Phase transformation kinetics in a near-β titanium alloy

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STU MTF

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Research in Materials Science

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Content

1- Goal

To study the **phase transformation kinetics** during continuous heating of a **near-β titanium alloy** with different initial microstructures

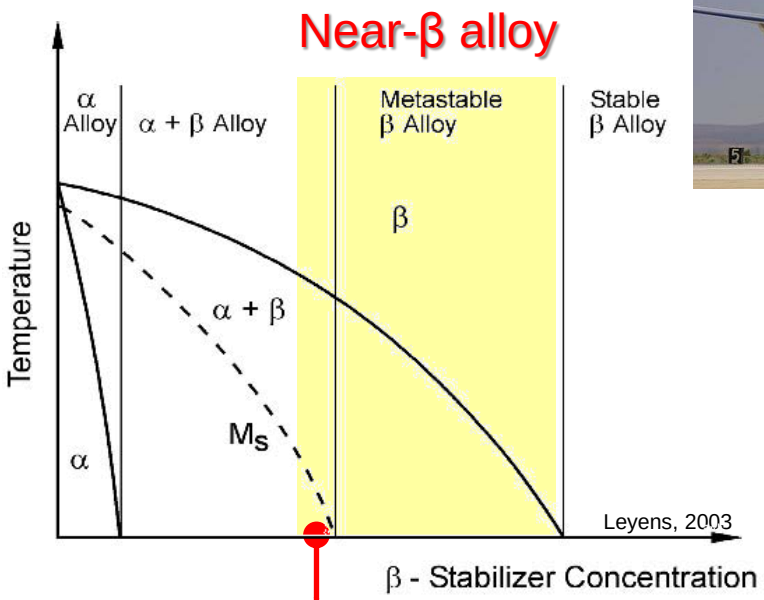
Methods

Differential Scanning Calorimetry (DSC)
Identification of precipitation and dissolution processes

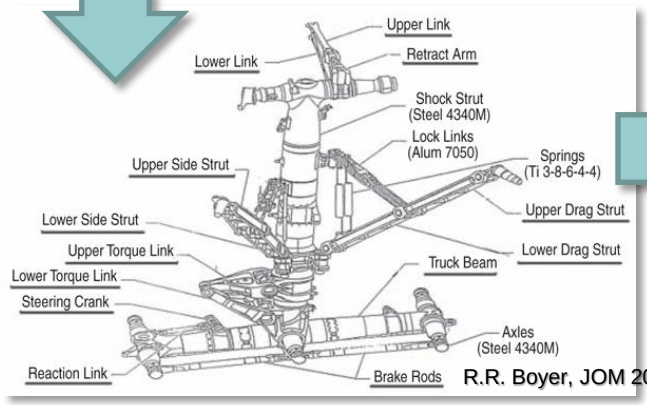
In situ High Energy Synchrotron X-ray diffraction (XRD)
Identification AND quantification of microstructural phases

2- Experimental

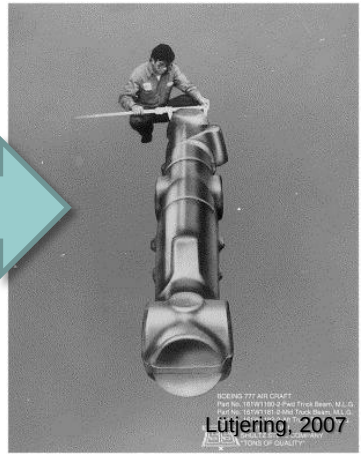
2.1. Material



Leyens, 2003

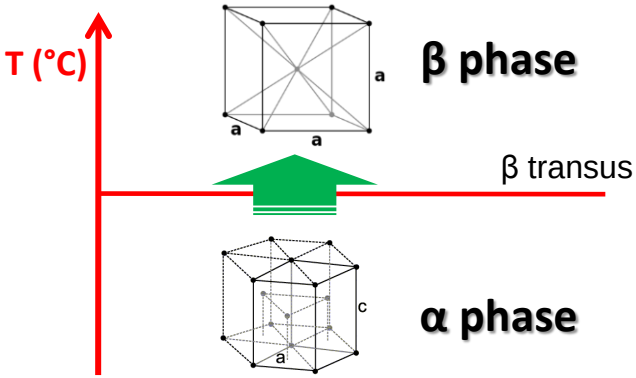


R.R. Boyer, JOM 2010



Lütjering, 2007

Ti-10V-2Fe-3Al



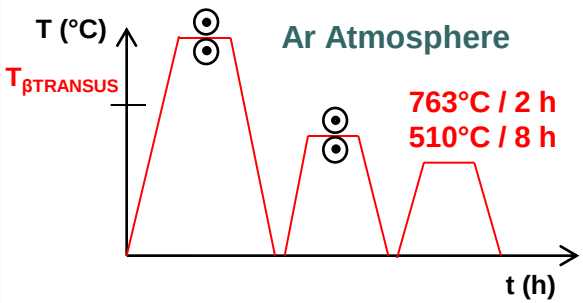
β transus Temperature	Mo eq. (wt.%) β Stabilizers	Characteristics	Aplications
808ºC	10,81%	• Excellent Forgeability • High strength • High toughness *(air, salt water)*	Aerospace industry *(variety of components)*

