Report on: „ Kinetics of phase transformations in titanium alloys" (MA1268)

Experimentalists: Pere Barribero Vila, Fernando Warchomicka, Guillermo Requena

In-situ high energy X-ray diffraction experiments of α+β and β-metastable titanium alloys with different initial microstructures were carried out at the ID15B beamline. The samples were heated up with a radiant furnace system and subjected to non-isothermal heat treatments to study the phase transformation kinetics of the alloys. One α+β Ti6Al6V2Sn (Ti662) titanium alloy and two β–metastable Ti10V2Fe3Al (Ti1023), Ti5Al5Mo5V3Cr1Zr (Ti55531), titanium alloys were studied in bimodal, lamellar and β water-quenched initial conditions (Fig.1). Different initial microstructural features are basically obtained using different thermal treatments for each corresponding alloy.

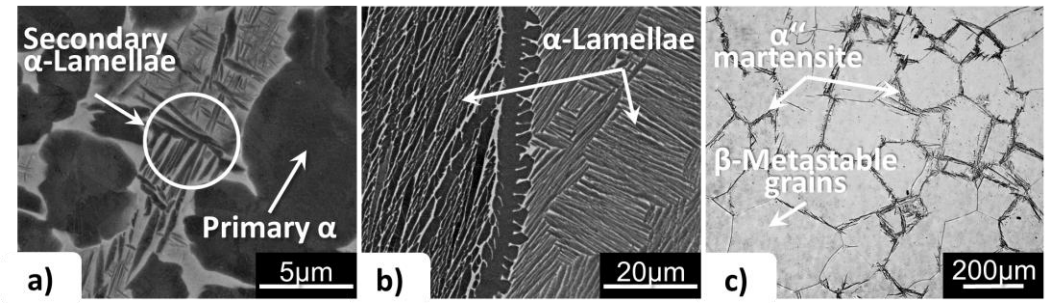

Fig.1. FEG-SEM images corresponding to the **a)** bimodal and **b)** lamellar microstructures for the Ti662 alloy. **c)** LOM image of the β water-quenched microstructure for the Ti1023 alloy

The characteristic diffraction images from the bulk material were recorded each 2s during continuous heating and cooling by means of a Pixium image-plate detector. The images presented an optimal grain average distribution without rotating the sample stage and it was decided to keep the sample fix, allowing to study the evolution of single spots during phase transformations. The intensity of the powder diffraction images was integrated along each ring in order to obtain the diffraction patterns that provide structural information of phases and are suitable for quantitative phase analysis. An example of the evolution of the diffraction patterns obtained during a continuous heating of the β water-quenched microstructure for a Ti1023 alloy is illustrated in Fig.2. For this case, metallographic observations (Fig.1c) as well as diffraction patterns at room temperature show a α''/β duplex-phase initial microstructure and further TEM studies determined the presence of athermal ω phase. The evolution of the diffraction patterns during the heating depicts the decomposition of the α''/β duplex-phase, where the isothermal ω phase appears before the precipitation of α and β phases at 600°C. After that, the α phase starts to transform into the β phase. The heating rate influences the α''

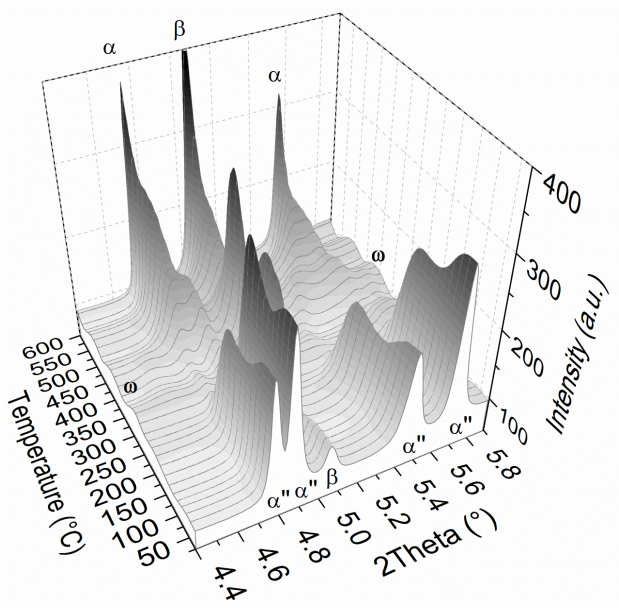

Fig.2. Example of the diffraction patterns obtained during a 20k/min continuous heating of Ti1023 alloy with an initial β water-quenched microstructure.

