Using Neutron Scattering for the Optimization of IN706-type Superalloys

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Technische Universität Braunschweig

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Technische Universität Braunschweig

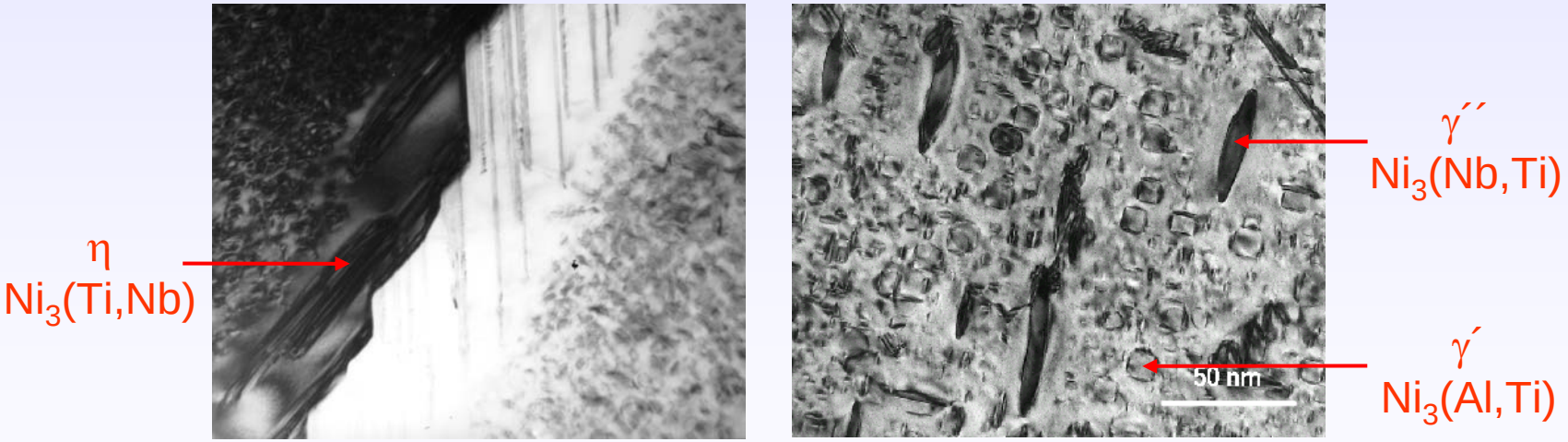
THE TEAM

- Dipl.-Ing. Dominique DelGenovese (TUBS)
- Dr. Martin Götting (TUBS)
- Dr. Debashis Mukherji (TUBS)
- Dr. Pavel Strunz (NPI, *Czech Republic)*
- Dr. Ralph Gilles (FRM-II, TUM)
- Dr. Markus Hölzel (FRM-II, TUM)
- Dr. Albrecht Wiedenmann *(*BENSC)
- Dr. Daniel Toebbens *(*BENSC)

Material groups:

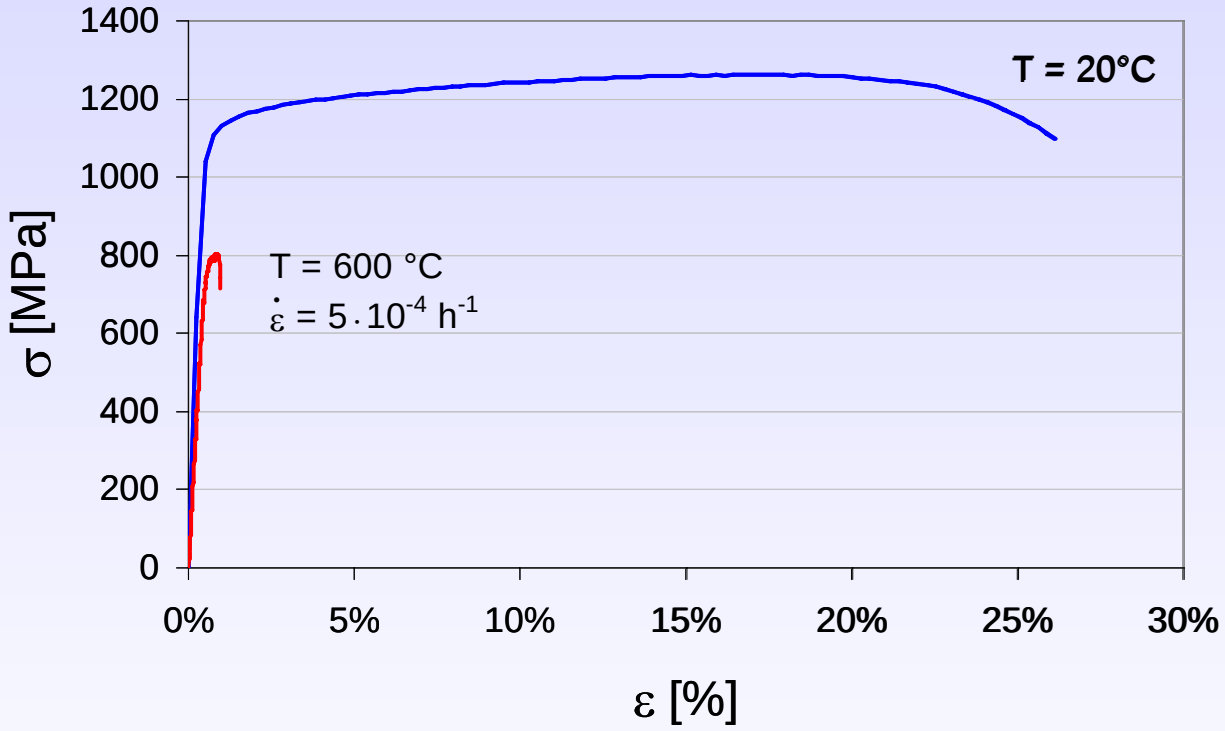
- γ'-strengthened alloys (Waspaloy, Nimonic 263, Udimet 500 ...)
- solid solution and carbide strengthened alloys (IN 617, Haynes 230)
- γ' / γ''-strengthened alloys (IN 706, IN 718, IN 625 ...)

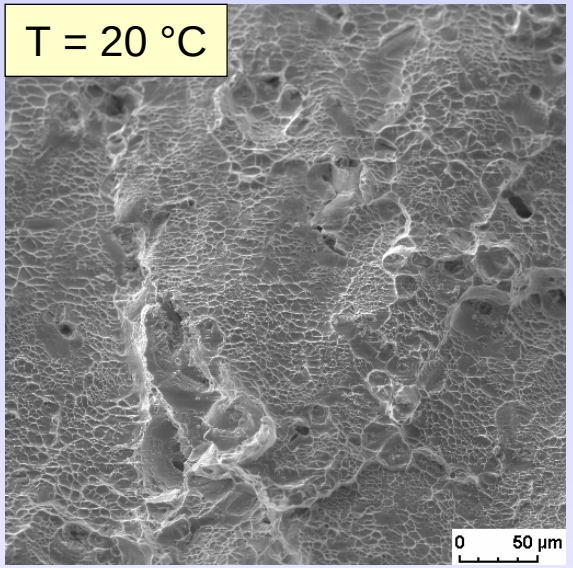
Ni	Cr	Co	Mo	Nb	Al	Ti	Fe	C
bal.	16.0	-	-	3.0	0.2	1.6	37.0	0.03

