Novel wrought γ/γ´ Cobalt base superalloys with high strength and improved oxidation resistance

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Stable and Metastable Multiphase Systems for Elevated Service Temperatures
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Materials and Microstructure

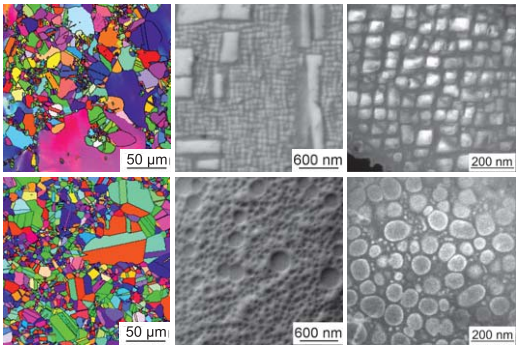
Elemental composition (at.%):

	Co	Ni	Al	W	Ti	Ta	Mo	Cr	Si	Hf	Zr	B	C
CoWAlloy1	42.3	32.0	6.0	3.0	2.5	1.5	-	12.0	0.4	0.1	0.01	0.08	0.08
CoWAlloy2	40.8	32.0	9.0	5.0	0.3	0.2	-	12.0	0.4	0.1	0.01	0.08	0.08
U720Li	14.3	54.9	5.2	0.4	5.9	-	1.8	17.3	-	-	0.02	0.09	0.12
Waspaloy	13.0	56.4	2.7	-	3.6	-	2.6	21.3	-	-	-	0.03	0.38

Production route:
Casting
Homogenization 1250°C/3 h
Hot rolling at 1100°C

⇨ Heat Treatment:
Recrystallization 1000°C/4h or 1050°C/4h
Annealing 900°C/4h, 750 °C/16h

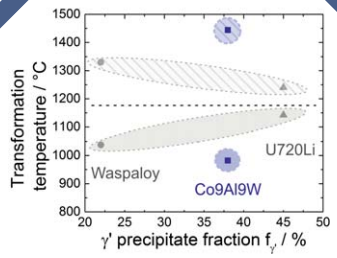
Resulting microstructure:



Alloy	γ´ Solvus / °C	γ´ Fraction / %	Median grain size / µm
CoWAlloy1	1070	54	3.5
CoWAlloy2	1030	53	7.9
U720Li	1142 [1]	45 [1]	3.8
Waspaloy	1038 [2]	22 [3]	32.3

[1] Y.F. Gu et al., Superalloys 2008, (2008) 53-61.
[2] D.R. Muzyka, Metals Eng. Q. 11 (1971) 12-20.
[3] H.J. Penkalla et al., Mater. Chem. Phys. 81 (2003) 417-423.

Motivation



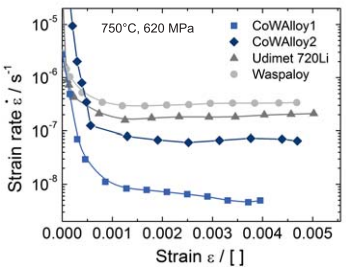
Ternary Co-base superalloy
+ high γ´ fraction, large processing window
- oxidation resistance, mechanical properties

⇩

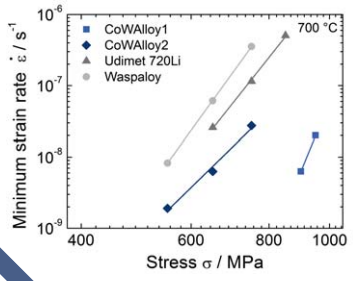
new alloys with improved oxidation resistance and mechanical properties

Creep Properties and Mechanisms

Constant stress tests:

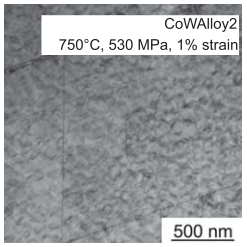


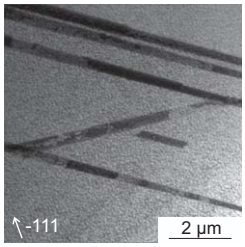
Load change tests - Norton Plot:

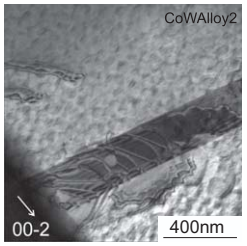


✓ better creep properties than the compared Ni-base alloys

creep mechanisms →



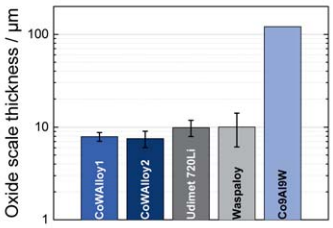




▶ deformation via stacking faults/twinning

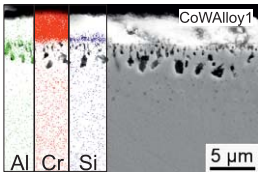
Oxidation

50 h at 900 °C

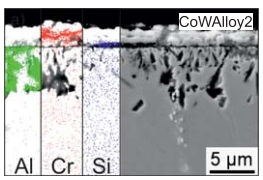


✓ significant reduction of the oxide scale thickness compared to ternary Co9Al9W

✓ oxide scale thickness in the same range as for comparable Ni-base wrought alloys

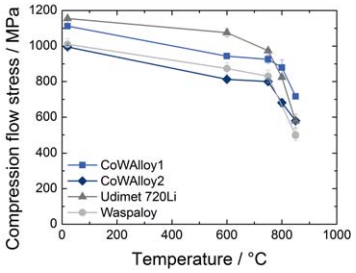


Oxide scale:
outer Cr-Oxide layer
intermediate Si-Oxide layer
inner Al-Oxide layer



Strength

Compression tests:
strain rate $\dot{\varepsilon}$ = 10^{-4} s^{-1}



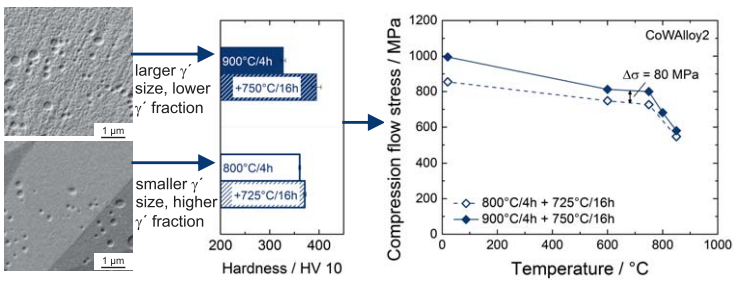
✓ comparable strength to Ni-base alloys

✓ above 800°C ⇨ even higher strength than Ni-base alloys

✓ much higher strength compared to Carbide-hardened Co-base alloys

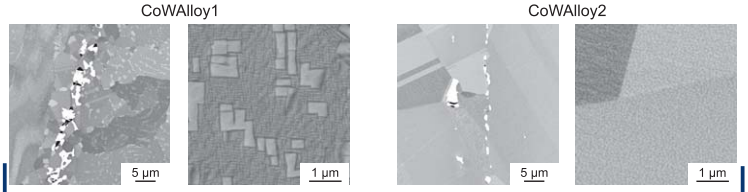
optimized strength by varying heat treatments

Heat treatment variations (CoWAlloy2):



Long Term Stability

1000 h at 700 °C in air



▶ no precipitation of third phase

▶ stable γ/γ´ microstructure

References:

S. Neumeier, L.P. Freund, M. Göken, *Novel wrought γ/γ´ Cobalt base superalloys with high strength and improved oxidation resistance*, Scripta Materialia 109 (2015) 104–107.
Patent application WO 2016/016437 A2

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