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Microstructural analysis and high temperature creep of Mo-9Si-8B alloys with Al and Ge additions

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UNIVERSITÄT BAYREUTH

Werkstoffe Metallische

Microstructural Analysis and High Temperature Creep of Mo-9Si-8B Alloys with Al and Ge Additions

Peter Kellner, Rainer Völkl, Uwe Glatzel

Metals and Alloys, University Bayreuth

Content

Mo-9Si-8B-xAl-yGe

Argon arc melting

Microstructural characterization

Tensile creep testing

Summary and outlook

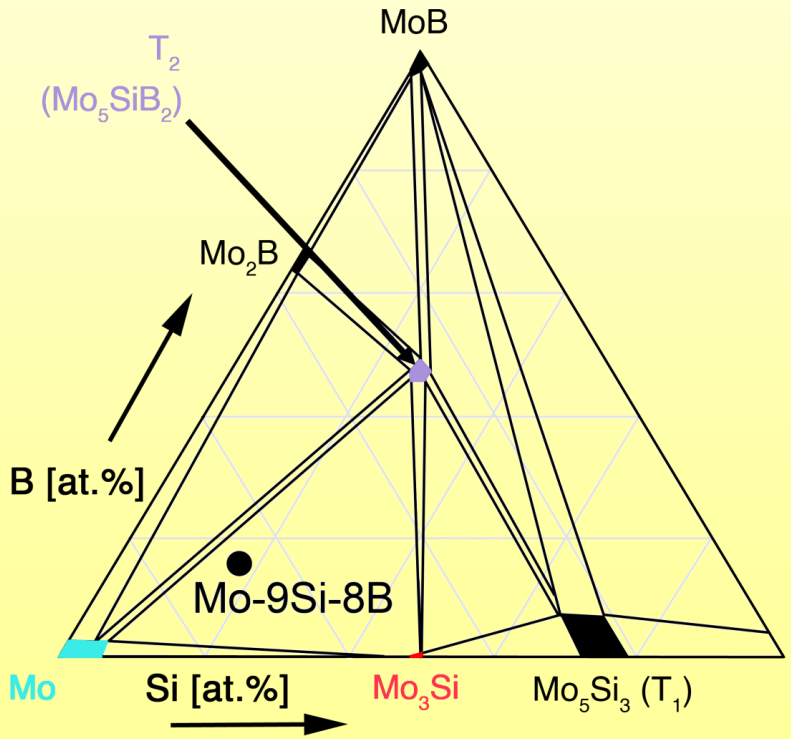
Mo-9Si-8B-xAl-yGe

Alloys: $Mo - 9Si - 8B - xAl - yGe$

$x = 0 \ldots 2\ at.\%$
$y = 0 \ldots 2\ at.\%$

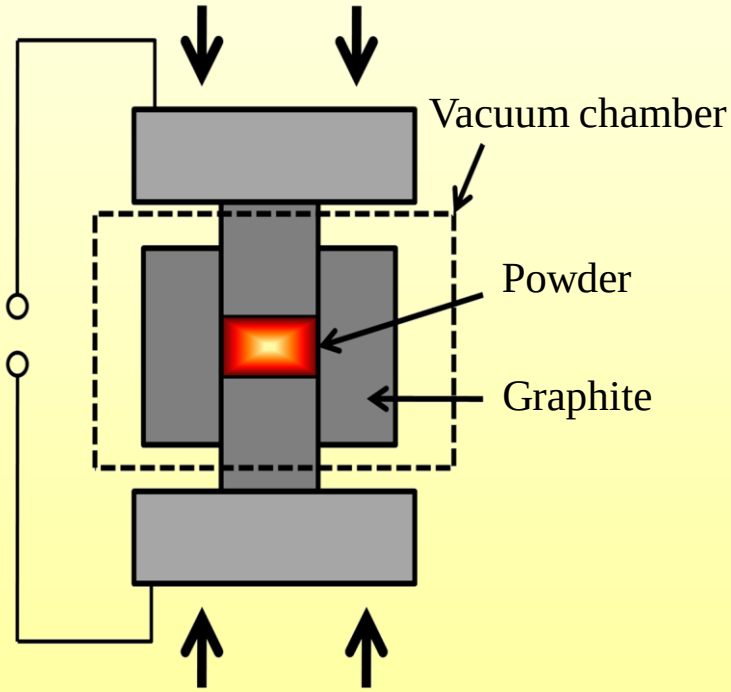
Aluminum and Germanium:

- Al reduces the initial crack density
- reduce the melting point of the alloy
- reduces slightly the density of the alloy