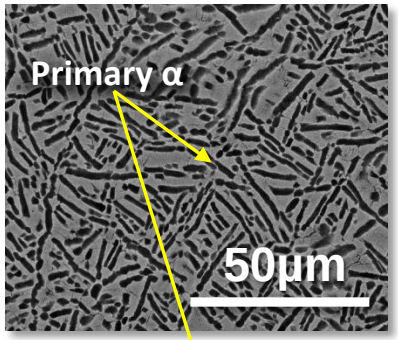
Handbook of Titanium Alloys, 2007

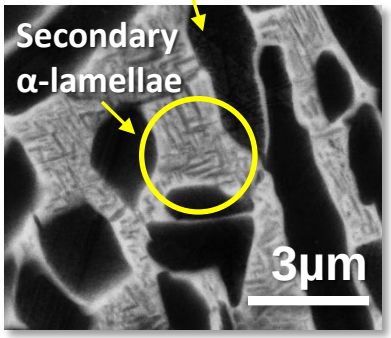
2- Experimental

2.1. Material: Initial microstructures

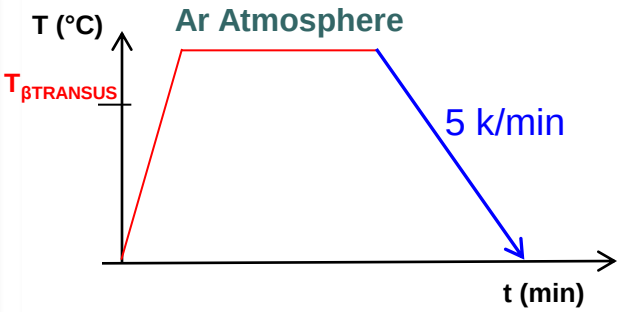
Bimodal

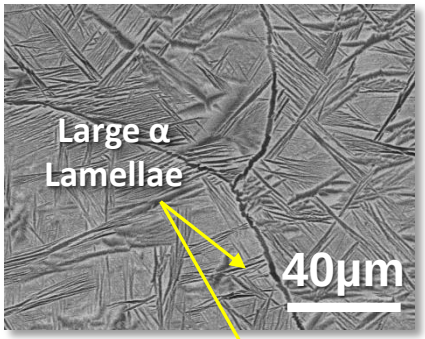


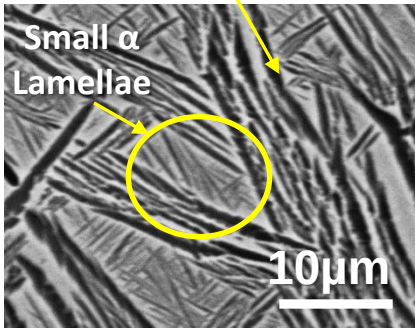




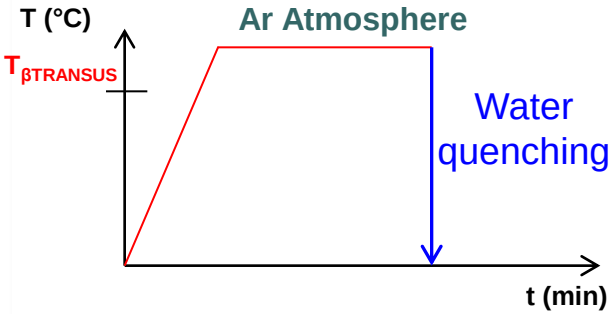
Lamellar

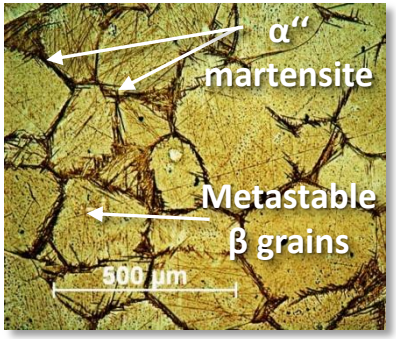


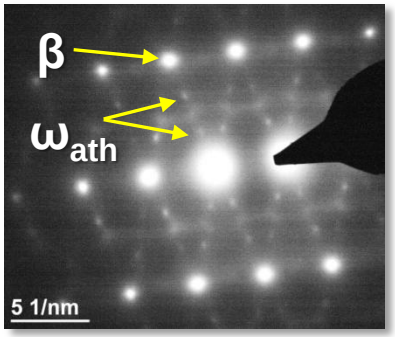




