In situ neutron dilatometry investigation of $\beta_o \rightarrow \beta$ phase transformation in TiAl alloys

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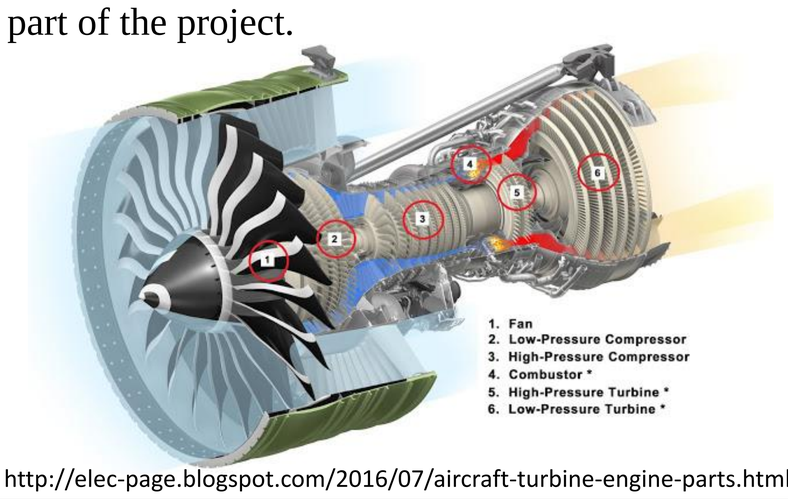
Introduction

The current PhD study project investigates novel attractive materials for advanced aero engines using neutron and high energy X-ray diffraction analysis applying a specially modified Dilatometer for in-situ measurements. This poster presents the neutron part of the project.

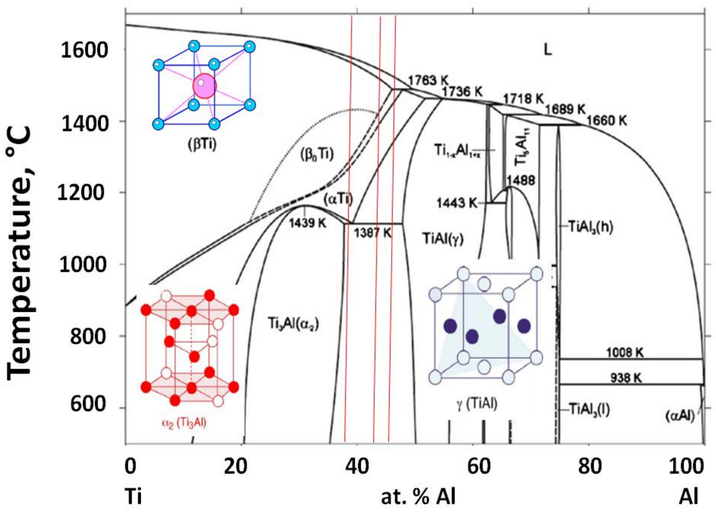


http://elec-page.blogspot.com/2016/07/aircraft-turbine-engine-parts.html

Constantly increasing demands for production of more enviromental friendly aero engines lead to intensive research to find high strength light weight materials for turbine blades. The turbine blades made of TiAl alloys in the aero engines of the most modern planes (e.g. Airbus A-320-NEO) achieve a decrease of the fuel consumption and the engine noise. Reduced fuel consumption is of special importance to reduce CO_2 emission and its deleterious effect on climate change. This is a prerequisite for an increasing future volume of air transport without detrimental ecological side effects.

TiAl alloys are characterized by high oxidation and creep resistence. However, there is demand for more cost-effective production to bring them into wider application.

Witusiewicz, Bondar et al. 2008

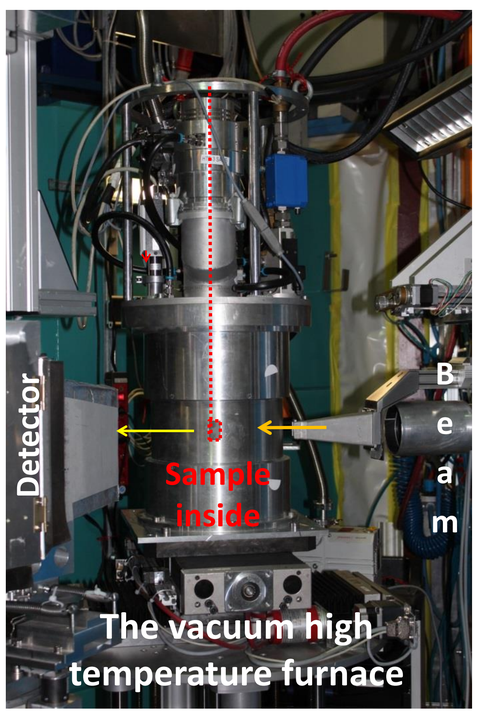


Presence of β/β_o improves the processing properties, but makes the material brittle at service temperature (700°C).

