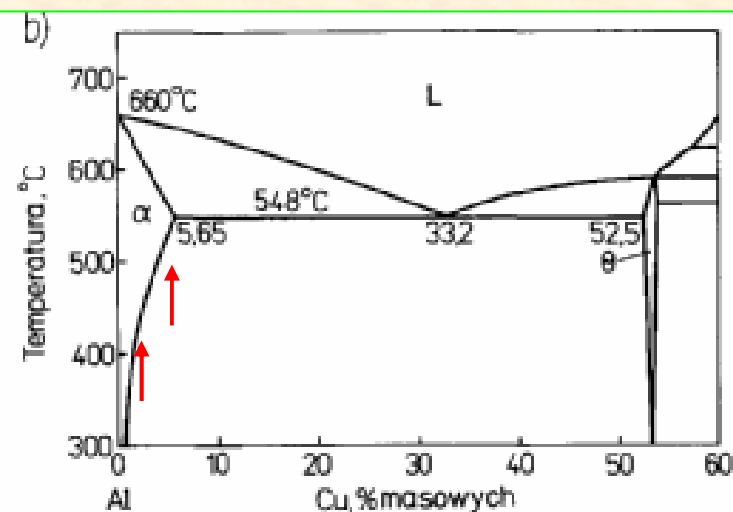
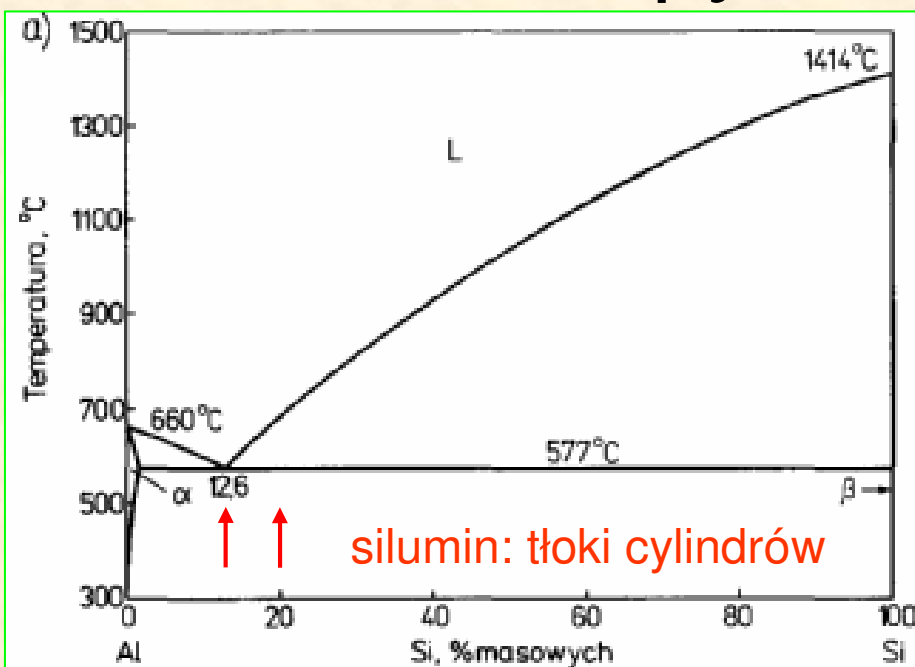
Materiał	Obróbka	R_e MPa	R_m MPa	Wydłużenie %	Umocnienia
Czysta miedź	wyżarzanie	33	210	60	–
Miedź 99,99%	wyżarzanie	70	200	55	roztworowe
Miedź 99,99%	odkształcenie 70% na zimno	360	395	4	odkształceniowe
CuZn30	wyżarzanie	115	340	57	roztworowe
CuZn30	odkształcenie 50% na zimno	450	595	5	roztworowe i odkształceniowe
CuSn8	wyżarzanie	165	415	63	roztworowe
CuNi30	wyżarzanie	140	380	45	roztworowe
CuNi30	odkształcenie 60% na zimno	545	580	3	roztworowe i odkształceniowe
CuZn20Ni15	wyżarzanie	130	380	42	roztworowe
CuZn20Ni15	odkształcenie 50% na zimno	545	635	2	roztworowe i odkształceniowe
CuBe2	przesycanie i starzenie	1270	1390	3	wydzieleniowe