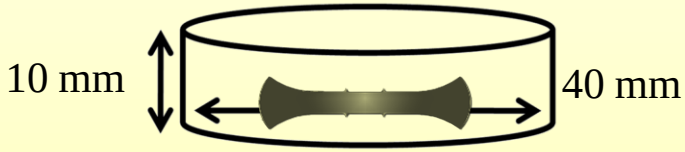
Powder metallurgy (SPS)

Spark Plasma Sintering (SPS) at KIT

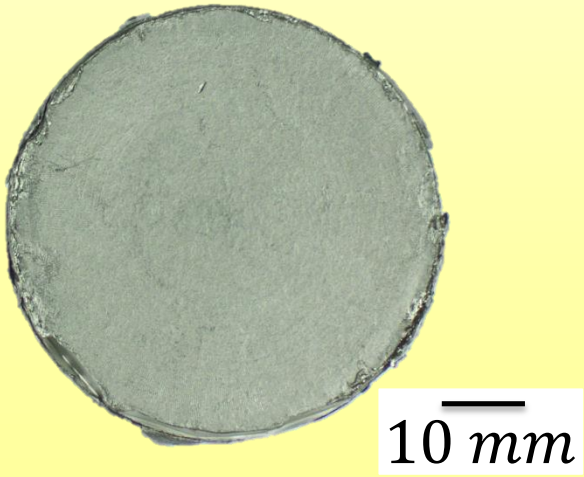


SPS specimen with schematic creep sample

Geometry:



$100\ g\ ;\ \rho = 9.1\ g/cm^3$



Melting metallurgy

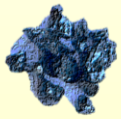
pure elements

arc melting

heat treatment

1850 °C for 24 h

creep specimen



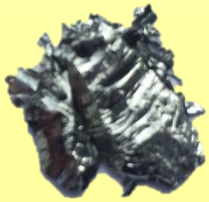
B

Mo

Al

$\overline{2\ mm}$

Si



Ge

Melting metallurgy

pure elements

arc melting

heat treatment

1850 °C for 24 h

creep specimen

Arc melting furnace

Melting metallurgy

pure elements

arc melting

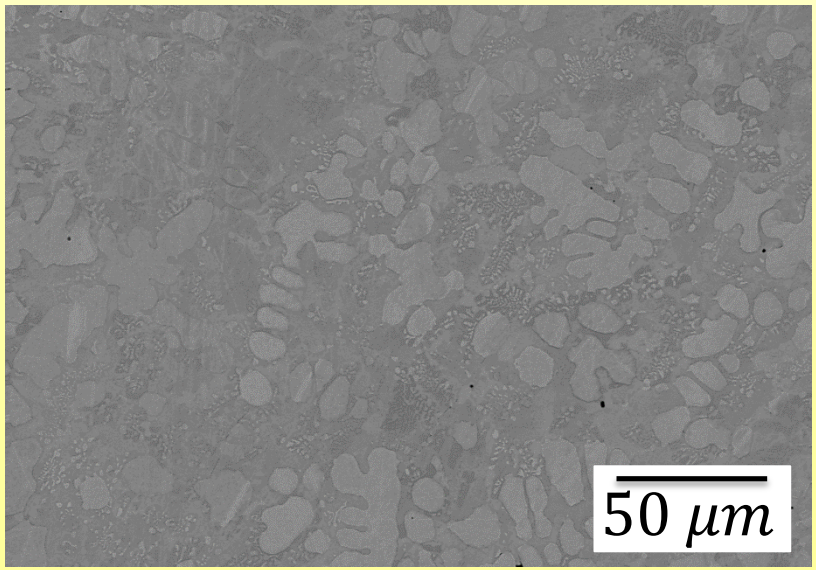
heat treatment

1850 °C for 24 h

creep specimen

Arc melting process

10 *mm*



50 *µm*

Melting metallurgy

pure elements

arc melting

heat treatment

1850 °C for 24 h

creep specimen

Vacuum cold wall furnace

Melting metallurgy

pure elements

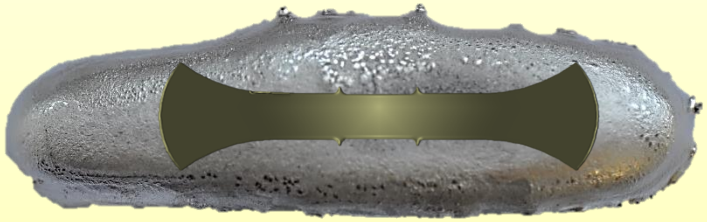
arc melting

heat treatment

1850 °C for 24 h

creep specimen

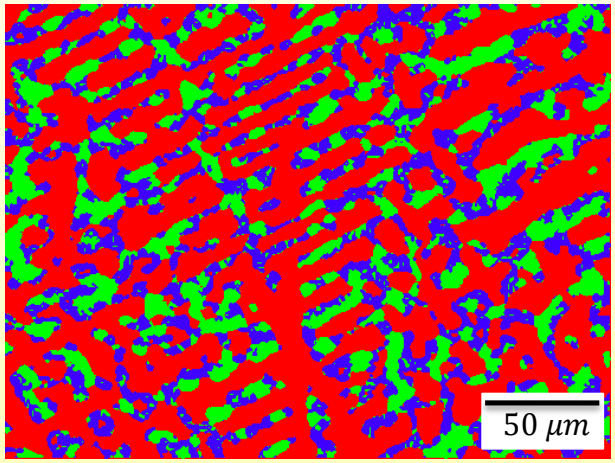
Arc melted specimen with schematic creep sample



$\overline{10\ mm}$

$30\ g\ ;\ \rho = 9.3\ g/cm^3$

Mo-9Si-8B-2Al



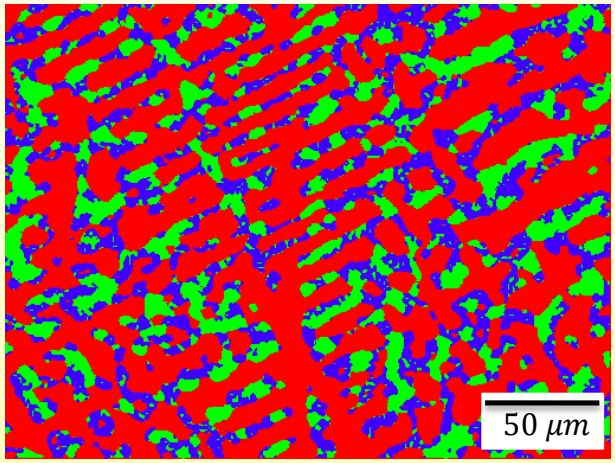
Heat treatment:
1850 °C
24 h

	Mo_{ss}	Mo_3Si	Mo_5SiB_2	Mo_5SiB_2 nominal composition
Mo	94.3	75.5	82.7	62.5
Si	4.2	21.4	16.9	12.5
B	$n.d.$	$n.d.$	$n.d.$	25.0
Al	1.5	3.1	0.6	–