Experiments: diffraction part

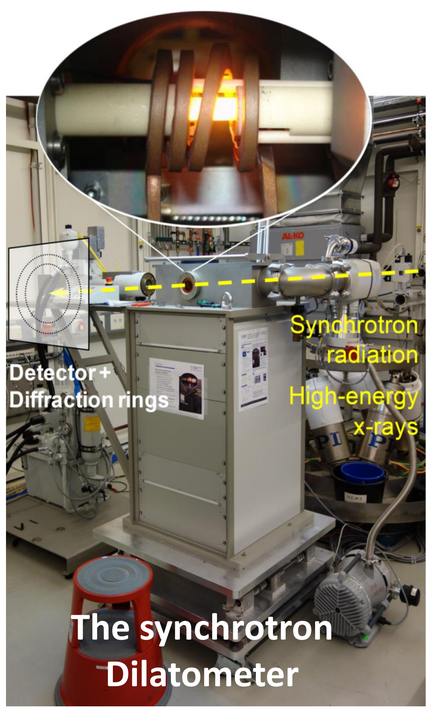
	Experiment with HTF	Experiment with dilatometer
Samples:	cylinders Ø5 mm, 20mm length	cylinders Ø5 mm, 10mm length
Gauge volume:	5x5x20=500 mm^3	5x5x10=250 mm^3
Monochromator:	Ge(311), λ= 2.1 Å,	
Detector:	3He-PSD (MWPC-multi wire proportional chamber25 x 25 cm^2; 256 x 256 pixels) plate-detector.	
2θ range	32.5 – 45.5 °	
Exposure time:	10, 30 min or 1 hour	10, 30 min, 1 picture every 10 min
Temperature range:	1100 – 1440 °C	1100 – 1250 °C
Heating ramp:	20K/min Step-wise heating	20K/min Step-wise heating
steps: Heating Cooling	10, 15, 25 °C; 25, 50 °C	10 °C during heating only

Interpretation: Rietveld refinements and Gauss-fit of single reflections



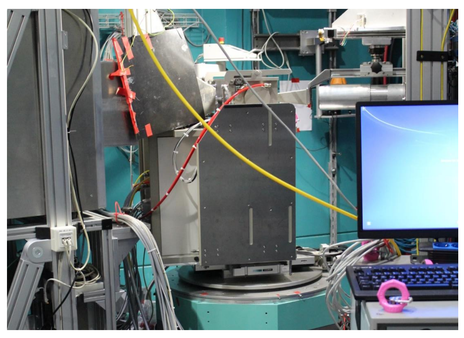
The vacuum high temperature furnace

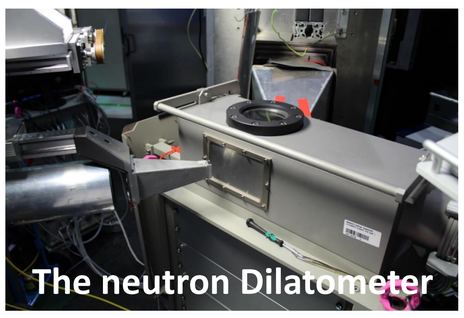
STRESS-SPEC, MLZ



The synchrotron Dilatometer

P07, Petra III, DESY



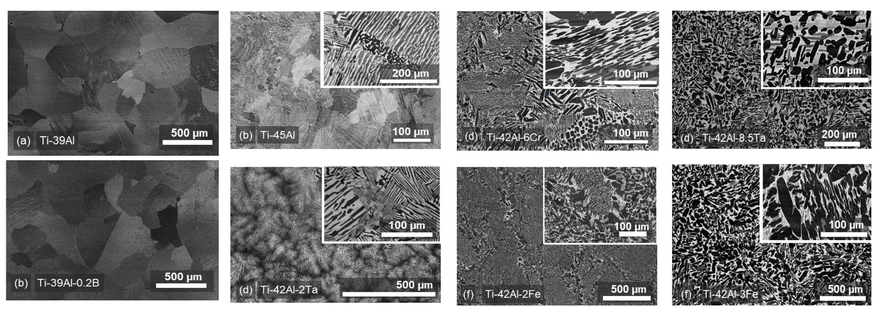


The neutron Dilatometer

STRESS-SPEC, MLZ

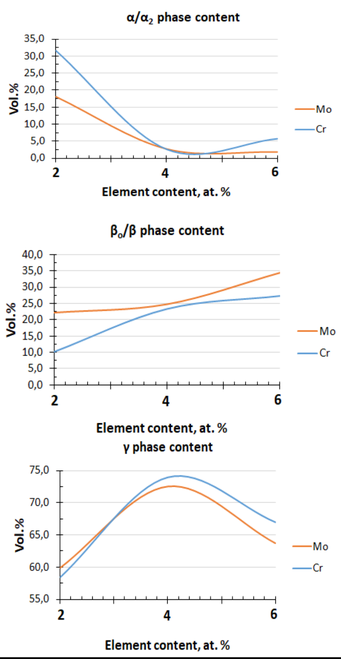
Results: an influence of third element

Microstructure types (SEM):