Stopy miedzi - zestawienie

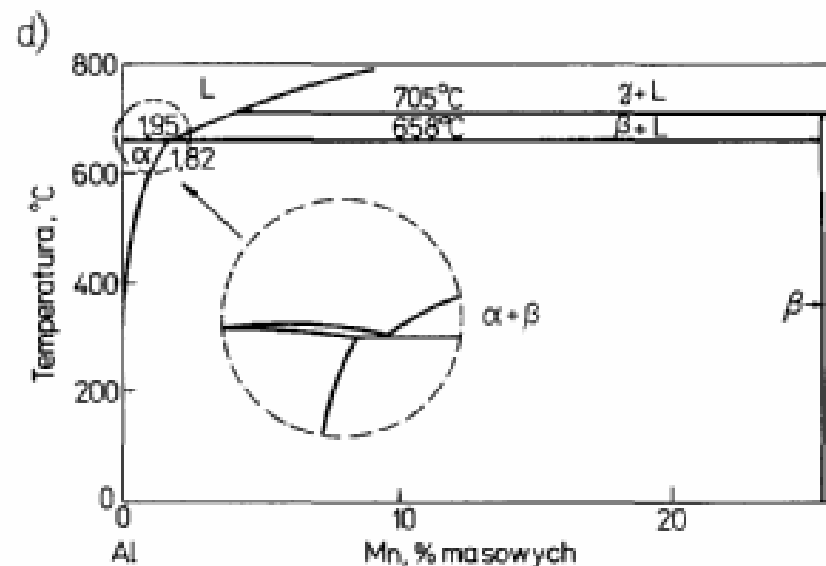
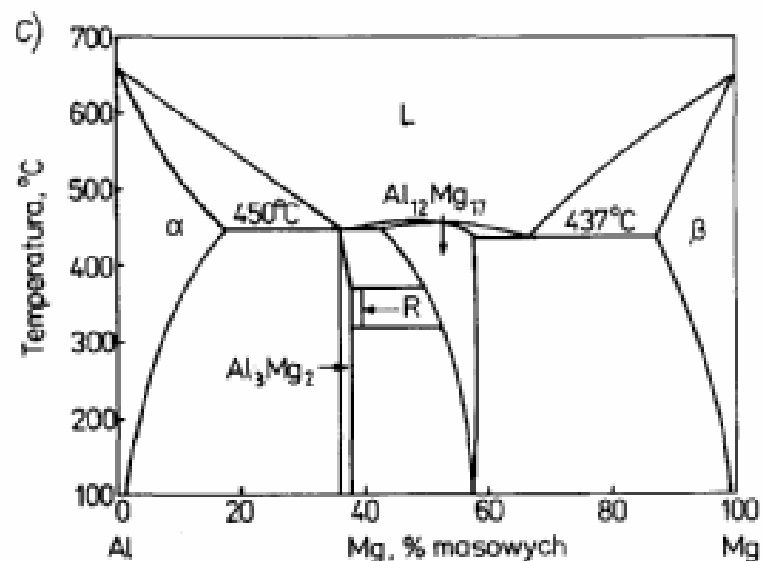
- 0.5-1% Cd zwiększenie wytrzymałości przy niezmienionej przewodności
- mosiądze do 39% Zn są jednofazowe, do kształtowania plastycznego
- brązy do 11% Sn jednofazowe, do odlewnictwa
- brąz berylowy nieiskrzący – narzędzia dla górnictwa
- Pb – poprawia skrawalność (do 4.5%, odlewniczność (do 40% Pb), panewki łożysk
- brąz fosforowy – sprężyny
- stopy z niklem...



Stopy aluminium



dural: starzenie wytrąceniowe

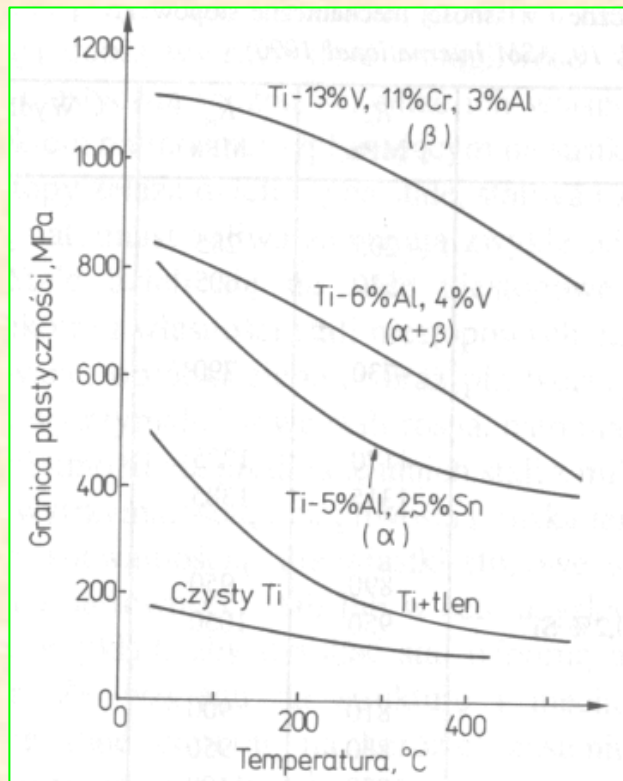


Stopy aluminium

TABLICA 8.7. Własności mechaniczne stopów Al umocnionych różnymi mechanizmami
(*Metals Handbook, tom 2, wyd. 10, ASM International 1990*)