Stated in at.%

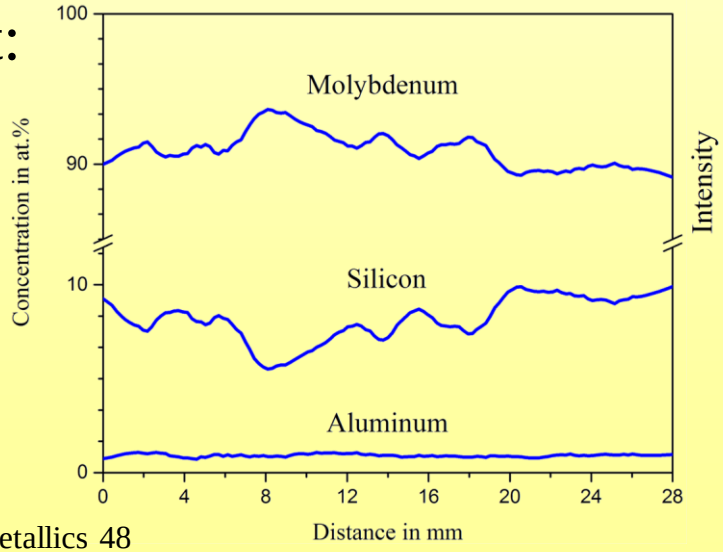
$$\frac{Mo}{Si} = \frac{4.9}{1}$$

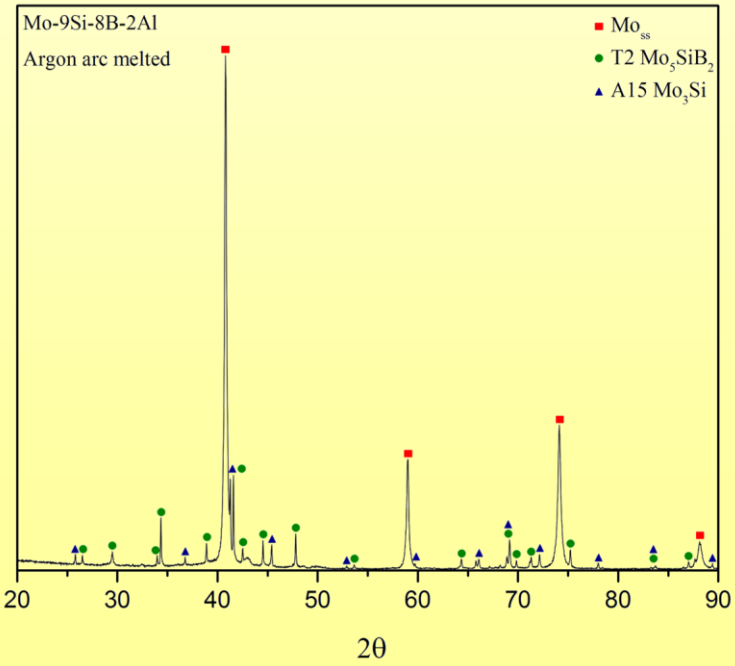
Mo-9Si-8B-2Al



	Mo_{ss}	Mo_3Si	Mo_5SiB_2
theo. composition	55%	15%	30%
Mo-9Si-8B (SPS) [1]	57%	14%	29%
Mo-9Si-8B-2Al	56%	22%	22%

