EFFECT OF LAMELLAR ORIENTATION AND WIDTH ON THE STRENGTH AND OPERATING DEFORMATION MECHANISMS OF FULLY LAMELLAR TIAL ALLOYS DETERMINED BY MICROPILLAR COMPRESSION

Cristina Gutiérrez-García, IMDEA Materials Institute, C/Eric Kandel 2, 28906 Getafe, Madrid, Spain
cristina.gutierrez@imdea.org
Ilchat Sabirov, IMDEA Materials Institute, C/Eric Kandel 2, 28906 Getafe, Madrid, Spain
María Teresa Pérez-Prado, IMDEA Materials Institute, C/Eric Kandel 2, 28906 Getafe, Madrid, Spain
Jon Mikel Molina-Aldareguia, IMDEA Materials Institute, C/Eric Kandel 2, 28906 Getafe, Madrid, Spain

Key Words: Titanium aluminides, Micropillar compression

Titanium aluminide alloys are of interest for the aerospace industry due to their low density(3.9-4.2g/cm^3), good high-temperature strength retention, high modulus and creep strength, as well as high resistance to oxidation. The TiAl alloys of commercial interest typically contain two phases: γ TiAl and α_2 Ti_3Al, but their microstructure can substantially vary depending on composition and thermomechanical history. They can be classified as fully lamellar, near lamellar, duplex or near gamma. Fully lamellar microstructures formed by colonies of lamellar γ and α_2 phases are typically obtained after heat treatment at temperatures above the α-transus, with the soaking temperature and cooling rate [1] being critical variables to determine the microstructural parameters, such as colony size, volume fraction and lamellar width. They present the best high temperature strength [1-2]; However, they lack room temperature ductility, which has limited their application so far.

In this context, several compositional families have been developed in the last years, especially as a function of alloying elements, such as, niobium, tantalum, tungsten or molybdenum, which stabilize the β phase affecting the volume fraction and size of lamellar colonies. Two of the most important families are TNB alloys, with high niobium concentration and small additions of boron and carbon, where solidification takes place through the □ phase and TNM alloys, with even larger additions of niobium and molybdenum. Solidification of TNM alloys takes place through the β phase inducing further grain refinement due to β→α transformation [3] during cooling.

The lack of ductility of fully lamellar TiAl alloys is associated with the anisotropic deformation of individual colonies, as a function of lamellar orientation (ϕ) with respect to the loading axis. In this regard, micropillar compression is a powerful technique to determine the different deformation modes of TiAl colonies as a function of lamellar orientation. This has been shown in previous studies for TNB alloys (Ti45Al2Nb2MnXB), where the outcomes of micropillar compression were compared with results obtained from macroscopic tests using polysynthetically twinned crystals (PTS) [4]. Three different deformation modes where found: a soft deformation mode (ϕ=45º) and two hard modes (ϕ=0º and ϕ=90º), due to the activation of different slip systems in each case. However, the role of lamellar width has not been studied in detail before.

This work focuses on an alloy belonging to the TNM family, with the objective of studying the role of lamellar orientation and lamellar width on the anisotropic mechanical response of individual colonies. For this, a Ti43.5Al4Nb1MoXB alloy was subjected to different thermal treatments with the objective of refining the lamellar width. In particular, after heating up and soaking at 1260ºC (above the α-transus), three cooling rates were selected to cool down to 800ºC (α_2 + β + γ region): 40ºC/min, 400ºC/min and 4000ºC/min. The cooling rate was reduced to 40ºC/min from 800ºC in all cases to avoid cracking. As a result, the average lamellar width was varied within a range of two orders of magnitude (from a few nanometers to more than 200nm) for the same alloy composition. The anisotropy of individual colonies and their deformation modes as a function of lamellar orientation were studied by micropillar compression. For this, square micropillars were milled by means of FIB with dimensions of 5 x 5 x 15μm^3. Uniaxial compression was carried out using a flat-punch diamond tip with a diameter of 10μm under displacement control mode at a strain rate of 10^{-3} s^{-1} up to a maximum engineering strain of 10%. Deformed micropillars were analyzed to relate the orientation of lamellar interfaces with the activation of different deformation modes. The results are compared with those obtained in TNB alloys as well as a function of the average lamellar width.

[1] F. Appel, J. Paul, M. Oehring, Gamma Titanium Aluminide Alloys: Science and Technology. Wiley, 2011.
[2] M.E. Kassner, M.T. Pérez-Prado. Fundamentals of Creep in Metals and Alloys, Elsevier, 2004.
[3] H. Clemens, S. Mayer, Adv. Eng. Mater. 15 (2013) 191–215.
[4] A.J. Palomares-García, M.T. Pérez Prado, J.M. Molina-Aldareguia Acta Mater. 123 (2017) 102-114.