Materiał i sposób umacniania	R_e MPa	R_m MPa	Wydłużenie %	R_e stopu/ R_e Al
Al o czystości 99,999%; wyżarzone	17	45	60	–
Al o czystości 99,6%; wyżarzone	30	70	43	1,8
Al – 1,2% Mn; roztworowe	42	110	35	2,5
Al o czystości 99,999% po 90% odkształceniu na zimno	110	130	10	6,5
Al – 4,4% Cu, 1,5% Mg, 0,6% Mn; wydzieleniowe	440	490	9	25,9
Al – 5,6% Zn, 2,5% Mg, 1,6% Cu; wydzieleniowe	500	570	11	29,4

Stopy tytanu



TABLICA 8.10. Składy chemiczne i własności mechaniczne stopów Ti
(Metals Handbook, tom 2, wyd. 10, ASM International 1990)

Skład chemiczny	R_e MPa	R_m MPa	Wydłużenie %
Tytan			
99,5% Ti	205	285	30
99,0% Ti	530	605	20
Stop α			
Ti-5% Al, 2,5% Sn	730	790	16
Stop β			
Ti-13% V, 11% Cr, 3% Al	1170	1235	8
Ti-11,5% Mo, 6% Zr, 4,5% Sn	1315	1385	11
Stopy bliskie α			
Ti-8% Al, 1% Mo, 1% V	890	950	15
Ti-11% Sn, 5% Zr, 2,2% Al, 1% Mo, 0,2% Si	950	1050	15
Stopy α + β			
Ti-8% Mn	810	900	15
Ti-6% Al, 4% V	880	950	14
Ti-7% Al, 4% Mo	1030	1100	16

Al-Ti alloys

Stopy tytanu i glinu, do zastosowań lotniczych; niestety kruche w niskich temperaturach

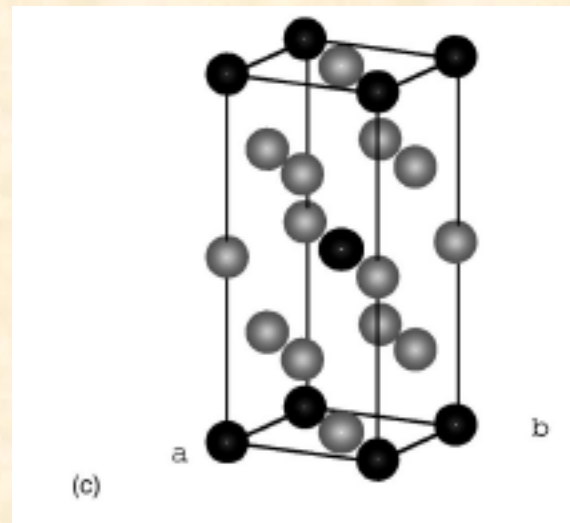
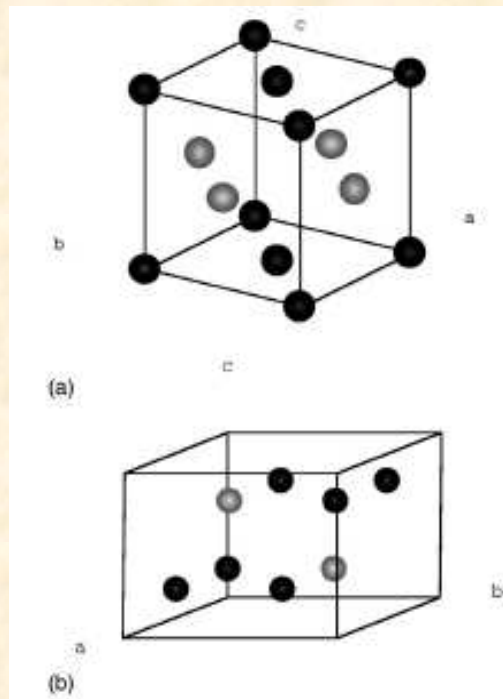


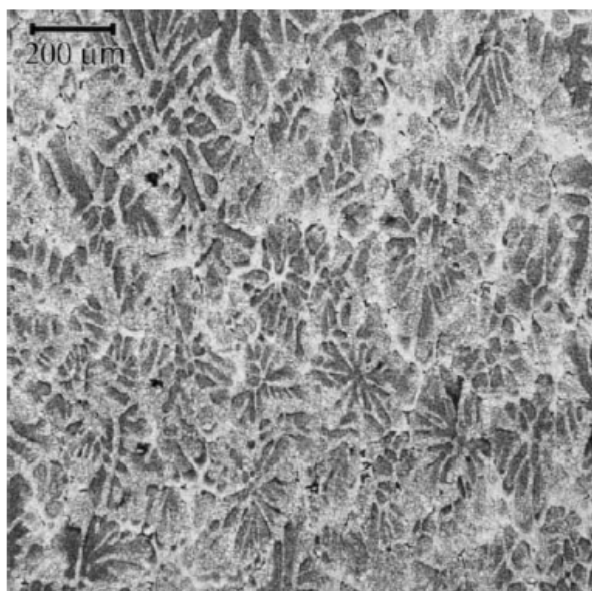
FIG. 1. Unit cells of TiAl (a), Ti₃Al (b), and Al₃Ti (c) alloys. Ti atoms are in black and Al atoms in gray.