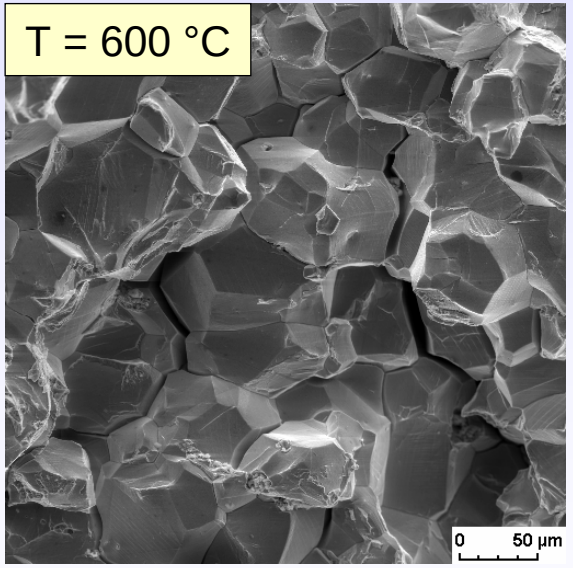


IN706

THE SAGBO MECHANISM







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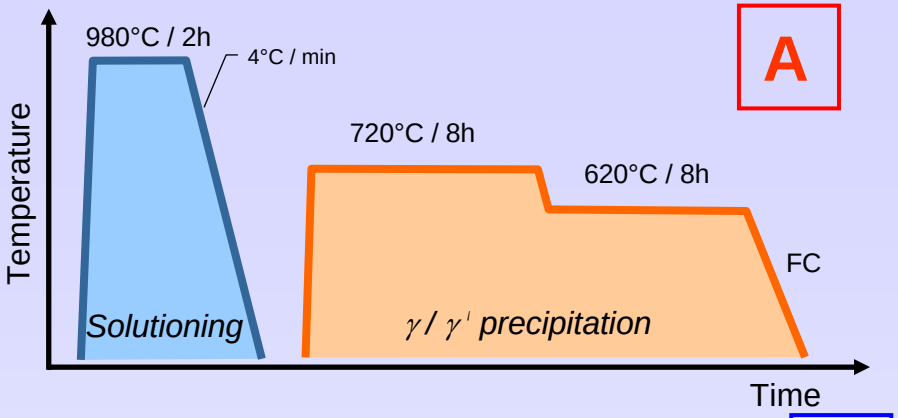
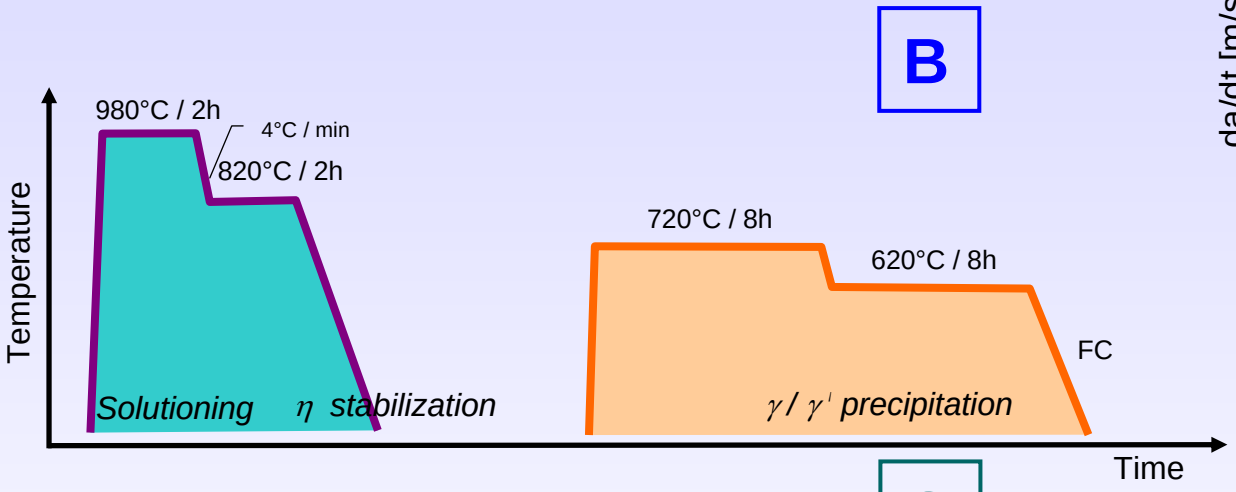
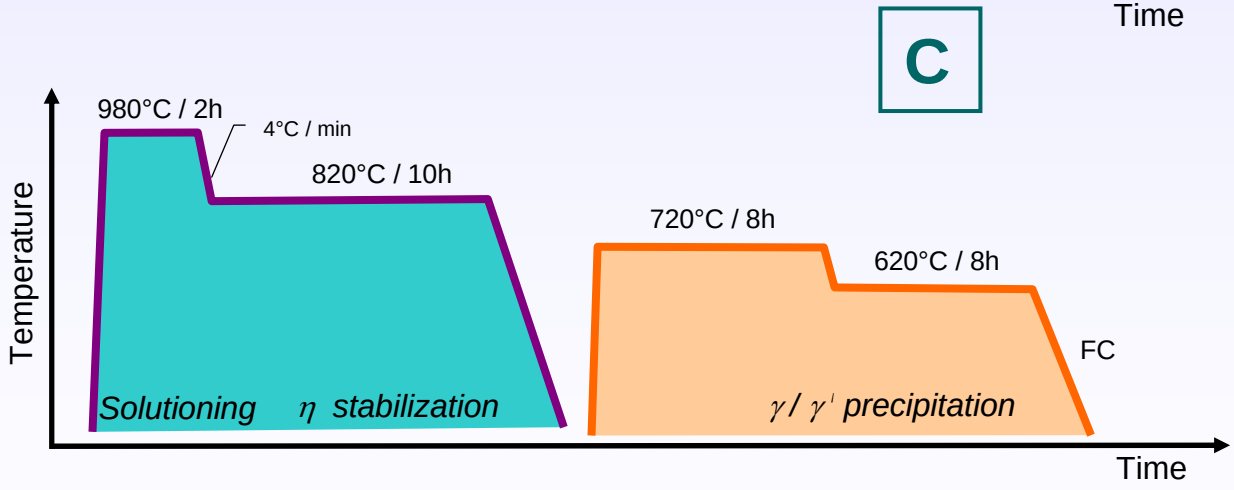
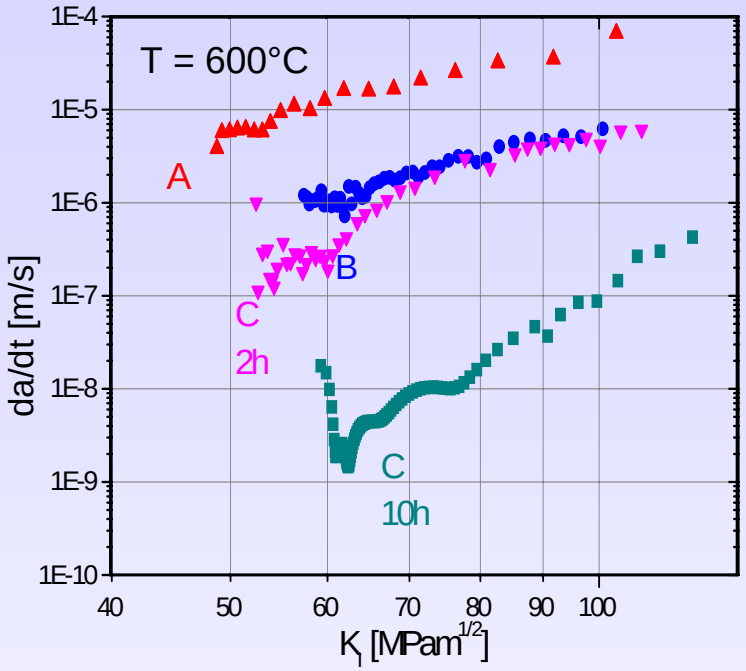
CREEP CRACK GRWOTH DATA









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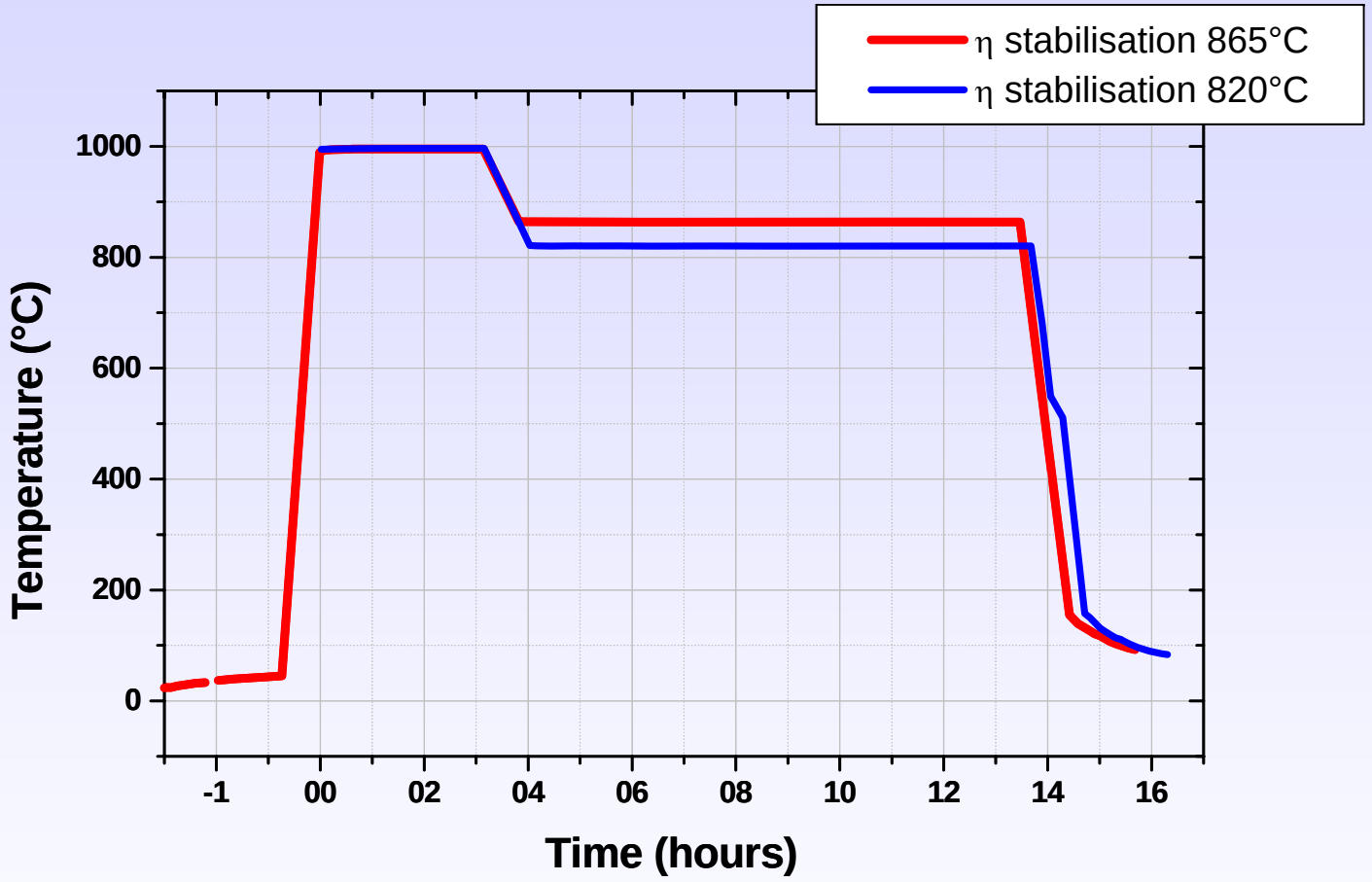
NEUTRON SCATTERING (SANS)