Beta quenched

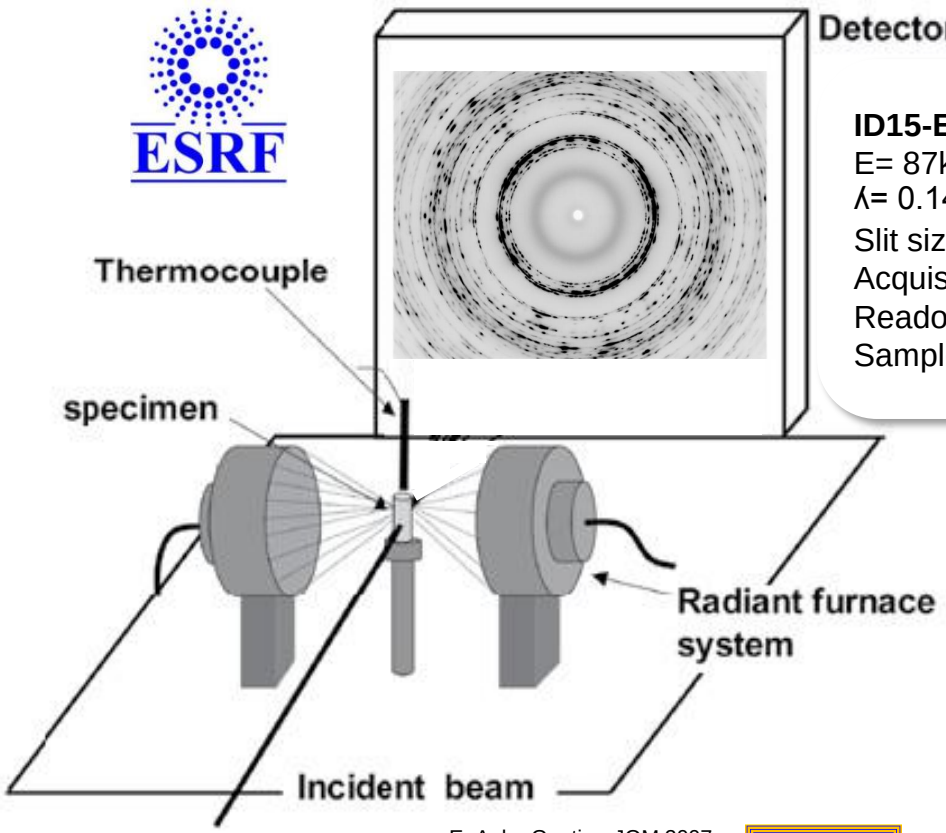






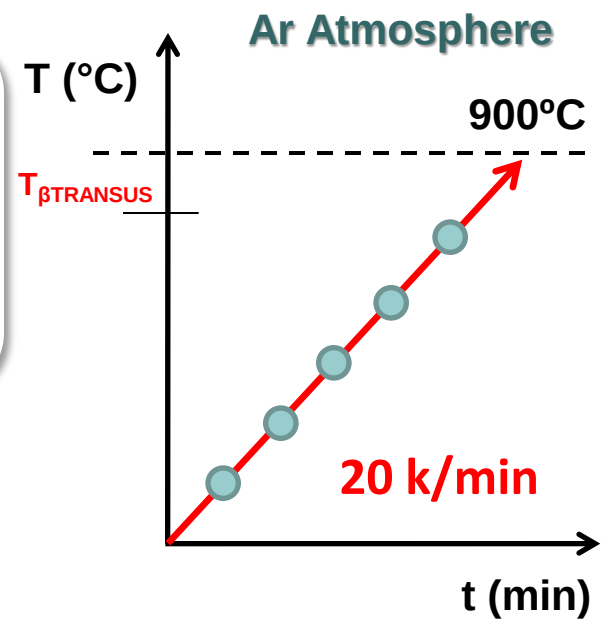
2- Experimental

2.2. Techniques: In Situ High Energy X-ray Diffraction



E. Aeby-Gautier, JOM 2007

ID15-ESRF
E= 87keV
ʎ= 0.1426Å
Slit size = 0.3x0.3 mm²
Acquisition time = 2s
Readout time = 1s
Sample size = 4x4x10 mm³



Data processing

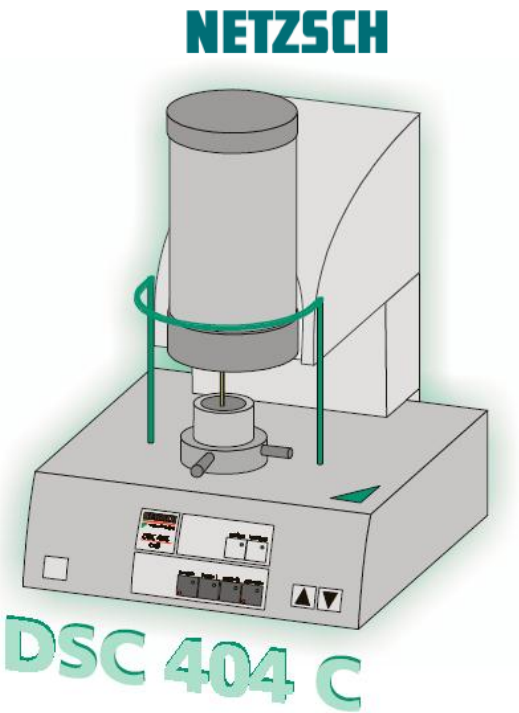
ImageJ
Image Processing and Analysis in Java

