DECHEMA FORSCHUNGSINSTITUT

Microstructural Tuning of Cr-Si Alloys for High Temperature Applications above 1200°C

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Motivation Cr-Si-alloys

1

today: Ni-base superalloys

melting temperature Ni: 1455°C

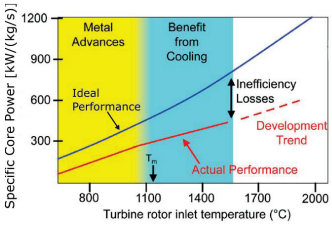
working temperature: < 1150°C

future candidates: refractory alloys

melting temperature Cr: 1907°C

Cr_{ss}-Cr_2Nb(Ta), Cr_{ss}-Cr_3Si

toughening *strengthening*



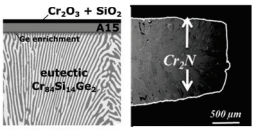
Thermal efficiency over temperature, after [1]

Motivation Alloying Elements

2

Ge, Si

- Enhanced oxidation & nitridation resistance



100h @ 1200°C, syn. air [2]

Mo

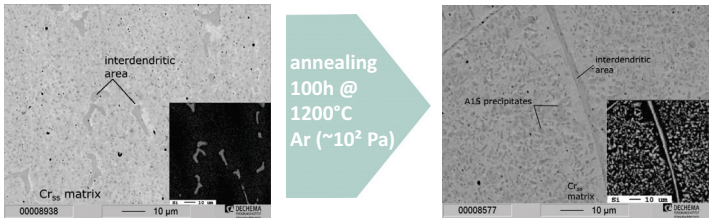
- Improves creep resistance of $(Cr,Mo)_3Si$/$(Cr,Mo)_5Si_3$ [3]
- Increases RT ductility of Cr [4]

Pt

- Cr + Pt form A15 Cr_3Pt
- Dissolution and reprecipitation of A15 phase strongly T dependent → heat treatability

Microstructural evolution of Cr-Si alloys

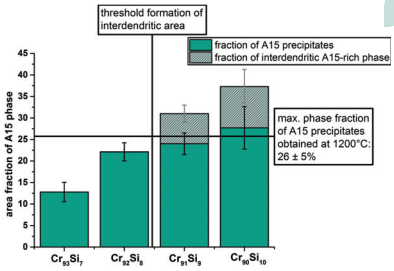
3



$Cr_{91}Si_9$ [at.%] as-cast condition

$Cr_{91}Si_9$ after annealing

- Increasing Si content → increasing A15 phase fraction (A_{A15})
- Interdendritic areas are coarse, precipitatates are fine and homogeneously distributed
- High fraction of precipitates + low interdendritic area = ideal mechanical properties

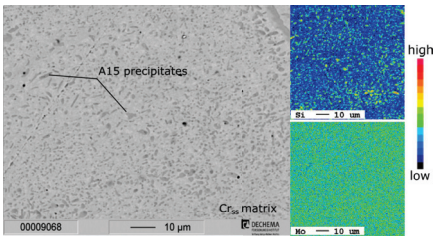


A15 phase fraction of Cr-Si alloys after 100h @ 1200°C

$Cr_{90}Si_8Mo_2$

Mo

4



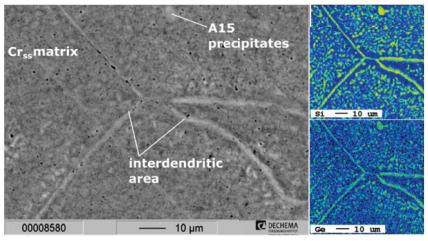
Microstructure after annealing (100h @ 1200°C): BSE image and EPMA element maps

- Mo is equally dissolved in A15 (2.0 ± 0.1 at.%) and Cr_{ss} (2.0 ± 0.1 at.%):
- Mo maintains fine homogeneous A15 precipitates due to a decrease in the diffusion kinetics (atomic radius, Mo distribution)

$Cr_{91}Si_7Ge_2$

Ge

5



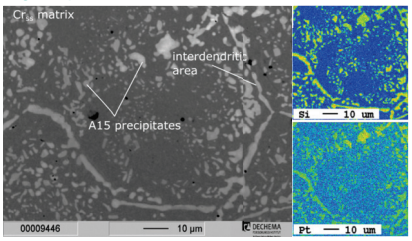
Microstructure after annealing (100h @ 1200°C)

- Ge and Si show mutual substitutability in both A15 and Cr_{ss} phases
- Ge decreases amount of interdendritic phase
- Ge substitution leads to the highest phase fraction of A15 precipitates

$Cr_{91}Si_7Pt_2$

Pt

6

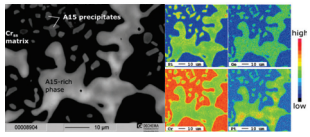


Microstructure after annealing (100h @ 1200°C)

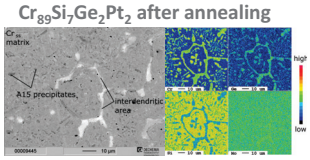
- Pt is predominantly an A15 phase former
- Up to 2 at.% Pt and Si are mutually substitutable in A15
- Pt leads to coarsening of the microstructure

Quaternary Alloys

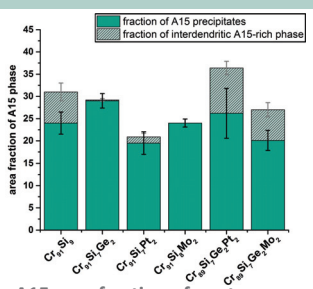
- All alloys consist of Cr_{ss} and A15 → offers targeted microstructural design
- Effects of elements on ternary alloys are also observed in the quaternary system:
- Chemical distribution
- Phase fractions of A15 precipitates and interdendrtic areas
- Lattice parameter change



$Cr_{89}Si_7Ge_2Pt_2$ after annealing

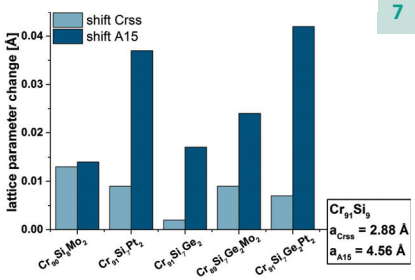


$Cr_{89}Si_7Ge_2Mo_2$ after annealing



A15 area fraction of quaternary and ternary alloys after 100h @ 1200°C

7



Lattice parameter change determined by XRD

[1] DECHEMA-Forschungsinstitut, High Temperature Materials
[2] Universität Bayreuth, Lehrstuhl Metallische Werkstoffe

[1] J.A. Lemberg et al., 2012
[2] A. Soleimani-Dorcheh, 2017
[3] S. V. Raj, 1995
[4] Y. Matsumoto et al., 2004

Werkstoffe Metallische

DFG

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