Phys. Rev. B 62, 1723 - 1732 (2000) Multiple-scattering EXAFS and EXELFS of titanium aluminum alloys
[T. Sikora](#) and [G. Hug](#) *Laboratoire d'Etudes des Microstructures, CNRS-ONERA, 2, 92322 Châtillon Cedex, France*
[M. Jaouen](#) and [J. J. Rehr](#) **Laboratoire de Métallurgie Physique, UMR 6630 du CNRS, Université de Poitiers SP2MI, Bd Marie et Pierre Curie, 86962 Futuroscope Chasseneuil Cedex, France*

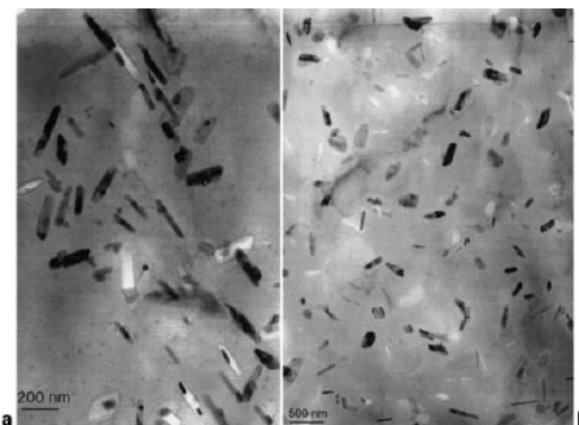
Al-Zn-Mg...- kompromis między twardością a łamliwością

- faza między-metaliczna $\text{Al}_7\text{Cu}_2\text{Fe}$ i nierozpuszczony Mg_2Si
- dendrytyczna sieć Al_3Zr
- wzrost twardości po hartowaniu
- wzrost moduły Younga pod wpływem obciążenia

Dumont et al. Precipitation microstructures in Al alloys 7040 and 7050 3



1 Microstructure of alloy 7050 after a slow quench: optical micrograph after orthophosphoric etching revealing the distribution of quench-induced particles. These particles are located in the high density regions of Al_3Zr particles, i.e. in the former dendrite interiors of the solidification microstructure, flattened by the rolling process



2 Bright field TEM micrographs of the microstructure of alloys a 7040 and b 7050 after a slow quench. Alloy 7040, which has a low quench sensitivity, shows narrow bands of coarse precipitates. Alloy 7050 is largely covered by wide bands of particles. The particle size is similar in both materials