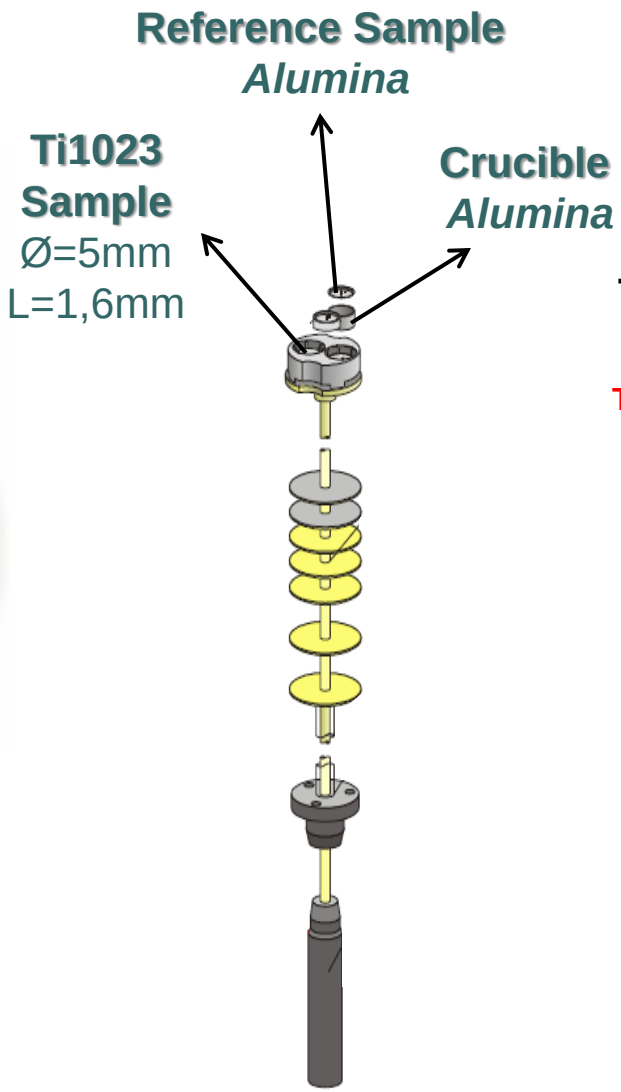
MAUD

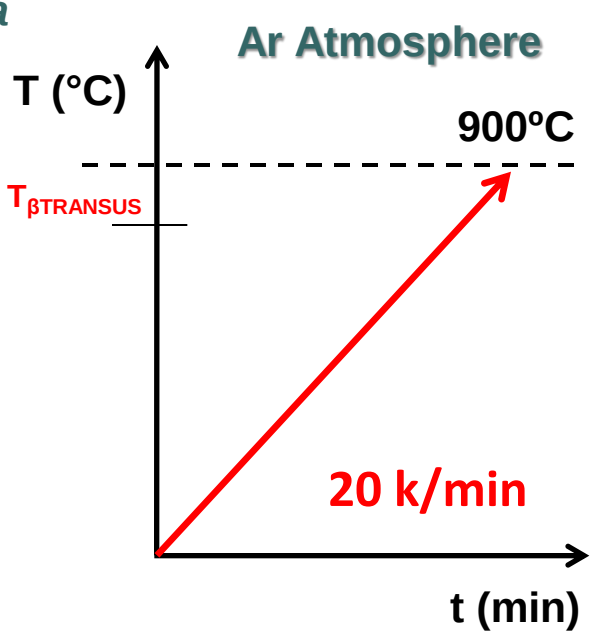
2D analysis (calibration/integration/ image analysis)	Image processing	Quantitative phase analysis (Rietveld)