865°C ⟷ 820°C



In-situ measurement at elevated temperatures

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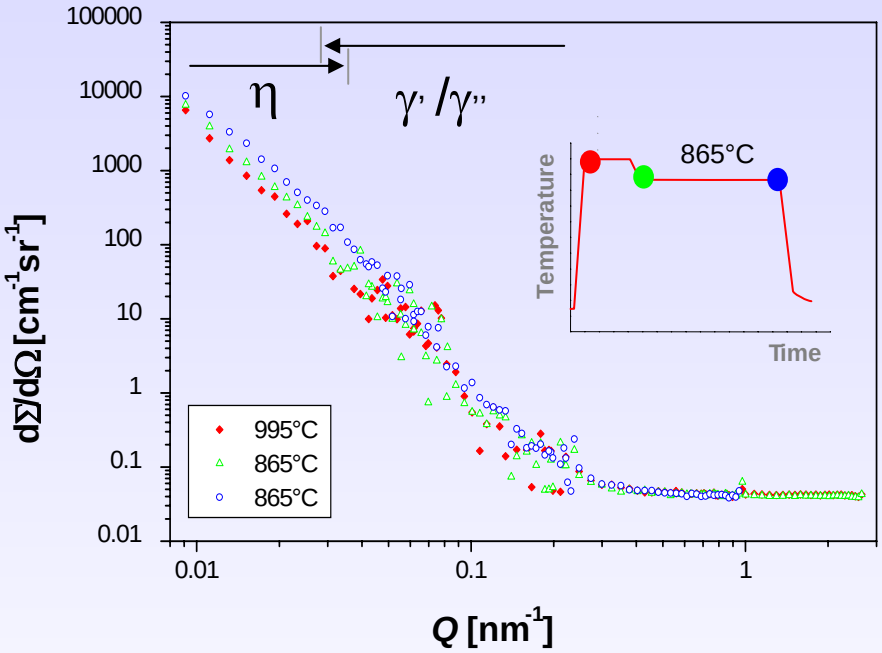

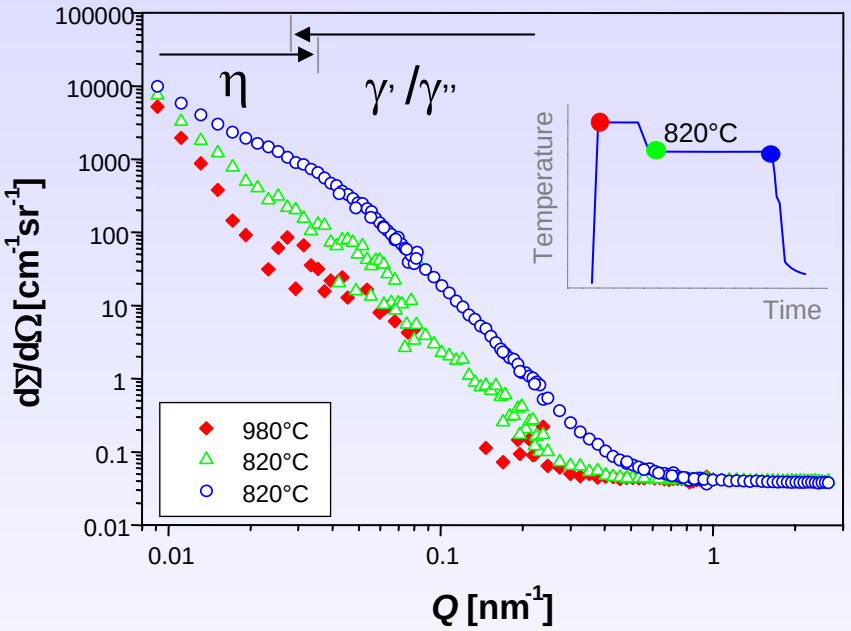

In-situ measurement at elevated temperatures

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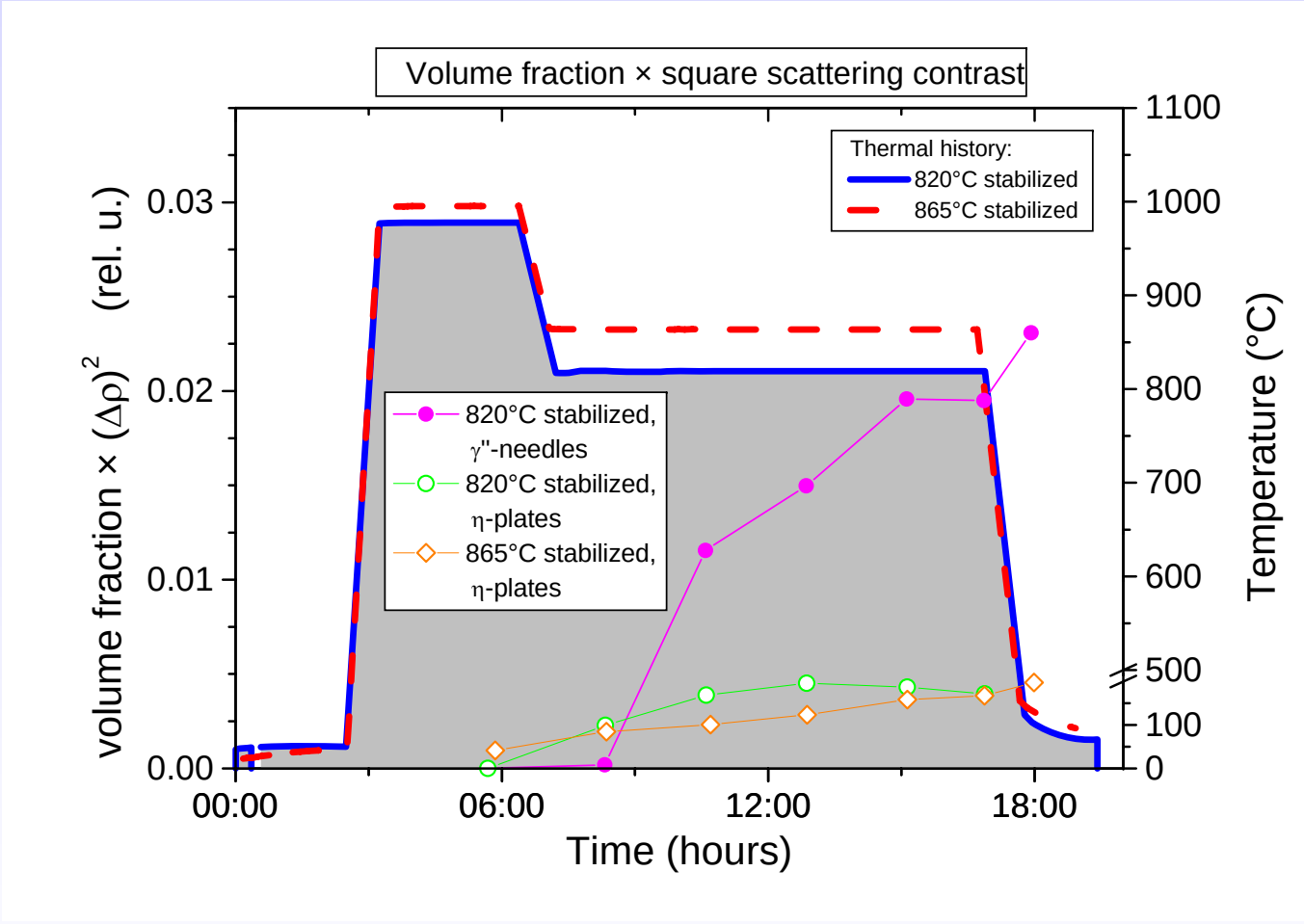