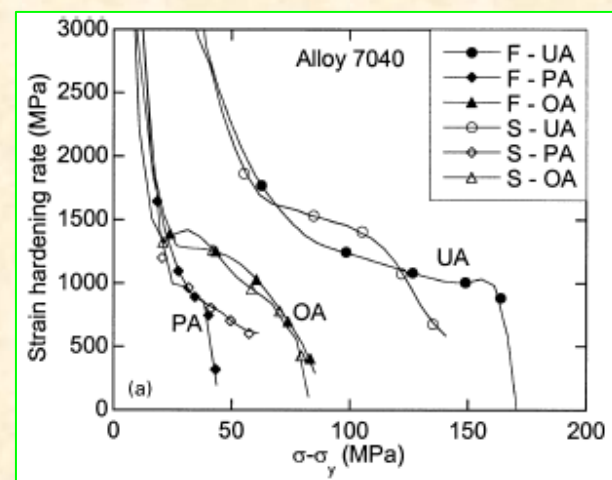
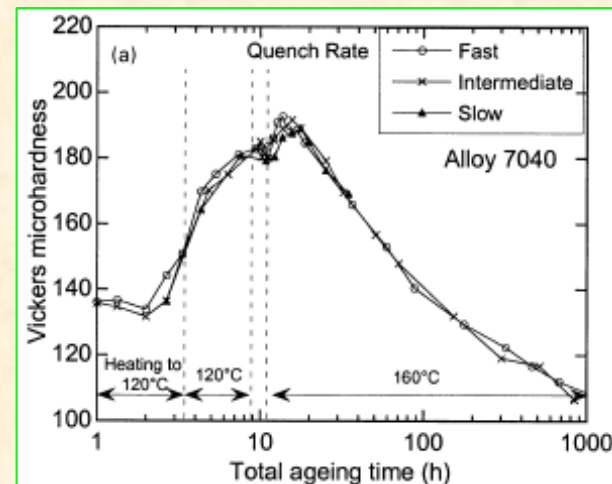
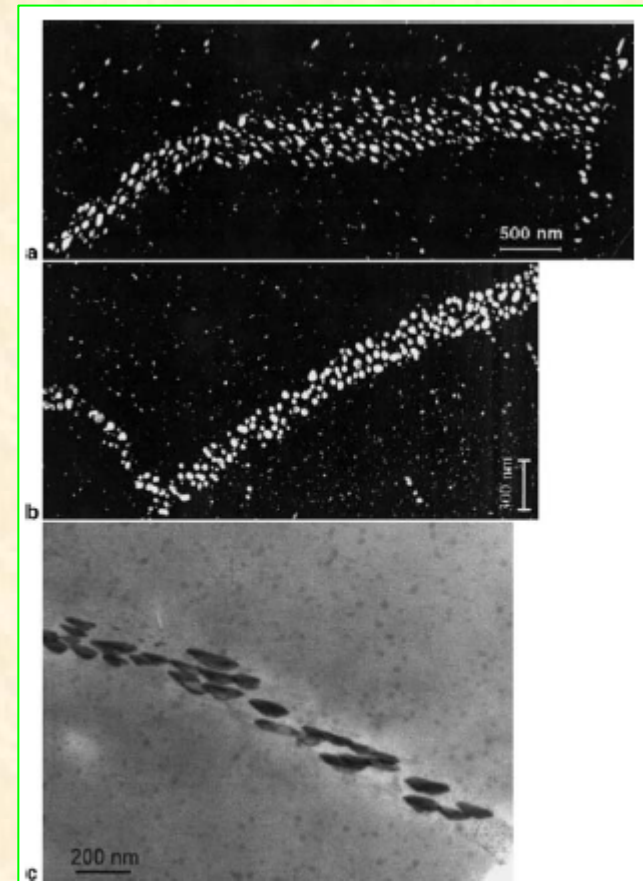
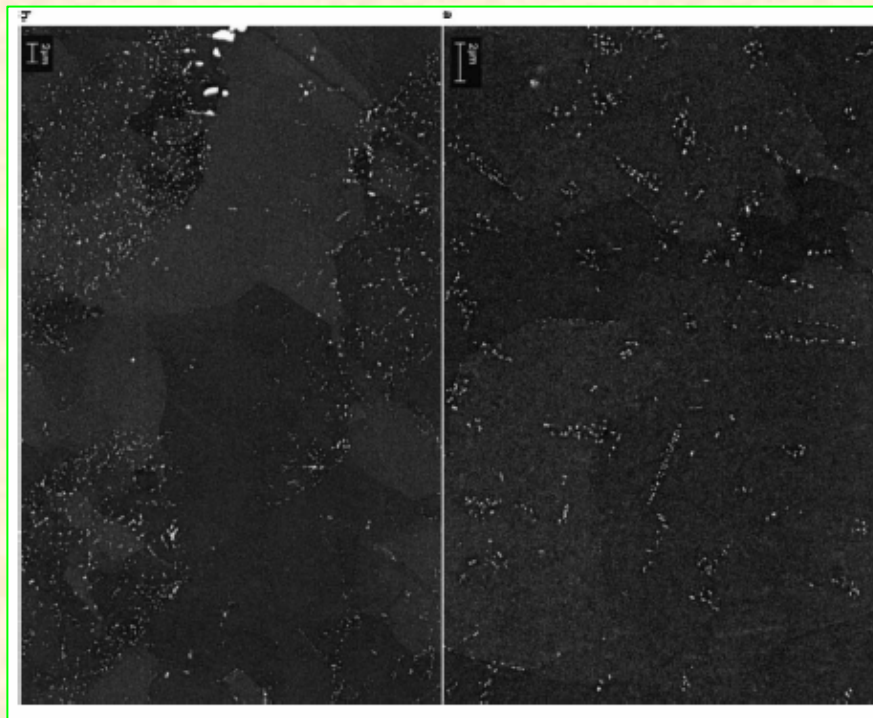


Table 1 Composition of alloys 7040 and 7050 in wt-%, balance Al

	Zn	Mg	Cu	Zr	Fe	Si
7040	6.51	2.01	1.64	0.11	0.08	0.05
7050	6.33	2.46	2.2	0.11	0.1	0.08

Al-Zn-Mg...= stopy samolotowe

- różna wielkość ziaren
- wytrącenia Zn-Mg-Cu na granicy ziaren



5 **a b** dark field TEM micrographs of grain boundary precipitates in **a** alloy 7040 and **b** alloy 7050, after a fast quench rate and in the overaged condition; **c** bright field TEM micrograph of grain boundary precipitates in alloy 7040 after an intermediate quench rate and in the overaged condition