2- Experimental

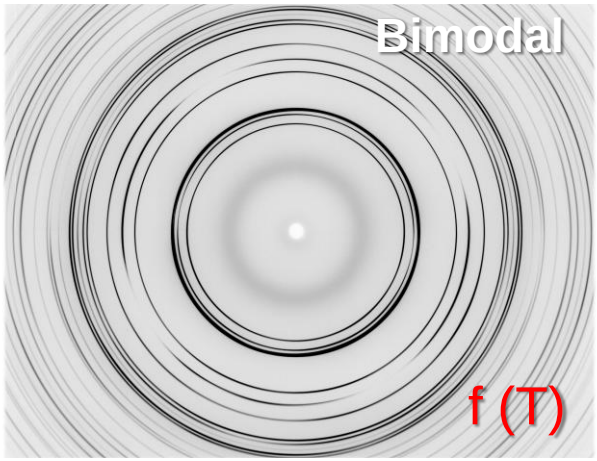
2.2. Techniques: DSC

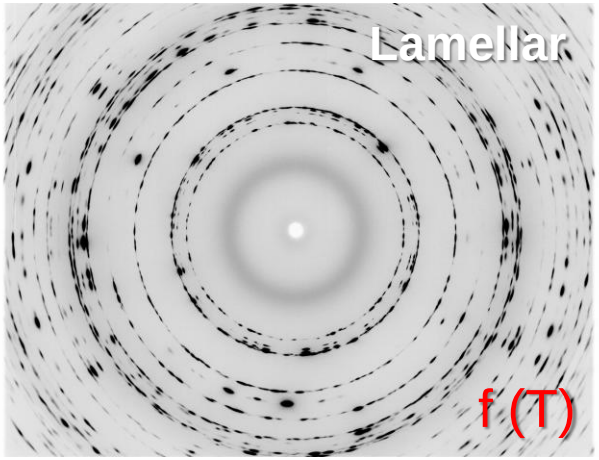


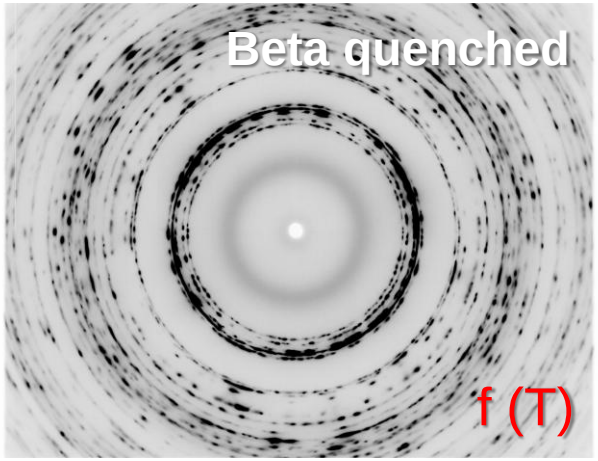


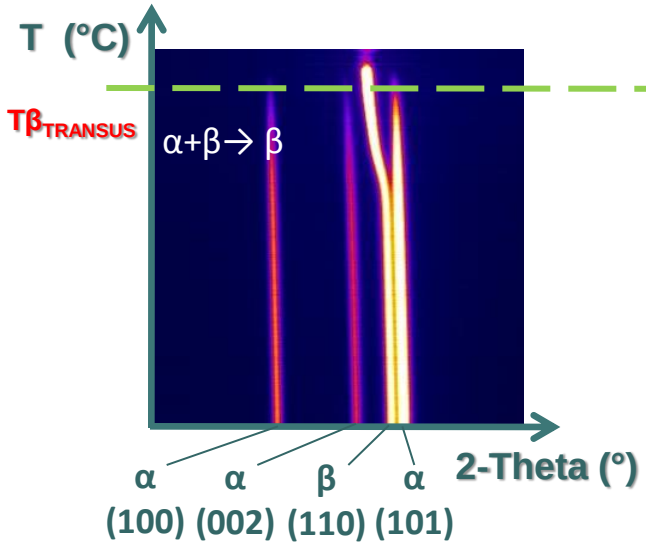


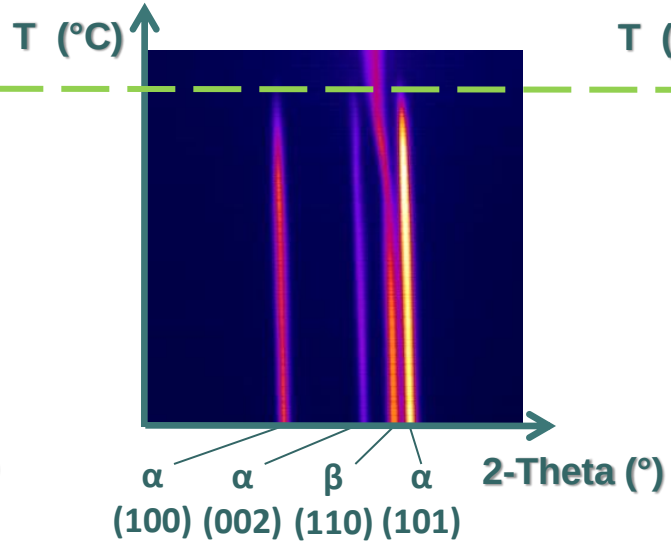
3- Results

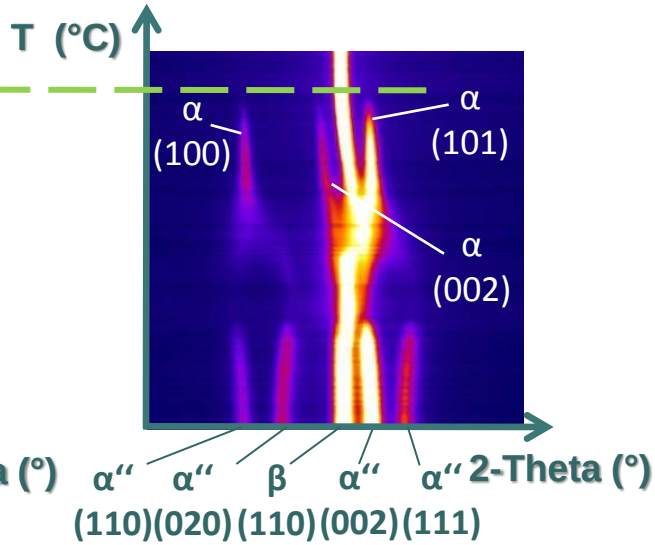

Bimodal
f (T)


Lamellar
f (T)


Beta quenched
f (T)

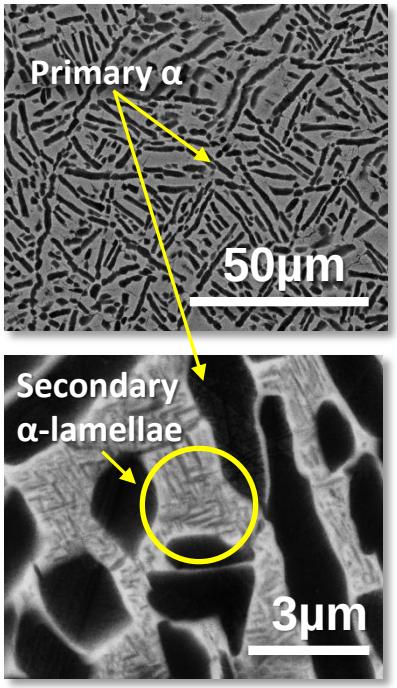

T (°C)
Tβ TRANSUS
α+β→ β
α α β α
2-Theta (°)
(100) (002) (110) (101)