In-situ measurement at elevated temperatures

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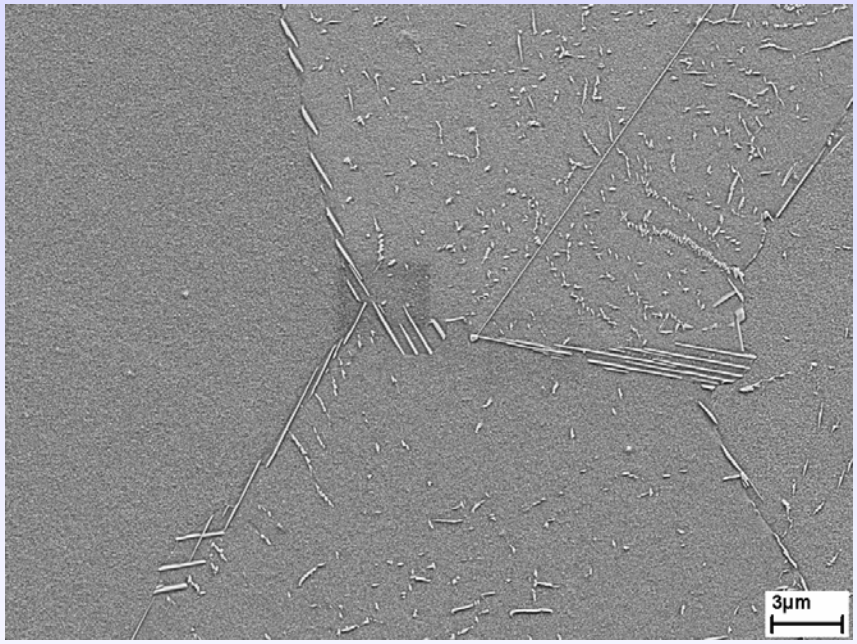
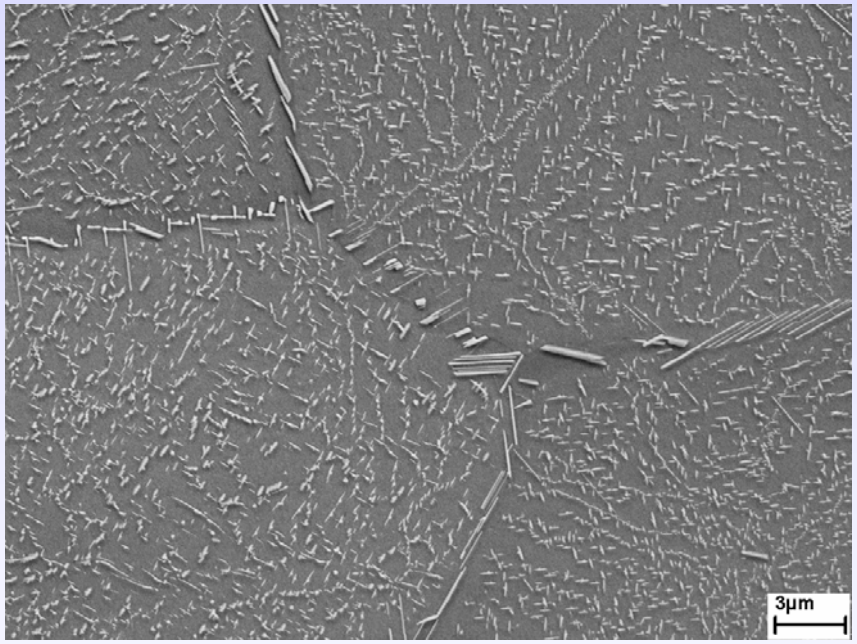
865°C ⟷ 820°C