3 Backscattered electrons images in the FEG-SEM microscope of the microstructure of alloys **a** 7040 and **b** 7050 after a slow quench. These images confirm the large difference in the extent of the coarse particles bands between the two alloys. These bands have a limited extent in the case of alloy 7040, whereas they cover a large area in the case of alloy 7050

Super-stoppy niklu

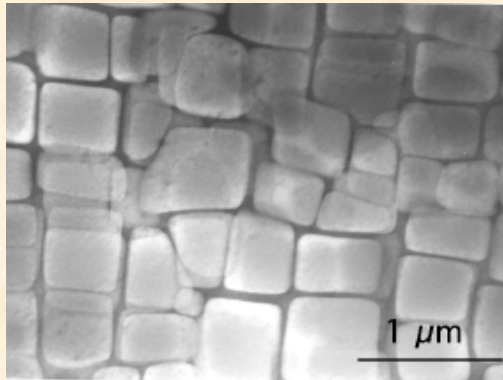
TABLICA 8.9. Skład chemiczny i własności mechaniczne stopów na podstawie Ni i Co
(Metals Handbook, tom 2, wyd. 10, ASM International 1990)

Material i skład chemiczny	R_e MPa	R_m MPa	Wydłużenie %	Umocnienie
Czysty Ni				
99,9% Ni	110	345	50	(wyżarzony)
99,9% Ni	620	650	4	odkształceniowe
Stopy Ni-Cu				
Ni-31,5% Cu	165	385	46	roztworowe
Ni-29,5% Cu-2,7% Al-0,6% Ti	790	1100	20	wydzieleniowe
Nadstoppy Ni*				
Ni-15,5% Cr, 8% Fe	310	655	40	wydzieleniowe
Ni-24 Mo, 6% Fe, 5% Cr, 2,5% Co	370	850	55	roztworowe
Ni-19% Cr, 5,1% Nb, 0,9% Ti, 0,5% Al	1040	1240	12	wydzieleniowe
Nadstoppy Fe-Ni				
Ni-28% Fe, 21% Cr, 3% Mo, 2,1% Ti, 0,3% Al	815	1210	24	wydzieleniowe
Nadstoppy Co				
Co-20% Cr, 15% W, 10% Ni	445	970	62	wydzieleniowe
* Wszystkie nadstoppy zawierają ok. 0,1% C.				

Super-stopý niklu

Alloy		Cr	Co	Mo	W	Ta	Nb	Al	Ti	Fe	C	B	Zr	Re	Hf	Others
Astroloy	PM	14,9	17,2	5,1				4	3,5		0,03		0,04			
CMSX2	SX	8	4,6	0,6	7,9	5,8		5,6	0,9							
CMSX4	SX	5,7	11	0,42	5,2	5,6		5,2	0,74					3	0,1	
CMSX6	SX	9,8	5	3		2,1		4,8	4,7							
CMSX10	SX	2	3	0,4	5	8	0,1	5,7	0,2					6	0,03	
FT750DC	wrought	20			3,5			2,3	2,1	5	0,07	0,005				0.4 Si
Hastelloy X	wrought	22	1,5	9	6					18,5	0,1					0.5Mn, 0.5Si
Hastelloy S	wrought	15,5		14,5				0,2		1	0,02	0,009				0.02 La
Inconel 600	wrought	15,8								7,2	0,04					0.2Mn, 0.2 Si
Inconel 718	wrought	18,6		3,1			5	0,4	0,9	18,5	0,04					0.2Mn, 0.3Si
MA758	MA/ODS	30			0,5			0,3			0,05					0.6 yttria
MA760	MA/ODS	19,5			3,4			6		1,2	0,06					1.0 yttria
MA6000	MA/ODS	15			3,9			4,5	2,3	1,5	0,06					1.1 yttria
MAR-M200	cast	9	10		12		1	5	2		0,15	0,015	0,05			
Nimonic 80A	wrought	19,5	1,1					1,3	2,5			0,06				
Nimonic 105	wrought	14,5	20	5					1,2	4,5		0,2				
PM1000	MA/ODS	20						0,3	0,5	3						0.6 yttria
Rene N5	SX	7	8	2	5	7		6,2						3	0,2	
Rene N6	SX	4,2	12,5	1,4	6	7,2		5,75						5	0,15	
Rene 41	wrought	19	11	10				1,5	3,1		0,09	0,05				
RR2000	SX	10	15	3				0,05	4							1 V
SRR99	SX	8,5	5		9,5	2,8		5,5	2,2							
TMS 63	SX	6,9		7,5		8,4		5,8	0							
Udimet 500	wrought	18	18,5	4				2,9	2,9		0,08	0,006	0,05			
Udimet 700	wrought	15	18,5	5,2				4,3	3,5		0,08	0,03				
Waspaloy	wrought	19,5	13,5	4,3				1,3	3		0,08	0,006	0,06			