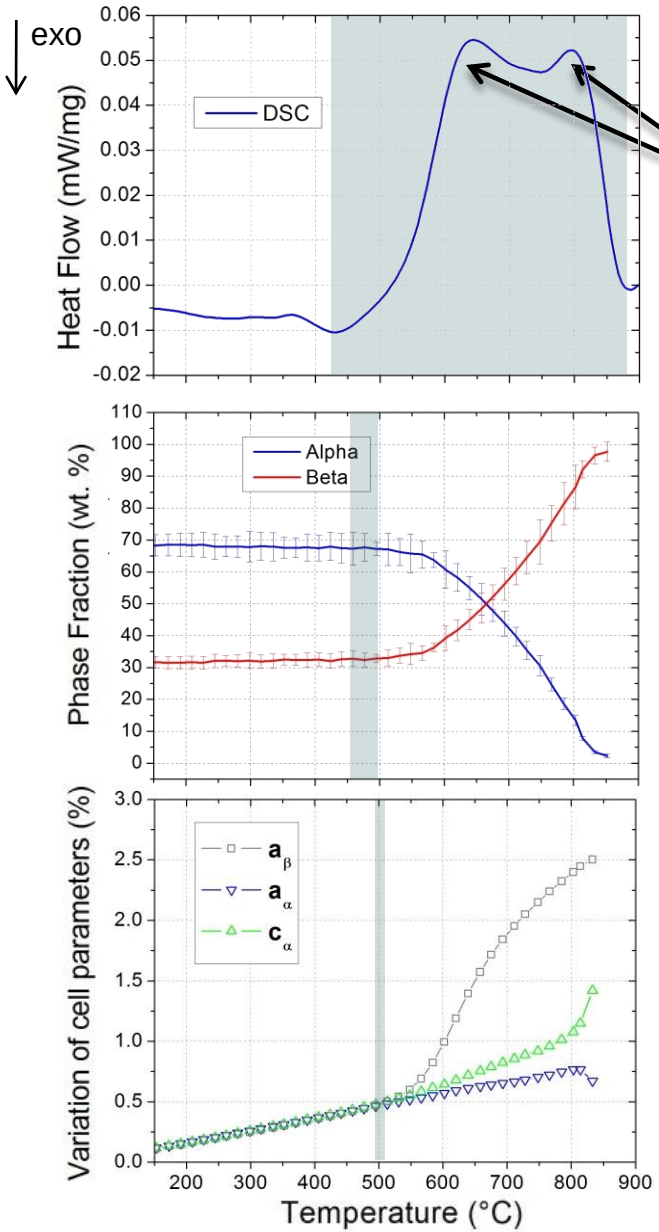

T (°C)
α α β α
2-Theta (°)
(100) (002) (110) (101)


T (°C)
α
(100)
α
(101)
α
(002)
α'' α'' β α'' α''
2-Theta (°)
(110)(020) (110) (002) (111)

3- Results

3.1. Bimodal microstructure





Two dissolution processes may indicate sequential dissolution of α secondary → α primary

Ti64, P. Barriobero Vila, Master's Thesis

Start α+β→ β
DSC T~ 425-450 °C
XRD T~ 450-500°C

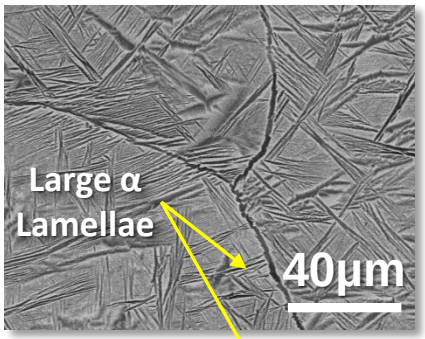
End α+β→ β
DSC T~ 875°C

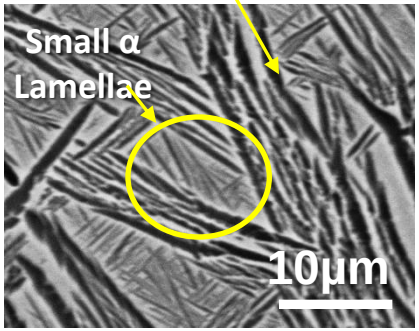
a_β shows a sudden increase at T=500°C

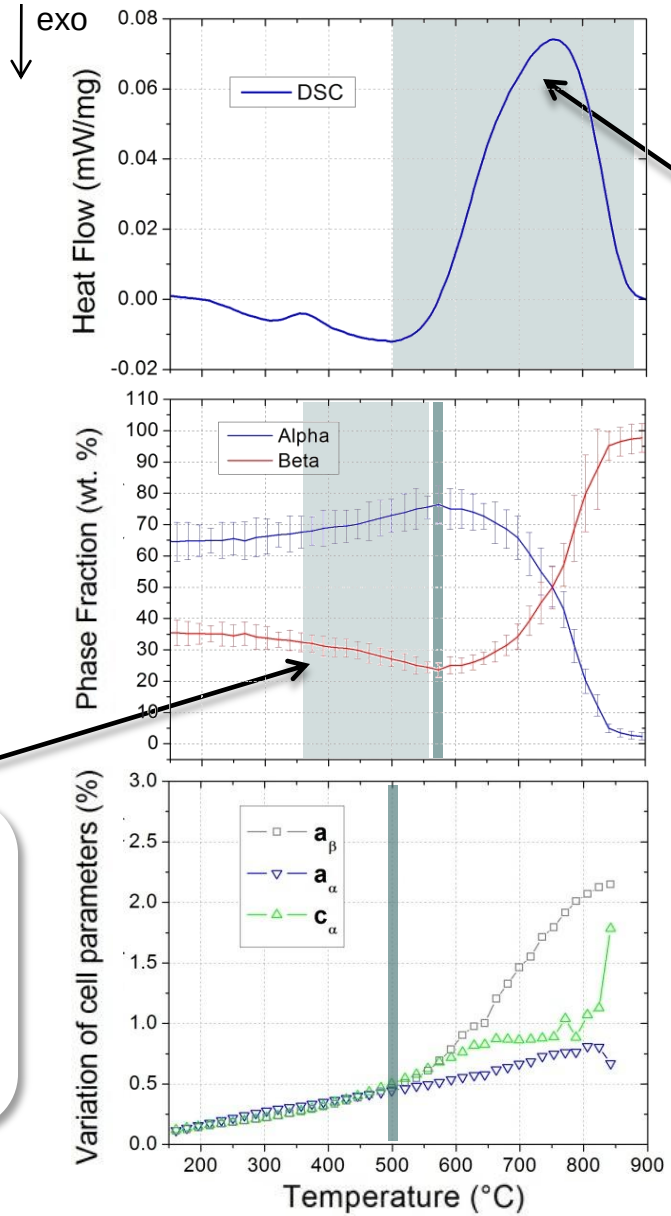
Diffusion of alloying elements

3- Results

3.2. Lamellar microstructure







Assymetric endotermic peak may indicate sequential dissolution of smaller and larger lamellae

Ti17, E. Aeby-Gautier, JOM 2007

Stabilization of alpha content between ~400<T<575ºC → increase from **~ 65wt%** to **~75wt%**