Nearly α_2 coarse grained	Fully Lamellar	Duplex inhomogeneous	Duplex homogeneous
Ti-39Al	Ti-42Al	Ti-42Al-2Mo	Ti-42Al-0.2B
Ti-39Al-0.2B	Ti-45Al	Ti-42Al-2Cr	Ti-42Al-4Mo
	Ti-42Al-2Nb	Ti-42Al-10Nb	Ti-42Al-6Mo
	Ti-42Al-2Ta	Ti-42Al-6Cr	Ti-42Al-8.5Ta
	Ti-42Al-8.5Nb (HIP)	Ti-42Al-1Fe	Ti-42Al-10Ta
		Ti-42Al-2Fe	Ti-42Al-3Fe
			Ti-42Al-4Cr

Phase content (Synch.):



Phase transformation temperatures:

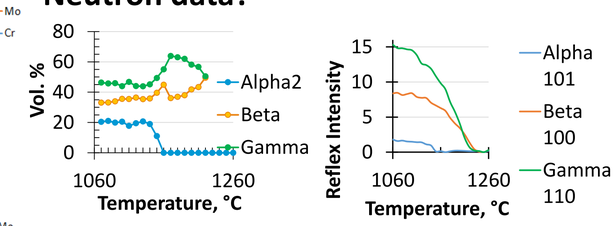
First Sample Set

Sample	β_0 100		α_2 101		γ 110	
	Gauss 100	MAUD	Gauss 101	MAUD	Gauss 110	MAUD
Ti-42Al			1120	1120	1190	1210
Ti-45Al			1120	1130	1285	1310
Ti-42Al-2Fe	1120	1130	1160	1160	> 1210	>1210
Ti-42Al-2Mo	1230	1250	1140	1150	1210	1220
Ti-42Al-2Cr	1090	1110	1110	1125	1170	1170
Ti-42Al-2Nb			1120	1130	1190	1190
Ti-42Al-2Ta			1100	1130	1180	1190

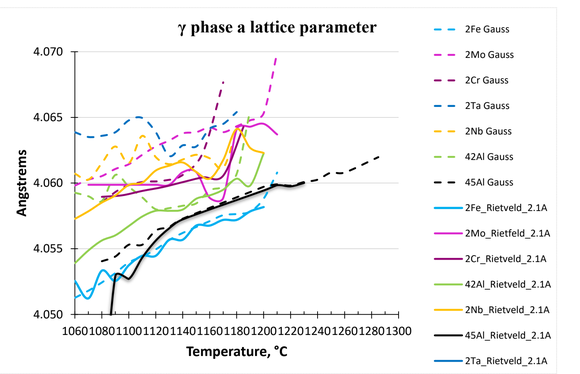
Second Sample Set

	Beta 100	Alpha 101	Gamma 110
Ti-42Al-1Fe	x	1110	1180
Ti-42Al-3Fe	1110	x	1210
Ti-42Al-4Cr	1120 (1130)	x	1190 (1200)
Ti-42Al-6Cr	1110 (1120)	x	1180
Ti-42Al-4Mo	1250(FWHM), (1260)	x	1230(FWHM), (1240)
Ti-42Al-6Mo	1210 (FWHM)	x	1190(FWHM)
Ti-42Al-0.2B	x	1100	1160

How Precise can MAUD analyse Neutron data?



a. Phase composition of Ti-42Al-2Mo refined from the neutron data	b. Change of neutron reflection intensities



Lattice parameters from neutron data show less scatter if analysed by Gauss-fit instead of MAUD.

Conclusions

By using a dilatometer as specimen environment it is possible to determine influence of the third element on different properties:

- higher content of the β-stabilizing elements gives higher β_o content, but similar or lower $\beta_o \rightarrow \beta$ phase transformation temperature
- the more β-stabilizing elements are present, the more homogeneous and fine grained microstructure could be observed.
- Difference of lattice parameters between samples does not correspond to element atom number change or their electronegativity. It could be explained as (1) by a complicated combinations of kinds of chemical bondings where both atom parameters are important, as well as (2) the small amount of the used 3rd element.

In situ dilatometry method improvement

Both neutron and synchrotron radiation are found well suited for in situ dilatometer investigations

Neutrons: - amount of ordered phases, No Site occupancy refinement.

Synchrotron: all phases together

- The brighter neutron source as ESS would be beneficial for achievement of similar to syncrotron heating rates for investigation of the heating rate depended phase transformations.

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