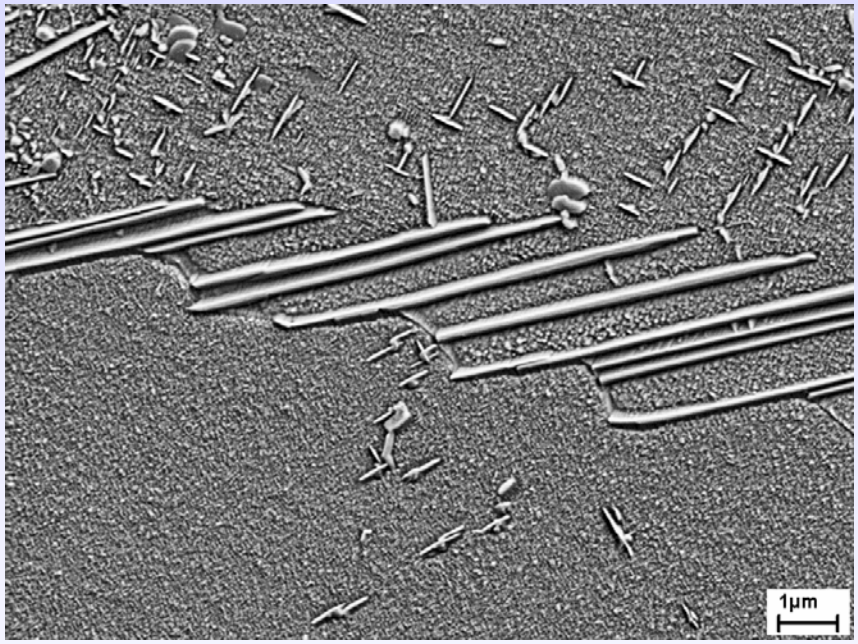
MICROSTRUCTURE

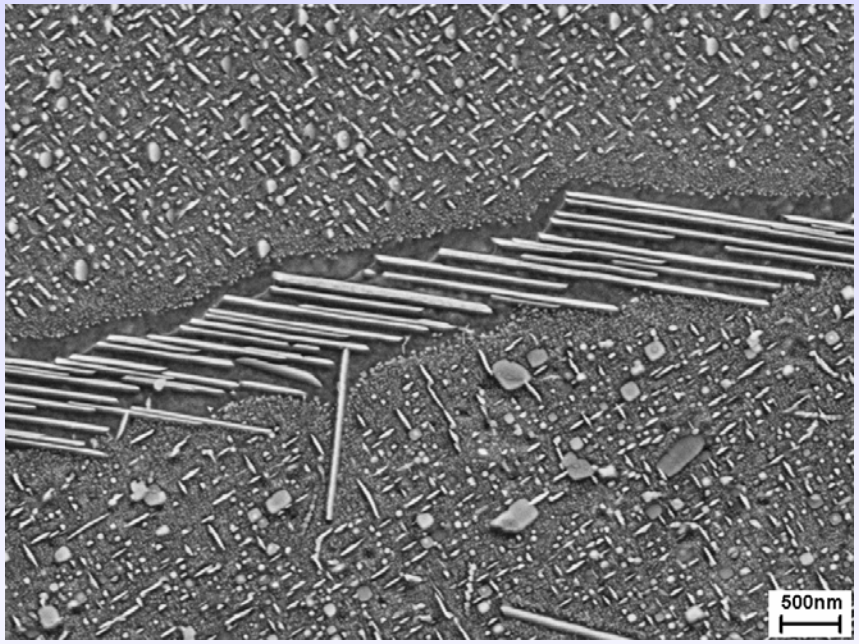




865°C ⟷ 820°C

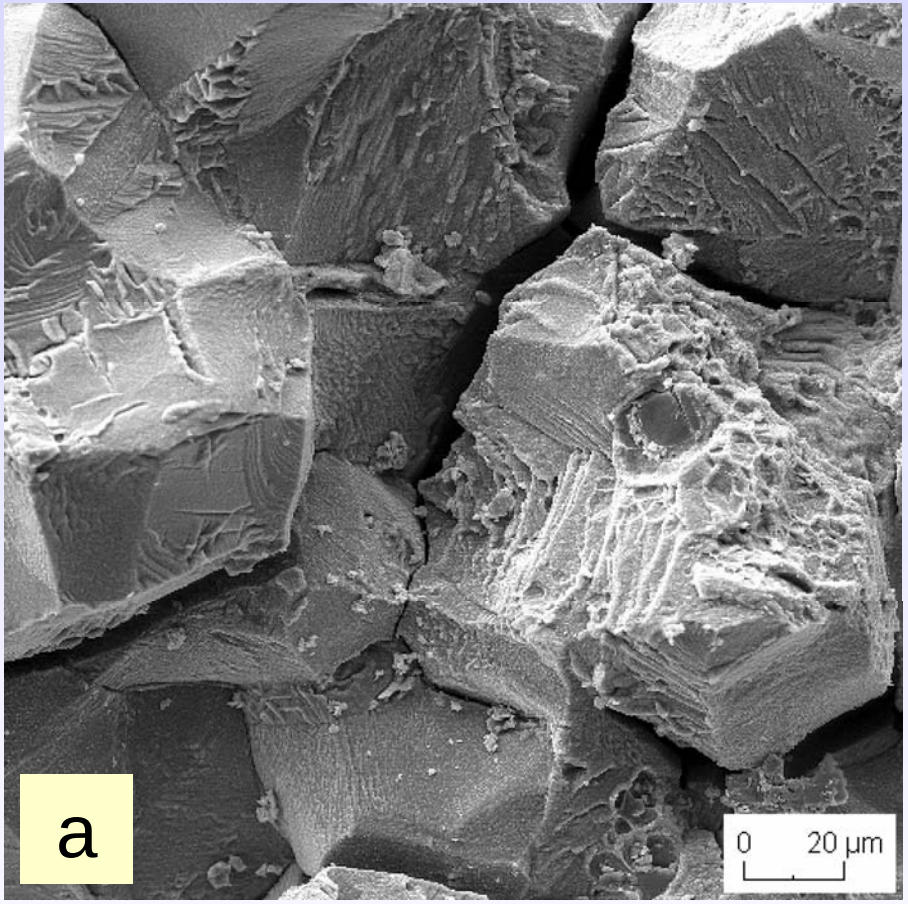
MICROSTRUCTURE



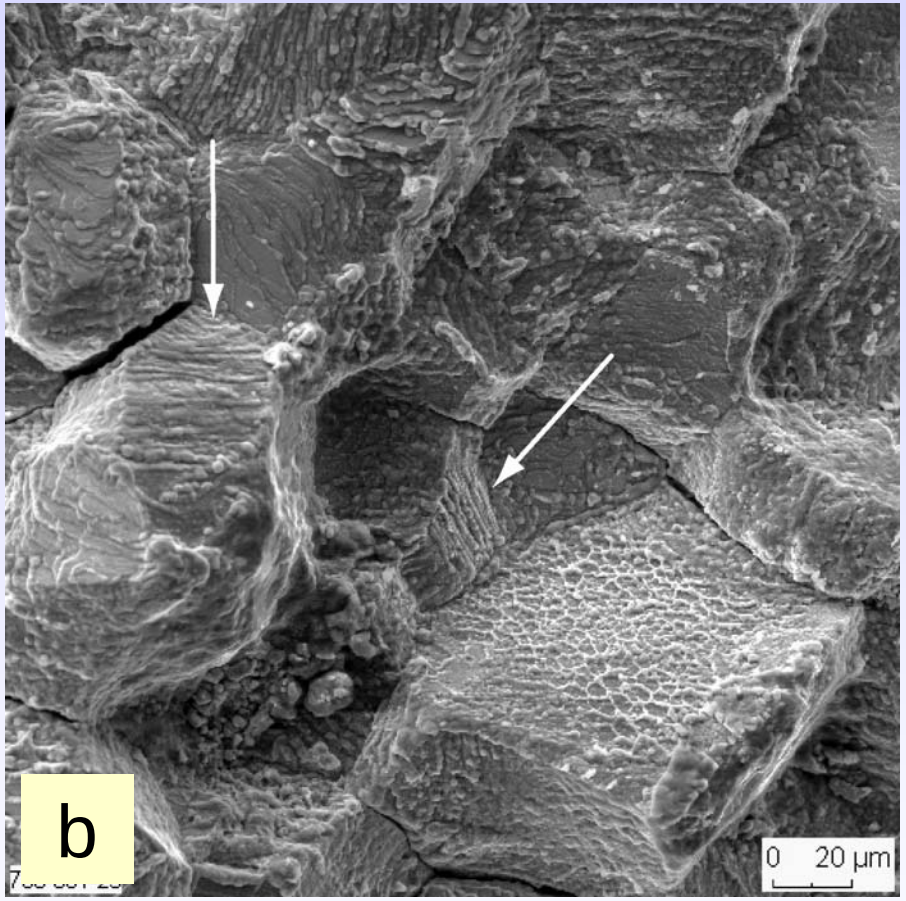


Creep Crack Growth at T = 600°C

FRACTOGRAPHY



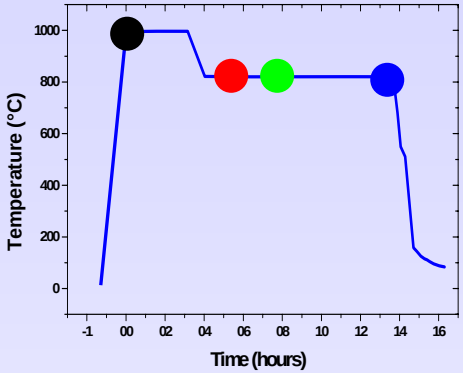
Heat treatment B

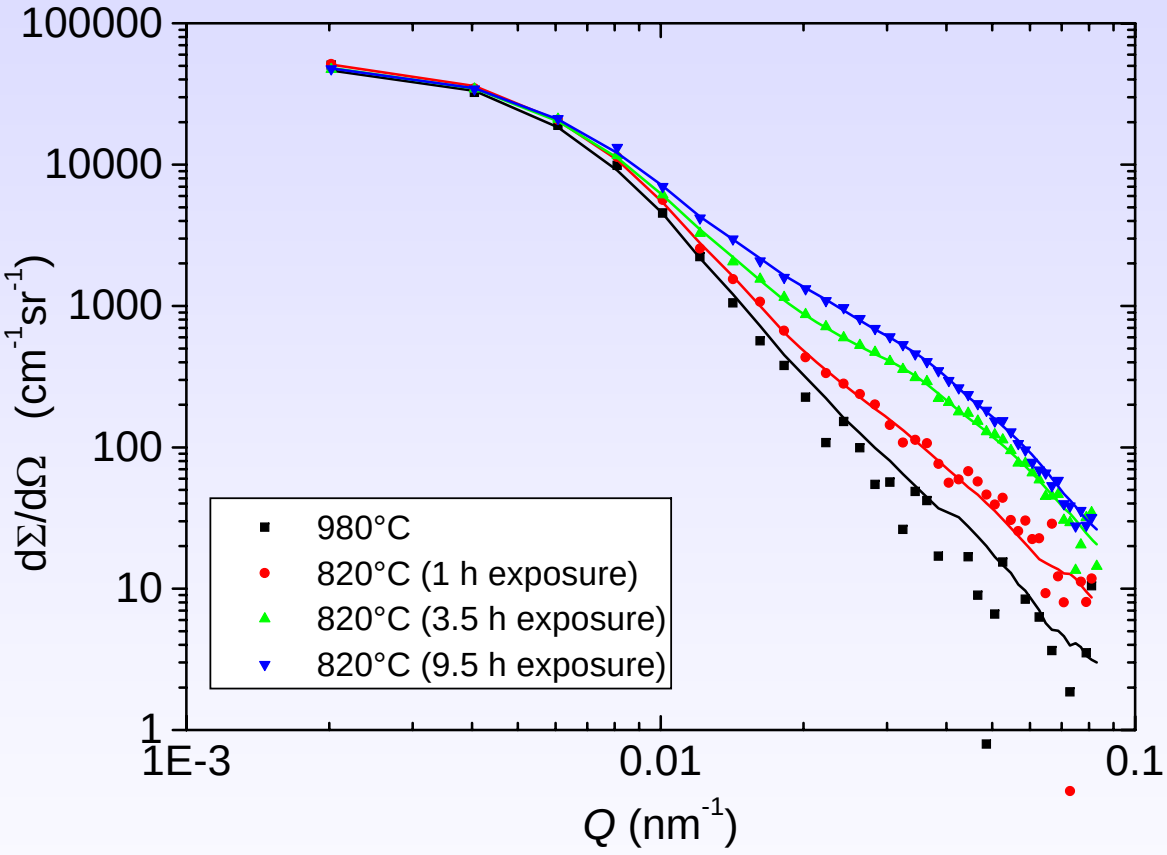


Heat treatment C

NEUTRON SCATTERING (SANS)