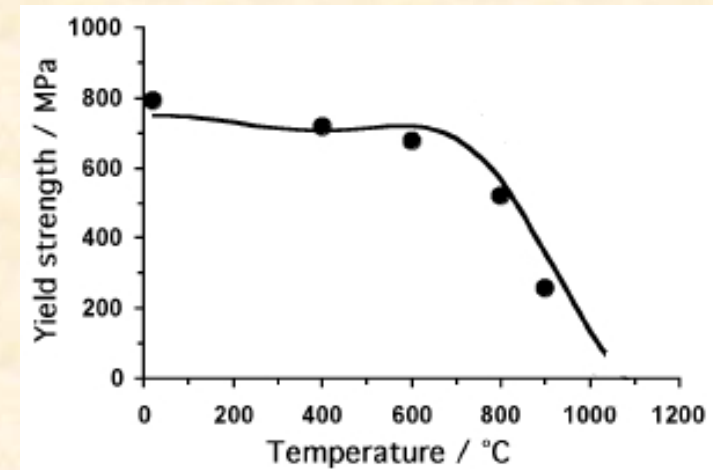
Super-stopý niklu



Transmission electron micrograph showing a large fraction of cuboidal γ' particles in a γ matrix. Ni-9.7Al-1.7Ti-17.1Cr-6.3Co-2.3W at%. Hillier, Ph.D. Thesis, University of Cambridge, 1984.



Transmission electron micrograph showing a small fraction of spheroidal γ' prime particles in a γ matrix. [Ni-20Cr-2.3Al-2.1Ti-5Fe-0.07C-0.005 B wt%.](#) Also illustrated are $M_{23}C_6$ carbide particles at the grain boundary running diagonally from bottom left to top right.



Stopy dentystyczne

Transmission electron microscopic investigation of a Pd–Ag–In–Sn dental alloy Biomaterials **Volume 24, Issue 10**, May 2003, Pages 1705-1712

W. H. Guo^{a, 1}, W. A. Brantley^{, , a}, W. A. T. Clark^b, P. Monaghan^{a, 2} and M. J. Mills^b

a Section of Restorative Dentistry, Prosthodontics and Endodontics, College of Dentistry, The Ohio State University, 305 West 12th Avenue, Mailbox #191, P.O. Box 182357, Columbus, OH 43218-2357, USA

b Department of Materials Science and Engineering, The Ohio State University, Watts Hall, 2041 College Road, Columbus, OH 43210, USA

Popular **palladium–silver dental alloys** for metal-ceramic restorations typically have compositions ranging from about 50–60% Pd and 30–40% Ag, and contain small amounts of low melting point metals, such as **Zn, In and Sn**, to improve **castability** by increasing the fluidity of the molten alloy; In and Sn also promote **strong bonding to dental porcelain** [1, 2, 3 and 4].

Phase	Composition (wt%)					Crystal structure			
	Pd	Ag	In	Sn	(Ga + Ru)	Type	<i>a</i> (nm)	<i>c</i> (nm)	
Eutectic	69.4 ± 1.4 to	5.6 ± 0.5 to	3.0 ± 1.4 to	12.7 ± 0.9 to	1.3 ± 0.1 to	fct ordered	0.400 ± 0.004 to	0.365 ± 0.007 to	
Lamella 1 ^a	71.3 ± 2.1	10.8 ± 0.3	5.0 ± 1.7	16.0 ± 0.7	2.2 ± 0.1		0.410 ± 0.002	0.374 ± 0.003	
Eutectic	50.5 ± 0.4 to	39.3 ± 1.0 to	0.0	0.0 to	0.0 to < 1.0	fcc	0.398 ± 0.001	—	
Lamella 2 ^a	55.6 ± 0.9	49.5 ± 0.4		5.1 ± 0.4					
Precipitate	68.7 ± 0.9	5.7 ± 0.5	7.7 ± 0.4	16.4 ± 0.7	1.5 ± 0.2	fct	0.407 ± 0.005	0.369 ± 0.006	
Matrix (without precipitate)	56.2 ± 0.5	38.5 ± 0.4	0.0	5.2 ± 0.7	0.0	fcc	0.398 ± 0.001	—	
Matrix (with precipitate)	62.2 ± 1.0	22.1 ± 1.2	6.1 ± 0.7	9.6 ± 0.5	< 1.0	—	—	—	