Heat treatment:
1850 °C
24 h

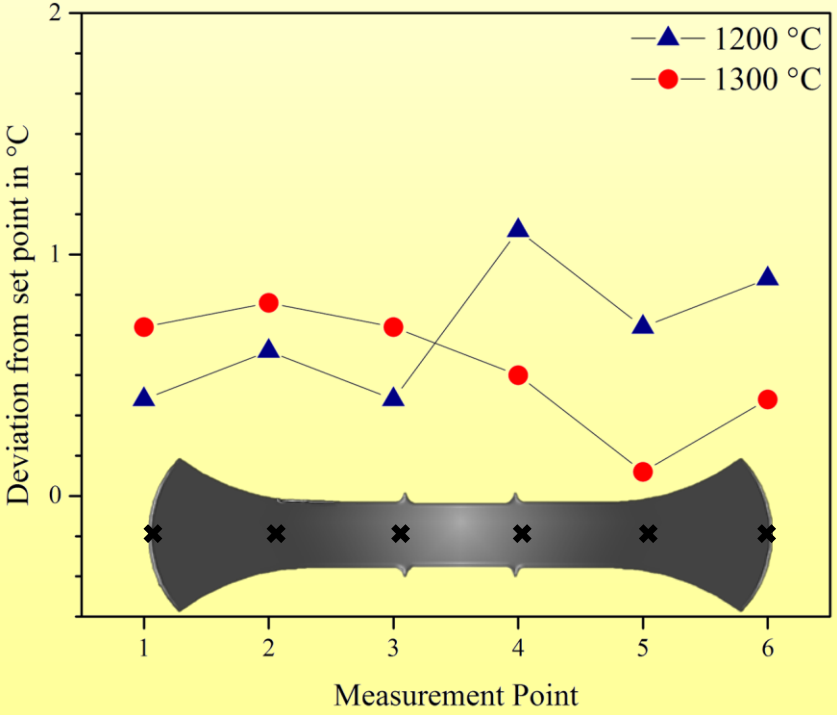


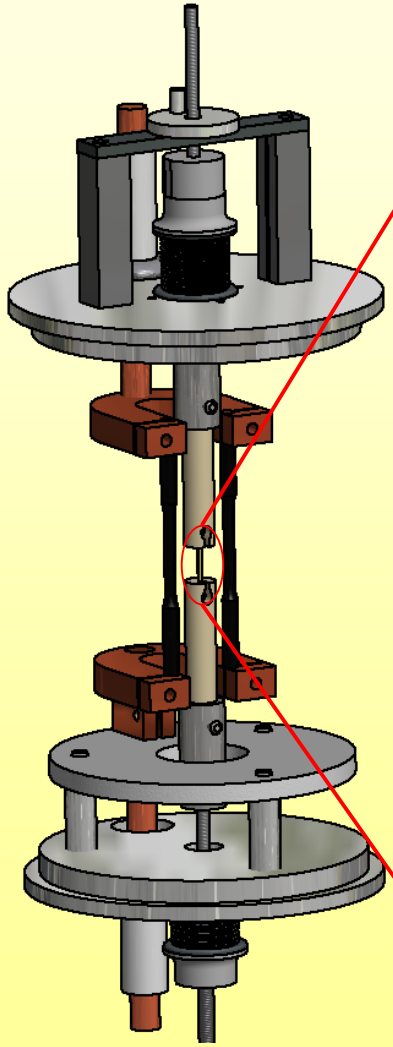


[1] C. Hochmuth, 2014, Intermetallics 48

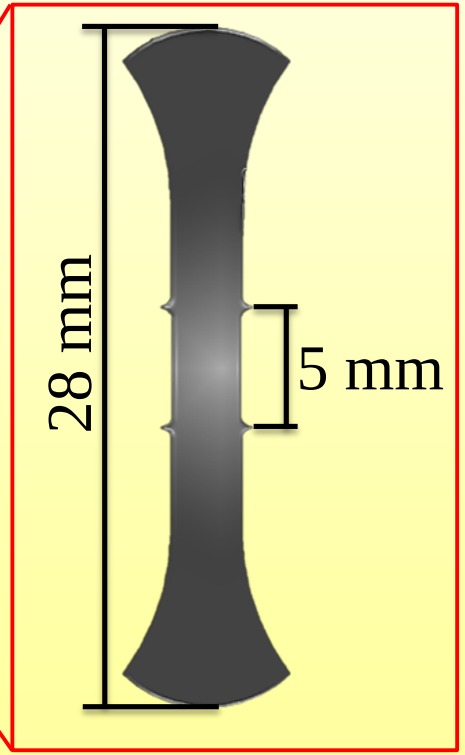
Creep testing device

- temperatures up to 1500 °C
- vacuum $8 \cdot 10^{-4}$ Pa
- small specimens