820°C / 10h ⟷ 820°C / 2h





In-situ measurement cycle at elevated temperatures

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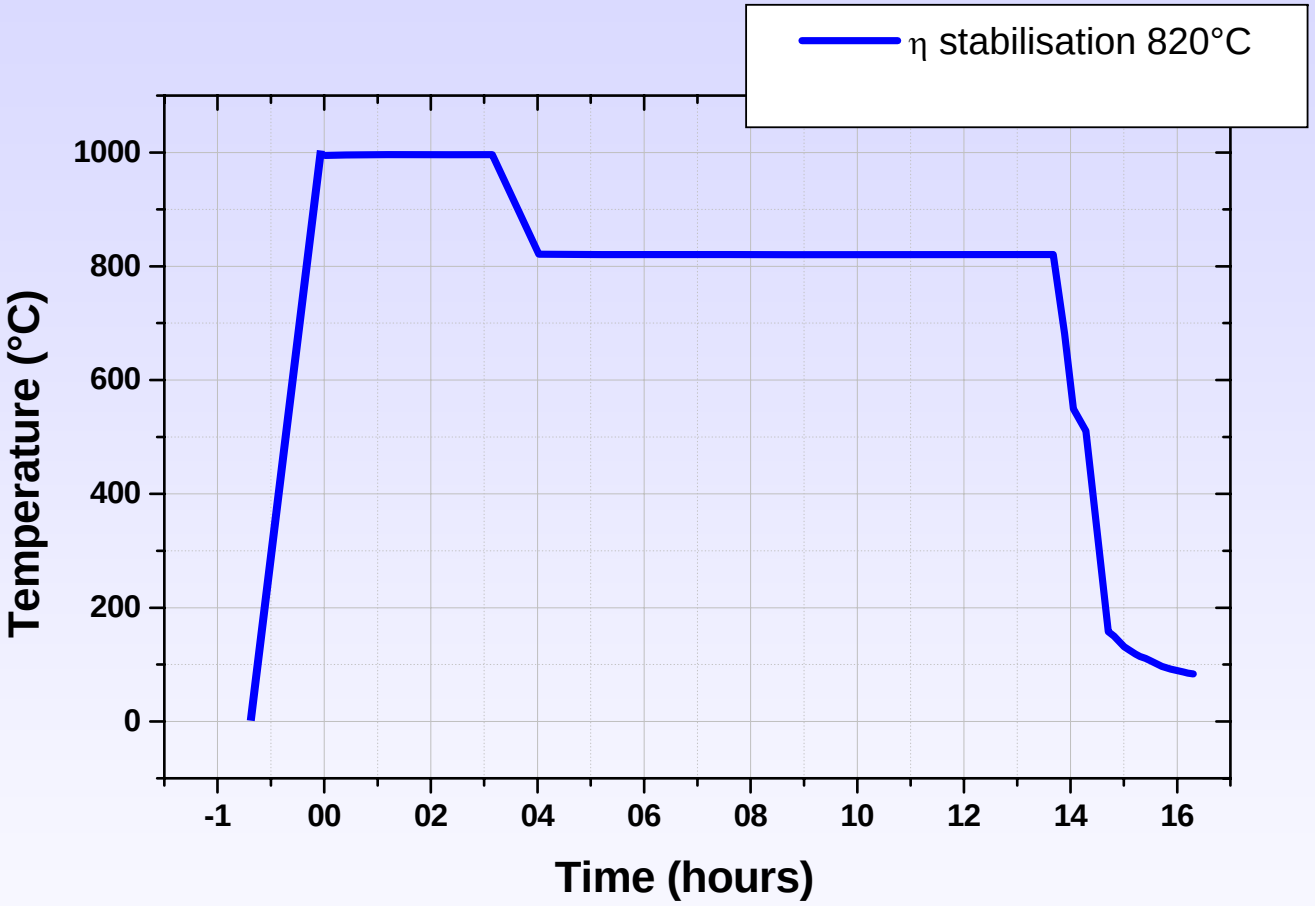
820°C / 10h ⟷ 820°C / 2h

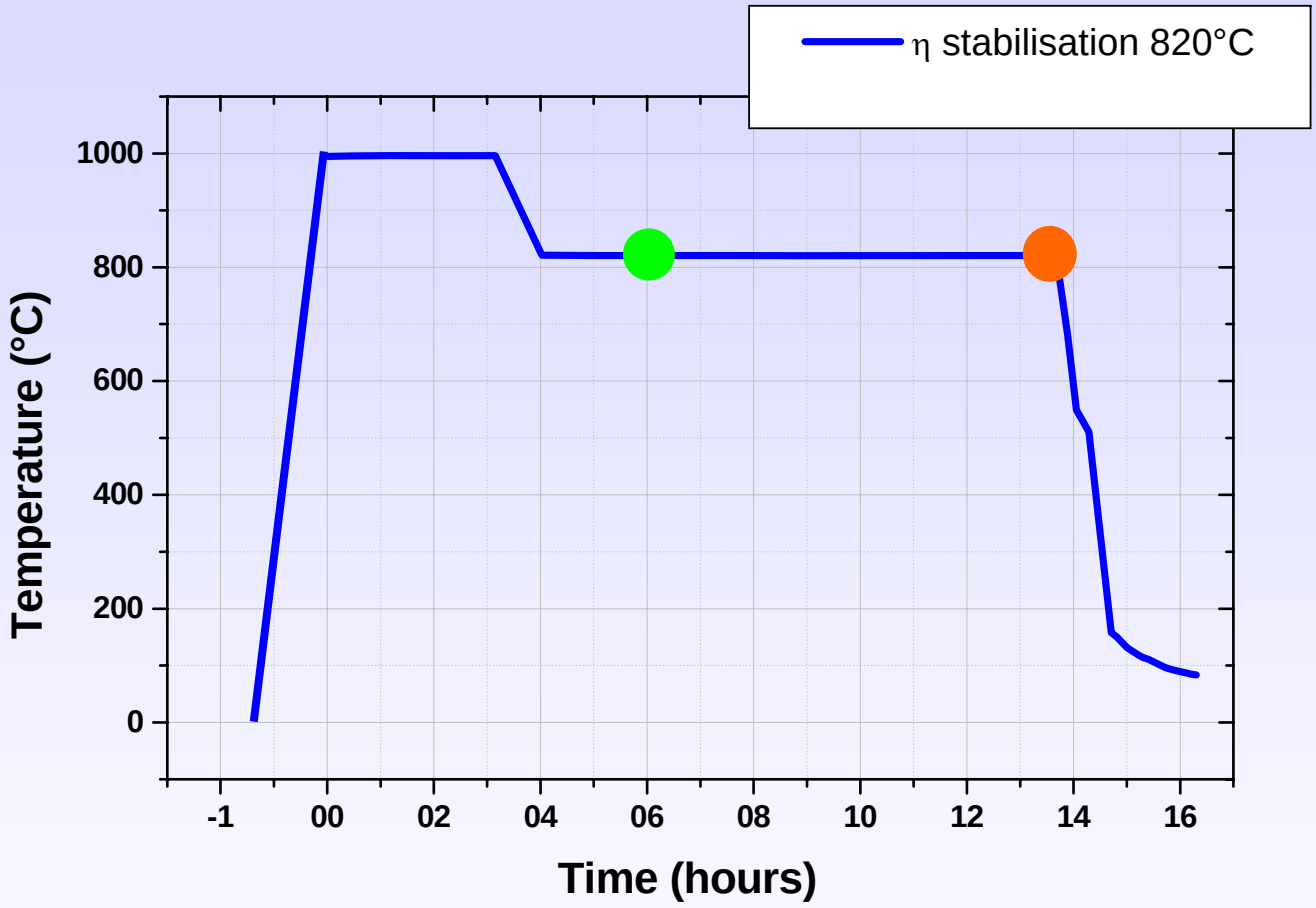


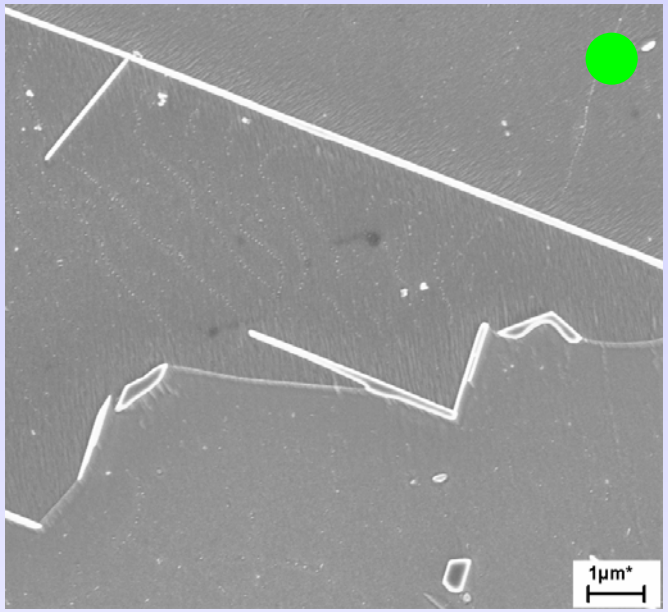
In-situ measurement cycle at elevated temperatures

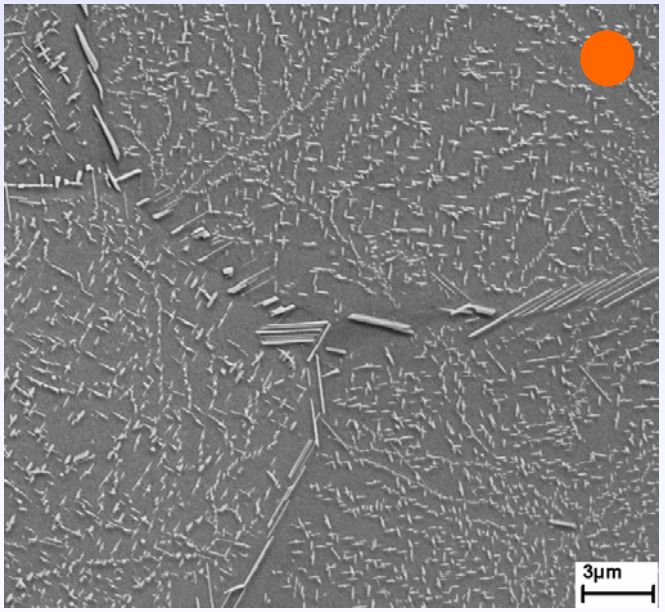
NEUTRON SCATTERING (SANS)