Table 1. Microstructural phases in as-cast Super Star Pd–Ag alloy

Stopy dentystyczne

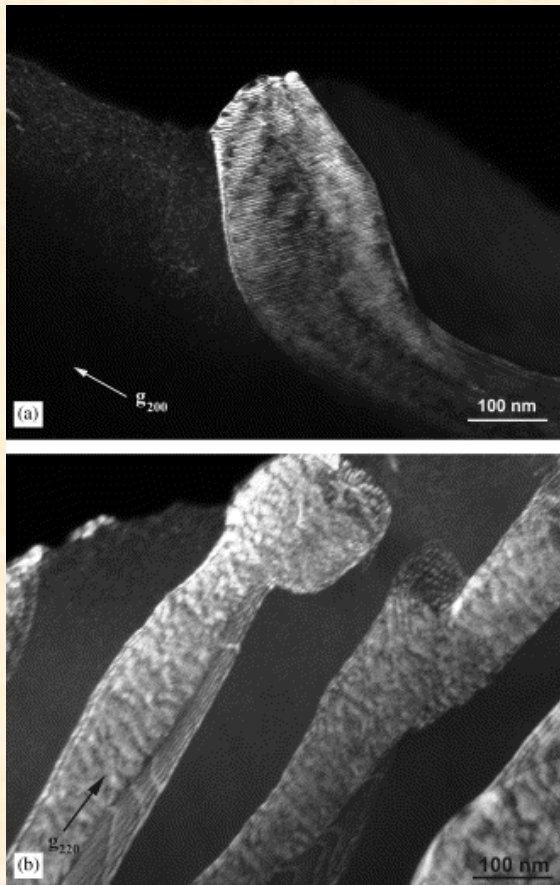


Fig. 1. Dark-field micrographs showing the morphologies of a dendrite (a) and the eutectic structure (b) in as-cast Super Star. For the two-beam condition used to obtain (b), the fct lamellae of the eutectic structure have a bright appearance and the fcc lamellae (i.e., the dark regions between the fct lamellae) are not imaged.

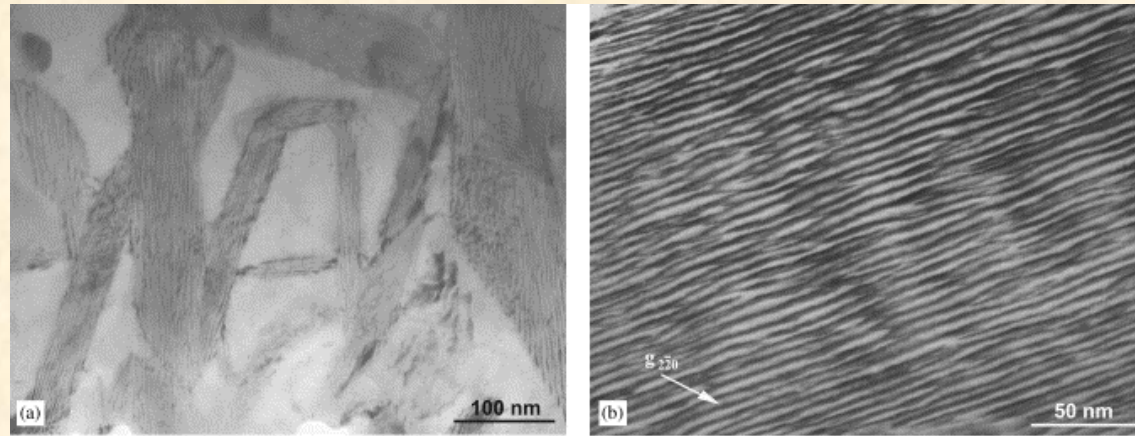


Fig. 2. Morphology of fct precipitates in the fcc palladium solid solution matrix of as-cast S-S. (a) Bright-field micrograph. (b) Higher-magnification bright-field micrograph of the striations within the precipitates.

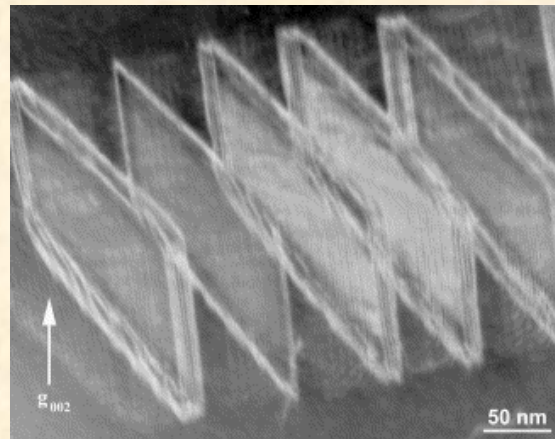


Fig. 3. Dark-field micrograph of heat-treated Super Star, showing discontinuous fct precipitates, which have rectangular platelet morphology. Dislocations are present in both the adjacent fcc palladium solid solution matrix and within the precipitates.

Fig. 4. Bright-field micrograph showing dislocations in the palladium solid solution matrix of Super Star after heat treatment simulating the firing cycles for a dental porcelain.