transformation, resulting in a shape memory effect for heating rates above 20K/min.
Quantitative phase analysis of diffraction patterns were carried out using the Rielveld method to obtain the evolution of volume fractions as well as that of the lattice parameters during heat treatment. An example of these results is shown in Fig. 3 where the bimodal and lamellar microstructures are compared for the Ti662 alloy. For the bimodal micostructure the α volume fraction remains almost constant up to around 600°C, before the α→β transformation. Above this temperature, α starts to transform into β at a different rate from the lamellar microstructure. Metallographic observation during interrupted tests show a good accuracy in the α volume fraction determined by in-situ X-ray diffraction. A strong increment of the a_β lattice parameter is observed close to the α→β transformation temperature with the bimodal microstructure showing a higher rate of change. During these changes of the β phase, α shows only a slight increase of the lattice parameters a_α and c_α. In the bimodal case, both a_α and c_α follow a linear tendency while for the lamellar one c_α a clear non-linear behaviour is observed at T > 600°C. Similar changes were observed experimentally for Ti6Al4V and Ti17 (e.g. [2-4]). This behaviour has been interpreted as a change in the concentration of alloying elements (especially V, Al, Fe, Cr and Sn) based on theoretical thermodynamic equilibrium calculations.
Currently, the correction of the quantification by texture and the determination of the coefficient of thermal expansion by lattice parameter for each phase are being carried out.

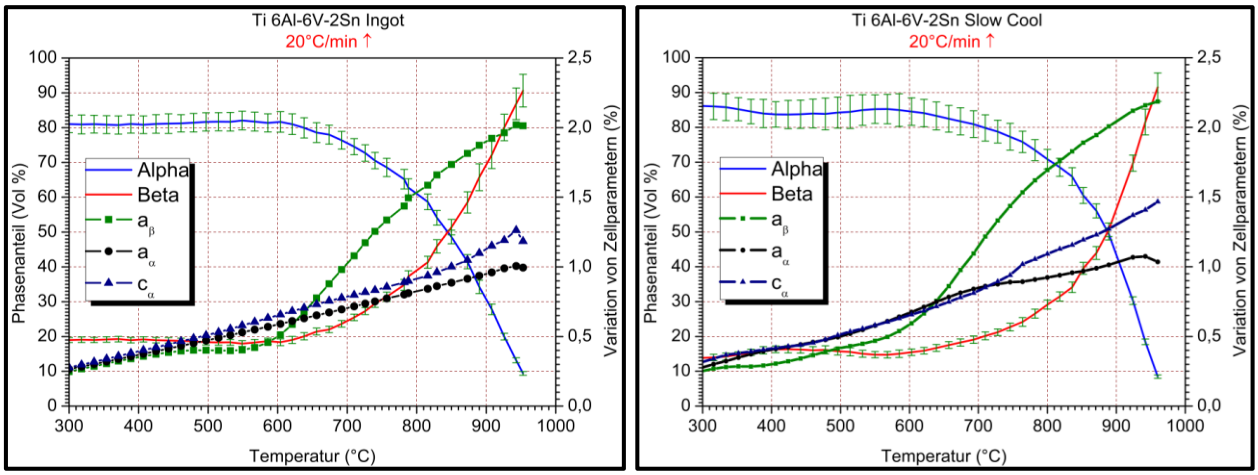

Fig.3. Evolution of phase volume fractions and lattice parameters as a function of temperature (heating rate 20k/min) for Ti662: **a)** bimodal microstructure and **b)** lamellar microstructure.

References

[1] T. W. Duerig, J. Albrecht, D. Richter, P. Fischer; Acta Metall. 30 (2161-2172)
[2] J. W. Elmer, T. A. Palmer, S.S. Babu, E. D. Specht; Materials Science and Engineering A 391 (2004) 104– 113
[3] F. Bruneseaux, E. Aeby-Gautier, G. Geandier, J. Teixeira, B. Appolaire, P. Weisbecker, A. Mauro; Materials Science and Engineering A 476 (2008) 60– 68
[4] E. Aeby-Gautier, F. Bruneseaux, J. Teixeira, B. appolaire, G. Geandier, S. Denis; JOM (2007) 54-58