NEUTRON SCATTERING (SANS)

820°C / 10h ⟷ 820°C / 2h







In-situ measurement cycle at elevated temperatures

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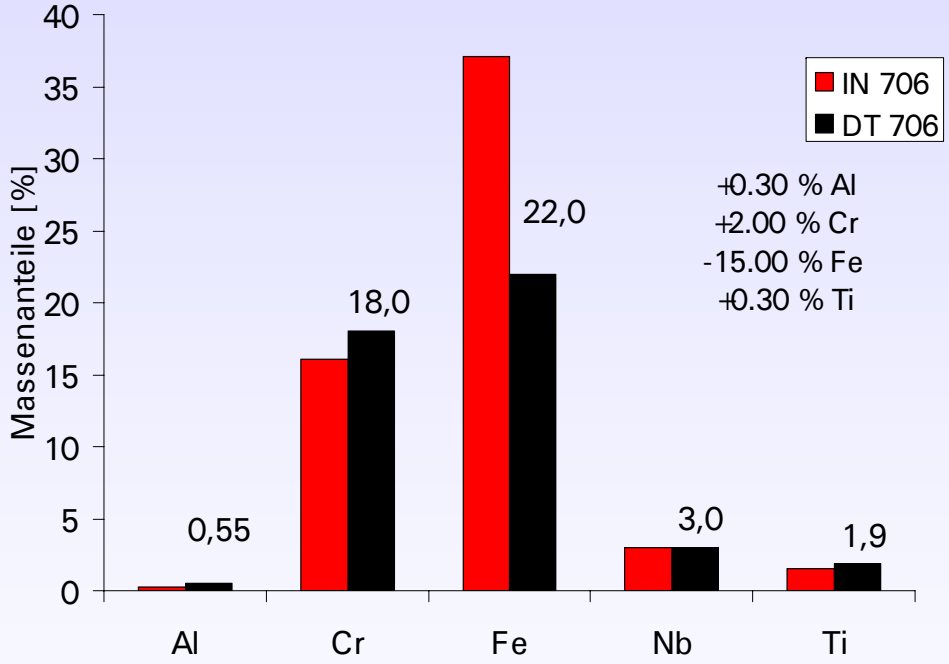
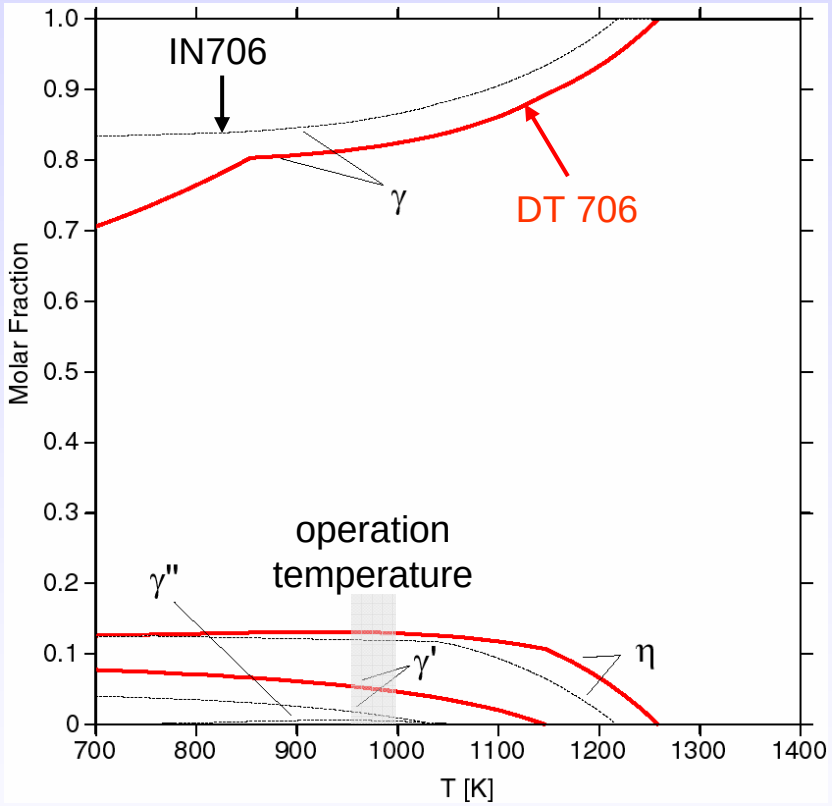
ALLOY DEVELOPMENT

- Concept:
  Development of a γ'/γ''-strengthened alloy similar to IN706 with improved microstructural stability