Start α+β→ β

DSC T~ 500-550°C

XRD T ~ 575°C

End α+β→ β

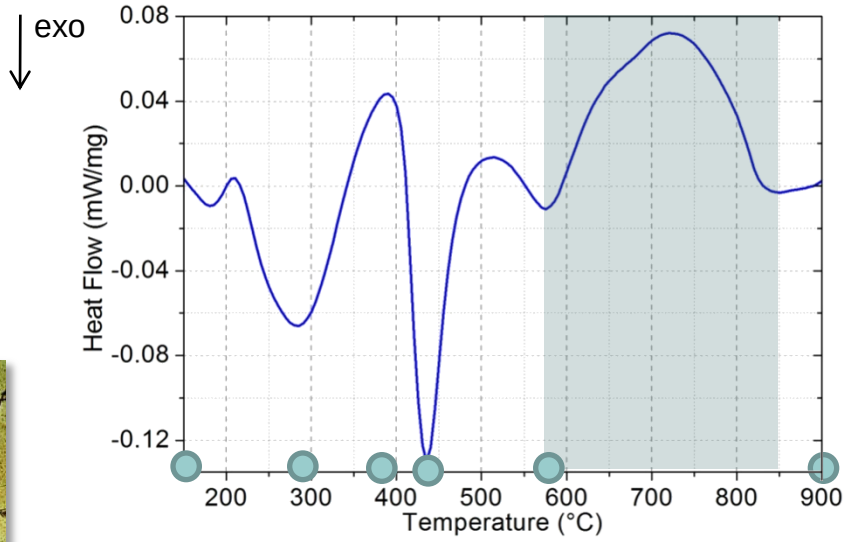
DSC T~ 875°C

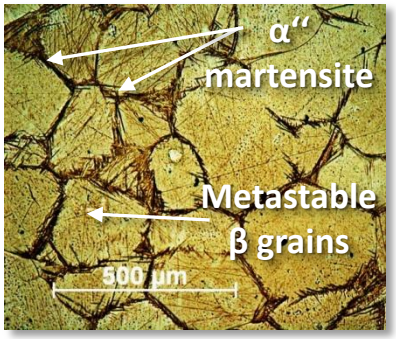
a_β shows a sudden increase at T=500°C

Diffusion of alloying elements

3- Results

3.3. Beta quenched microstructure

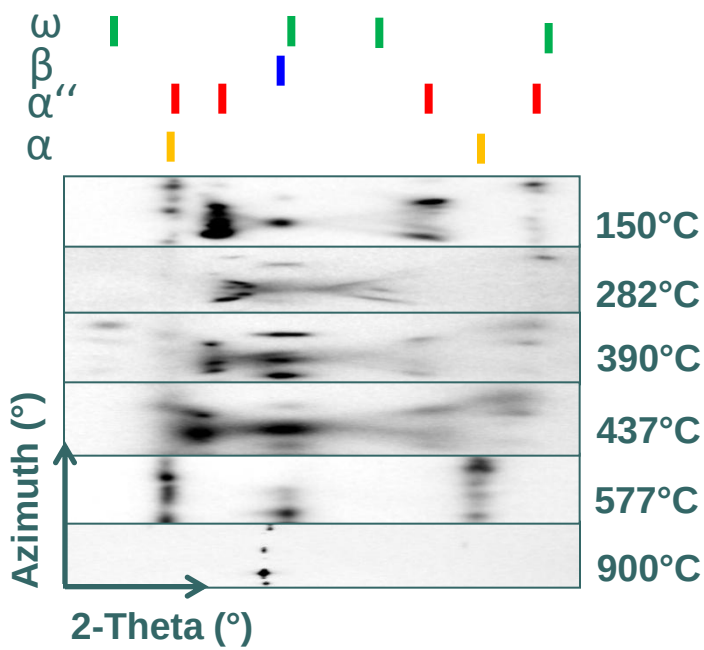




Start α+β→ β
DSC T~ 575 °C

End α+β→ β
DSC T~ 855°C

XRD: Beta quenched microstructure shows the presence of stable **α** and **β** plus metastable ω_{ath}, **ω**, **α''**, α''_{iso} phases at different stages during heating



$\omega_{ath.}$(TEM)+β+α''

ω+β +α''

ω+β +α''

β + $\alpha''_{iso.}$ →

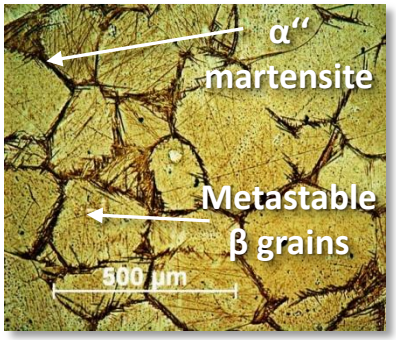
β+α

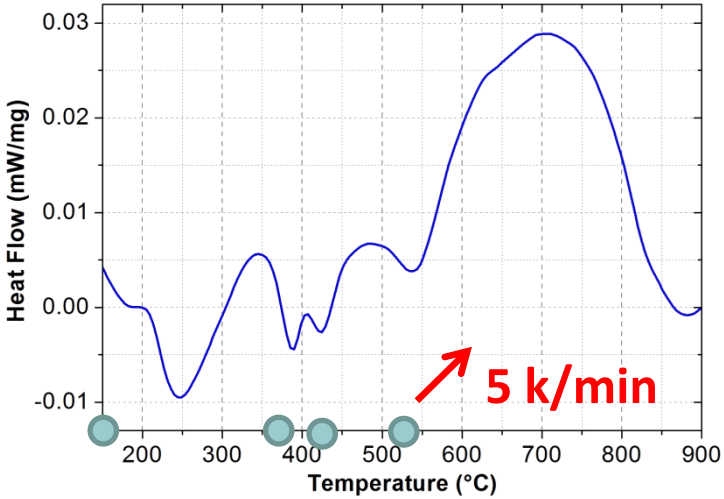
β

- E. Aeby-Gautier, Journal of Alloys and Compounds 2012
- Ivasishin, Materials Science and Engineering 2005