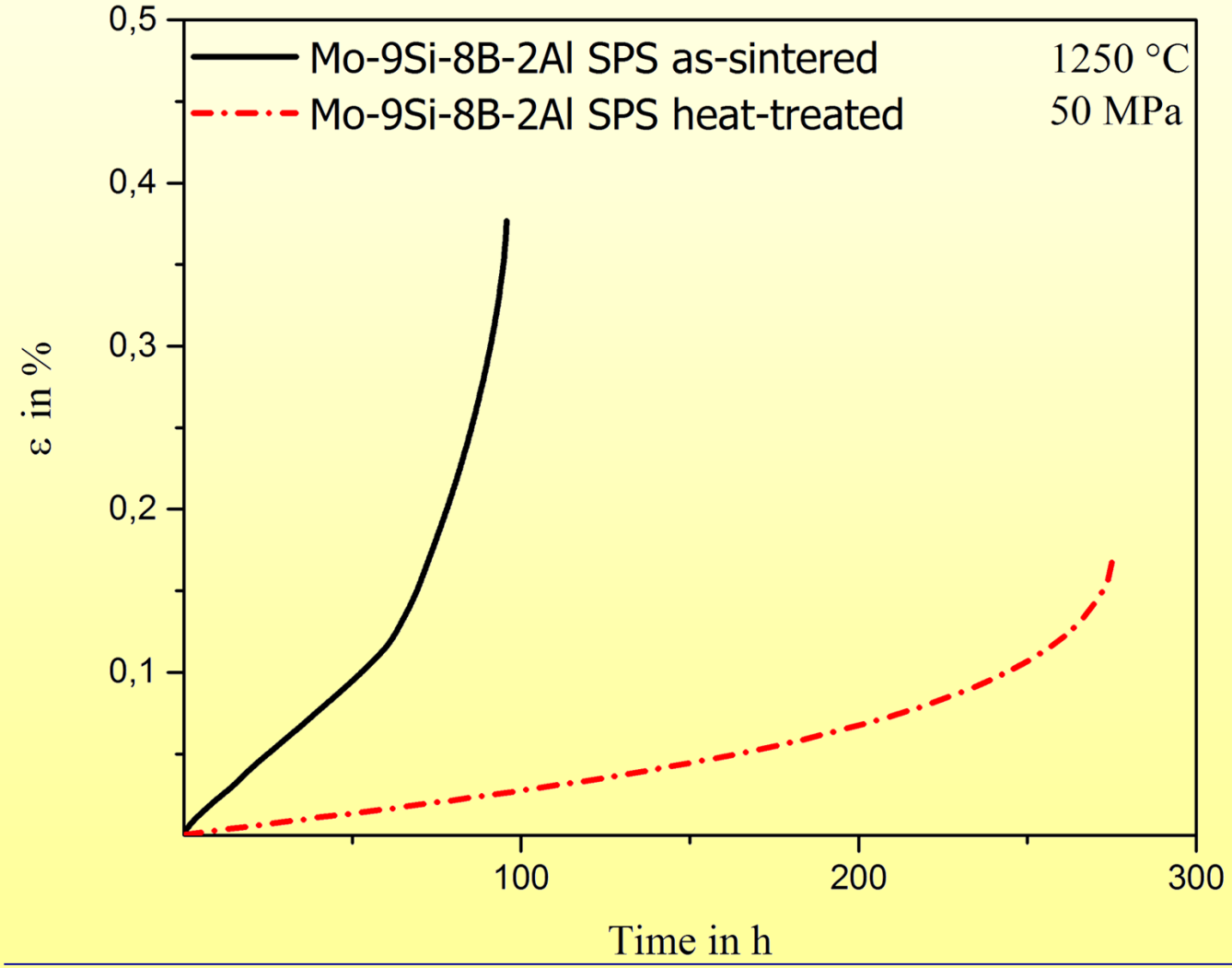


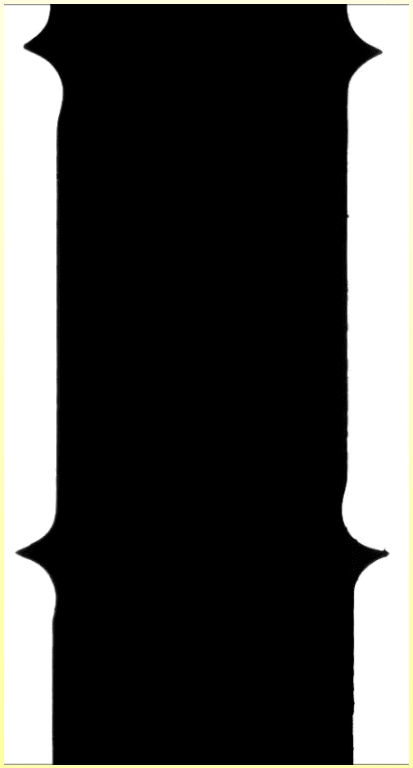


Specimen geometry



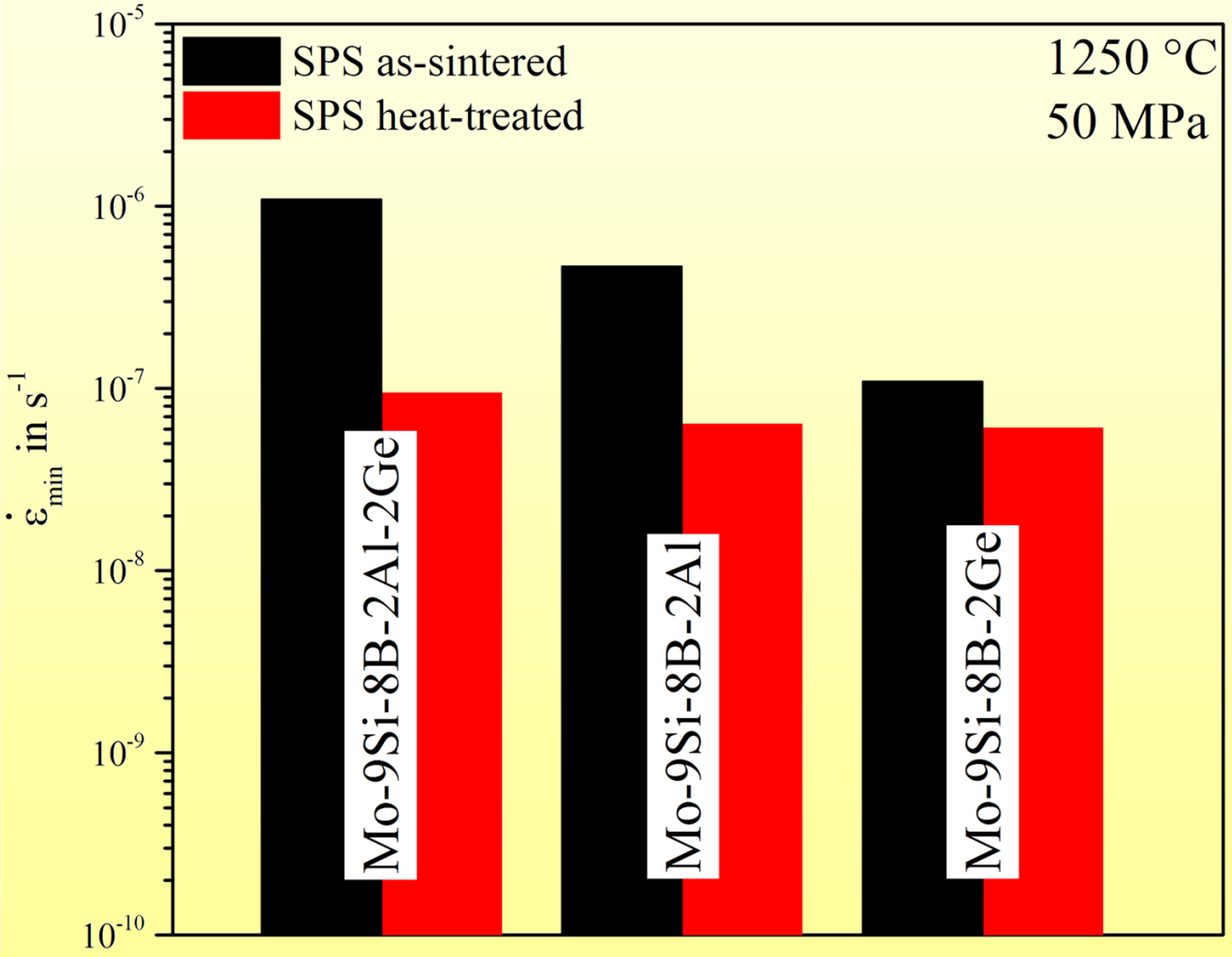
Creep tests



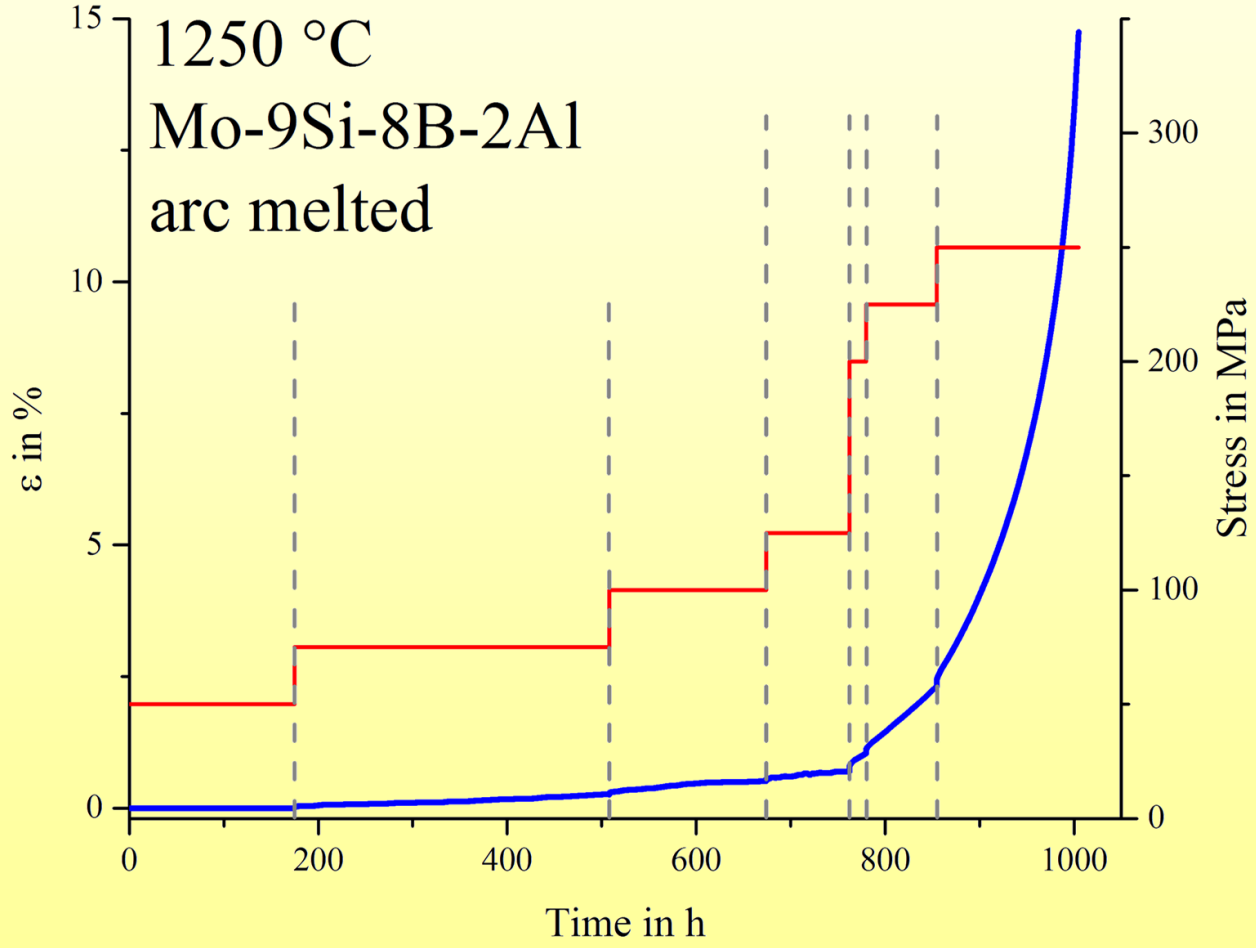


1 *mm*

SPS creep tests



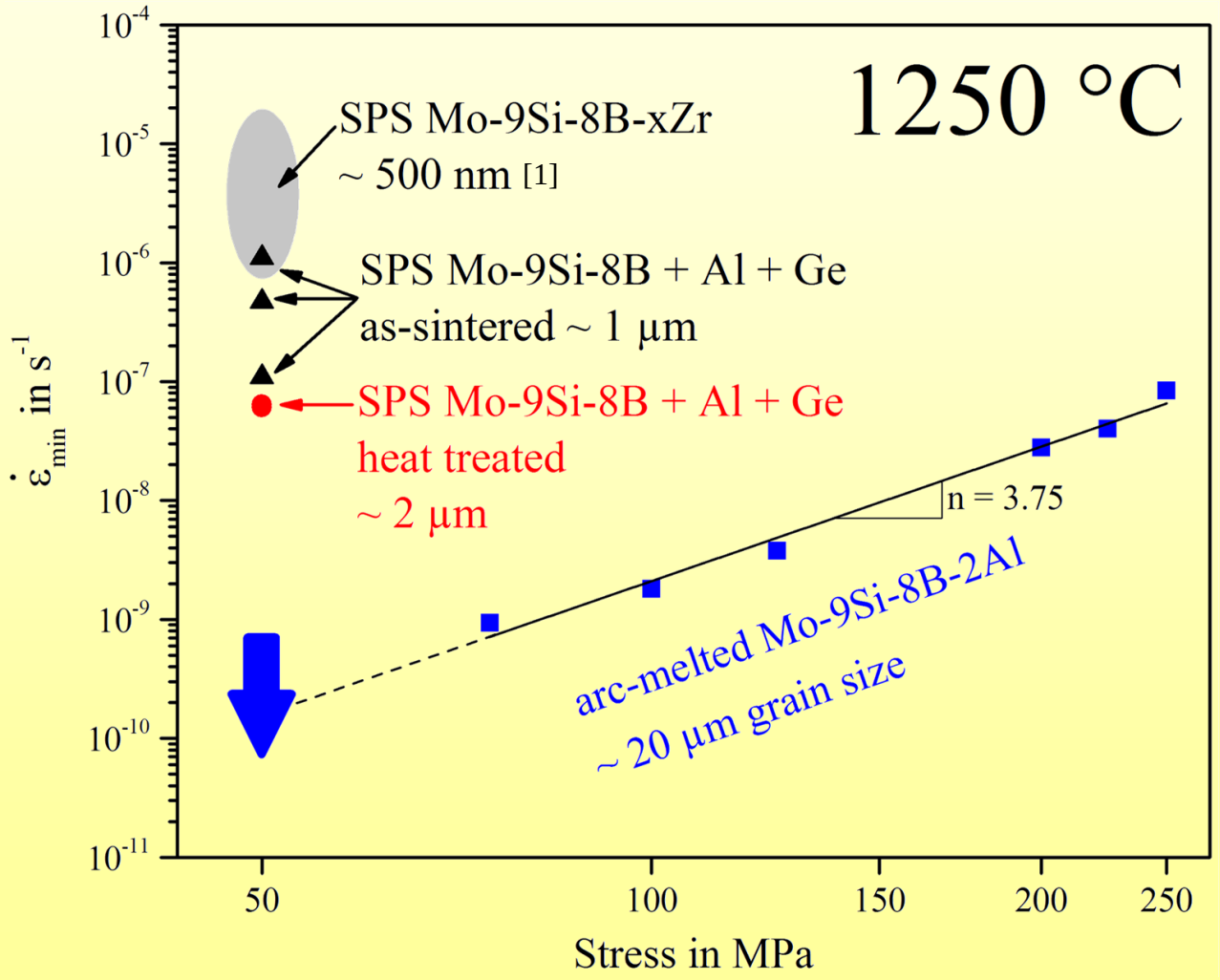
Arc melted creep tests



Arc melted specimen:

- test time in total over 1000 h
- no strain rate detected for 50 MPa after more than 150 h

Creep tests



doubling the grain size decreases the minimum strain rate one order of magnitude

[1] C. Hochmuth, 2014, Intermetallics 48

Summary and outlook

- successfully adapted the way of manufacturing ✔
- microstructural characterization with EDS, XRD and XRF ✔
- new creep testing device ✔
- creep test ✔
- FIB tomography
- microstructural characterization after creep testing

Thank you for your attention

Mo-9Si-8B-2Al: 1250 °C 250 MPa 150 h