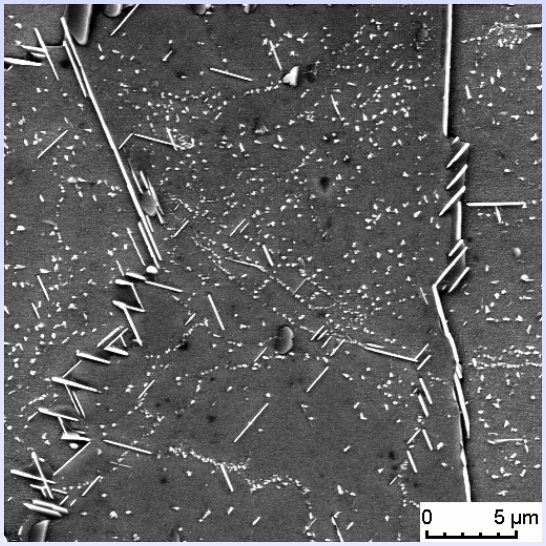


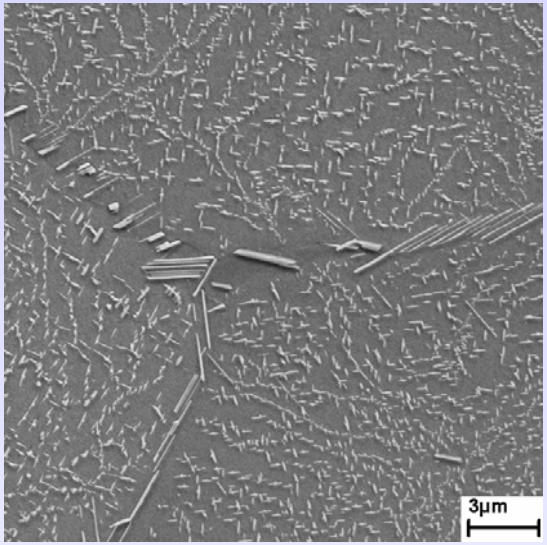
ALLOY DEVELOPMENT

DT 706
Ni-18Cr-22Fe-3Nb-1.9Ti-0.5Al

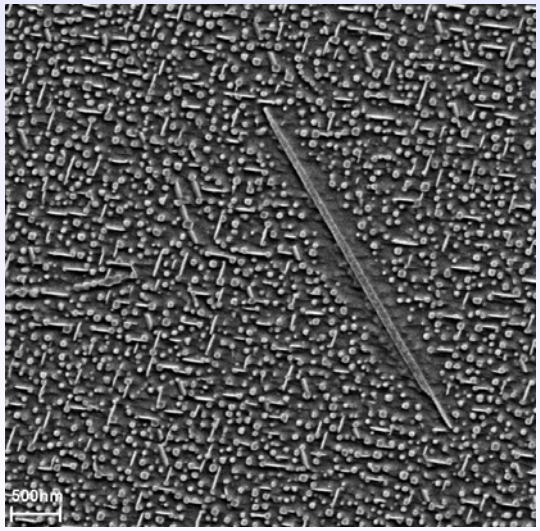
IN 706
Ni-16Cr-37Fe-3Nb-1.6Ti-0.2Al

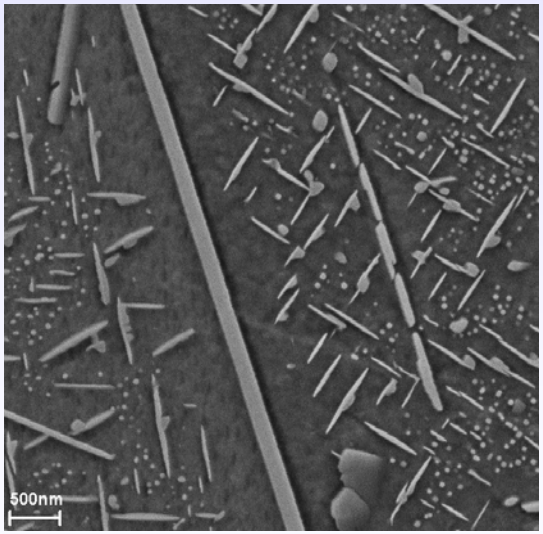
as heat-treated





750°C/750h





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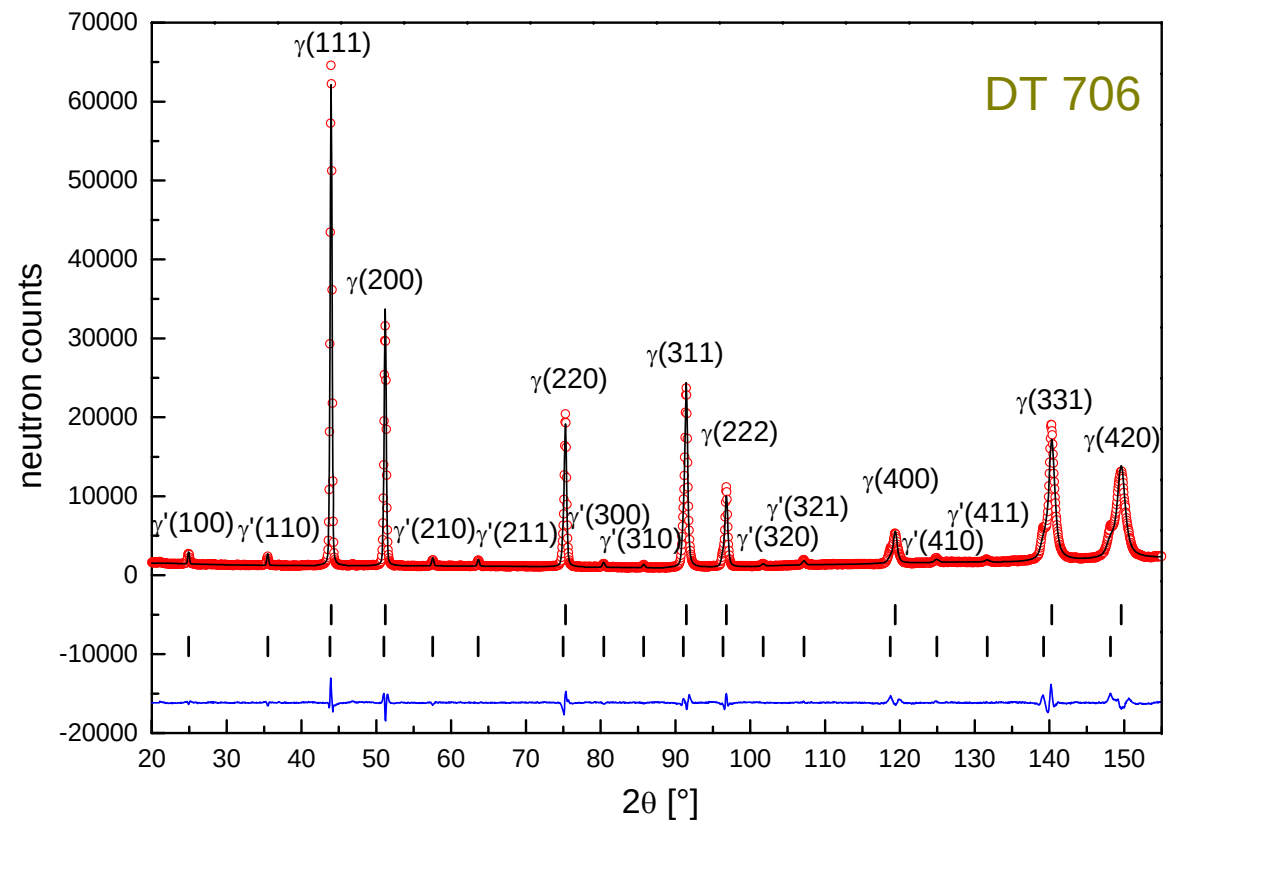
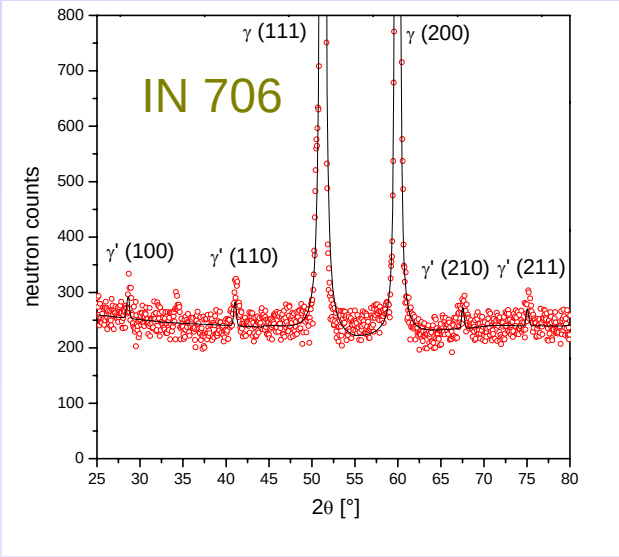
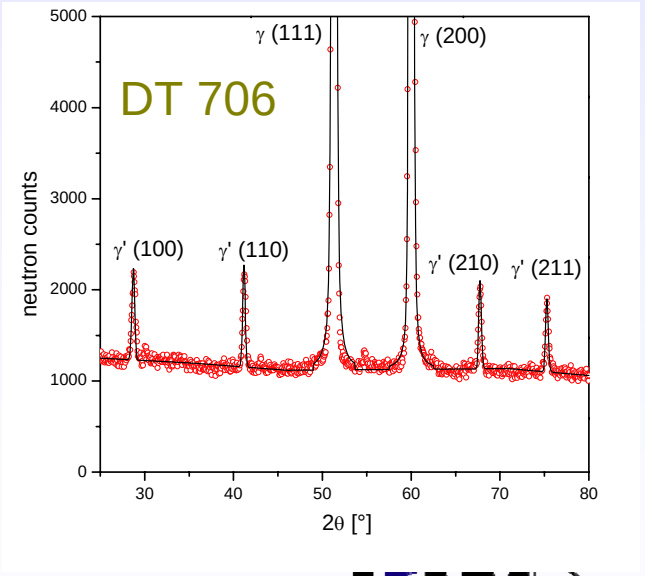
NEUTRON DIFFRACTION







Measurement at SPODI

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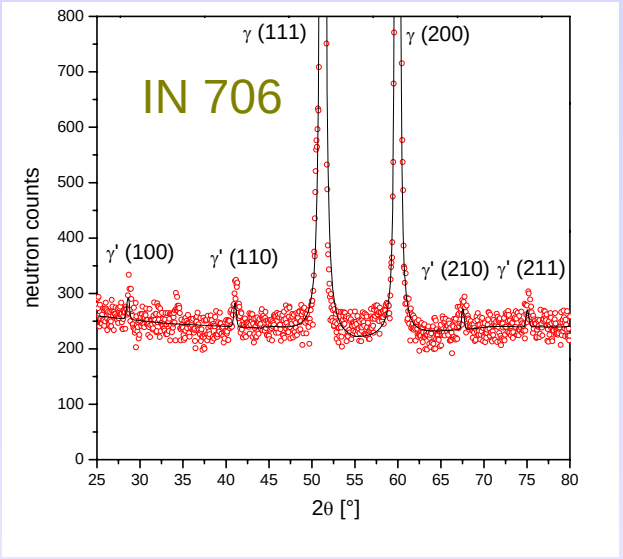
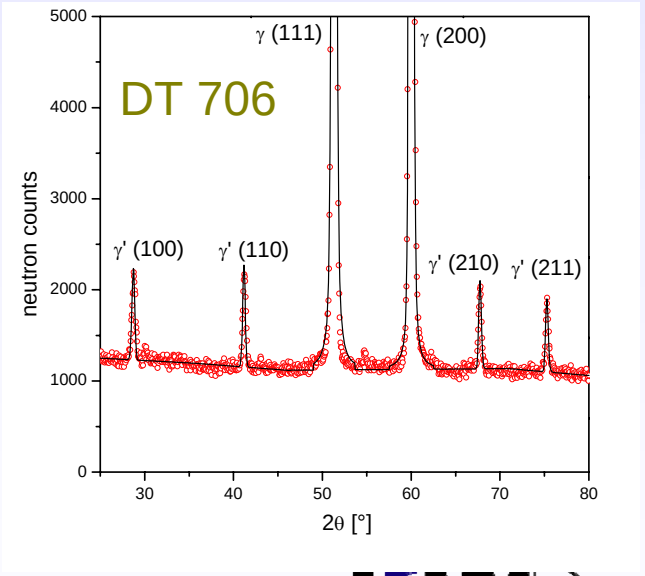
NEUTRON DIFFRACTION

	γ matrix	γ' / γ'' **co-precipitates**
lattice constants	a = 0.35886(1) nm	a = 0.36079(2) nm
weight fractions	≈ 95 %	≈ 5 %
lattice misfit	+ 0.54%	



	γ matrix	γ' / γ'' **co-precipitates**
lattice constants	a = 0.35853(1) nm	a = 0.35990(2) nm
weight fractions	≈ 80 %	≈ 20 %
lattice misfit	+ 0.38%	



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SUMMARY

- Neutron scattering and diffraction are powerful tools for alloy development and optimization as they allow for:
  - analysis of a representative material volume
  - time and temperature resolved analysis of phase transformations
- The mechanical behaviour of wrought superalloys such as IN706 crtically depends on careful control of the microstructre. Important factors for acceptable creep crack growth resistance are:
  - softening of the grain boundary regions
  - overaging of the precipitates