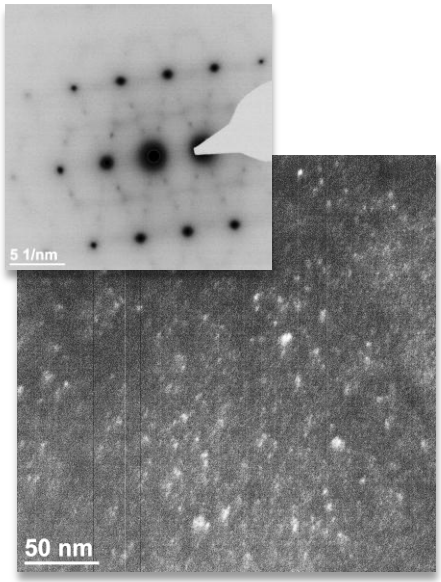
3- Results

3.3. Beta quenched microstructure

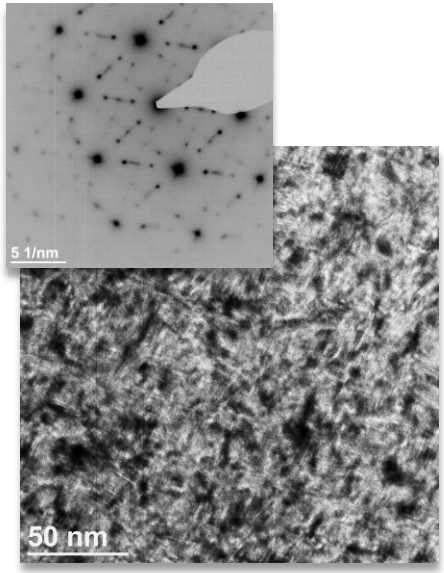




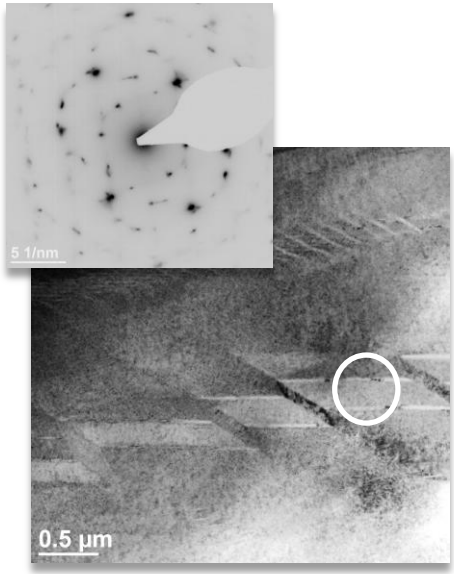
20°C



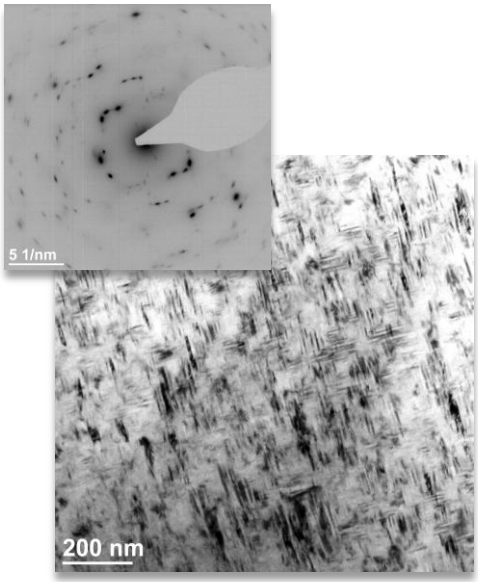
390°C



425°C



540°C



4- Summary

- **In Situ High Energy XRD:**

Reveals the phases and its weight/volume fraction as f(T)
The faster increase of the a_β cell parameter at a threshold temperature of 500ºC may be due to the diffusion of alloying elements into β phase (Al, Fe and/or **V**)

- **DSC:**

Reveals that the α phase (identified by XRD) dissolves at different stages depending on its morphology → fine lamella start to dissolve earlier than coarse lamellae or globular α

- The **bimodal and lamellar** microstructures show the presence of α and β phases at different stages during heating (no metastable phases were observed)

- The **beta quenched** microstructure presents a much more complex phase transformation kinetics as a consequence of the formation of the metastable phases α'', α''_{iso}, ω_{ath}, ω

4- Summary

Microstructure	Start α+β→ β Temperature (ºC)		a_β Increasing temperature (ºC)	End α+β→ β Temperature (ºC)
	DSC	XRD		DSC
Bimodal	425-450	450-500	500	875
Lamellar	500-550	575	500	875
Beta quenched	575	-	-	850

Bimodal **starts earlier due to the presence of smaller α-lamellae → higher surface energy**

Outlook:

- Metallography of microstructures frozen at different stages during heating to confirm the dissolution sequence of the different α morphologies

- The complex phase transformation kinetics of the Beta quenched microstructure will be quantified by Rietveld analysis.

Acknowledgements

David Lorrain (DSC), **Georg Fiedler** (Programming), **David Canelo** (XRD data processing), **Martin Stockinger** (Ti-alloys), **Sabine Schwarz** (TEM), **Fernando Warchomicka**, **Guillermo Requena**

Beamline Scientist:
Thomas Buslaps (ESRF-ID15)