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An automated method to analyze separately the microtextures of primary α_p grains and the secondary α_s inherited colonies in bimodal titanium alloys

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Abstract

A method was developed to automatically recognize the orientations of primary α_p grains and secondary α_s colonies of a bimodal titanium alloy, on the orientation map. Both populations of grains are dissociated by correlating the Electron Back Scattering Diffraction data with the corresponding Back Scattered Electron image on which a high chemical contrast is observed between the α_p and (α_s+$\beta_{residual}$) phases. The whole data processing is successfully applied to a large EBSD map of a bimodal IMI 834 billet. This allows to discuss the contribution of α_p grains and α_s colonies to the sharp texture heterogeneities observed in the billet.

Keywords: Ti-alloys; Bimodal microstructure; EBSD; Microtexture; Image processing

1. Introduction

Near α and (α+β) titanium alloys are widely used to design jet engine components. In the last two decades, their properties have been improved to increase the engine performances, by optimizing their microstructures. In particular, bimodal microstructures have been proposed for high fatigue and creep resistance [1]. Such a microstructure consists of equiaxed primary α_p grains surrounded by Widmanstätten secondary α_s colonies. It is obtained with an adapted thermomechanical heat-treatment in the (α+β) field. The α_p grains are formed by deformation and dynamic recovery/recrystallization of initially coarse α lamellae whereas the α_s colonies are inherited from the transformation of the β phase,

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present in the (α+β) field. After the transformation, a thin β layer still remains in between the α_s lamellae.

Unfortunately, engine parts made of bimodal titanium alloys can suffer from a dramatic fatigue debit when stress is dwelled at low temperature. Recently, this dwell fatigue sensitivity was related to sharp hcp texture heterogeneities, inherited from the forming process [2]. Up to now, these peculiar microtextures have either been detected using X-ray Diffraction [3] or automated Orientation Imaging Microscopy (OIM) [2]. As the primary α_p grains and the secondary α_s colonies have the same α-hcp crystal structure, such standard texture acquisitions do not allow to distinguish the α_p/α_s orientations. Consequently, the contribution of each population of grains, to the sharp local texture heterogeneities is not clearly understood.

In this paper, we present an original method of processing the α orientation map, which allows to identify the α_p and α_s microtextures of bimodal titanium alloys. To our knowledge, this is the first published attempt. In the first part, the different steps of the method are presented in detail and illustrated on an example. In the second part, the method is applied to a large EBSD map of a forged IMI 834 billet. The resulting α_p and α_s microtextures are presented and their contributions to the local texture heterogeneities are discussed.

2. Description of the method

2.1. Data acquisition and strategy for α_p/α_s separation

The EBSD technique is based on the acquisition and automatic indexation of Kikuchi diffraction patterns, on a 70°-tilted sample in Scanning Electron Microscope (SEM). The resulting orientation data are commonly displayed as an orientation map, built by assigning to each measurement point, a specific color related to its orientation. Such map provides of course information about the spatial orientation distribution of a given crystal structure. Moreover, it offers the possibility to characterize the material microstructure by analyzing misorientations between neighboring measurement points (for example: the grain size and morphology). Consequently, it is a powerful tool to correlate local orientation distribution with microstructural features of a material.

Fig. 1 shows an example of EBSD map obtained on an IMI 834 bimodal titanium alloy. The pixels are colored according to the color key given with the standard triangle on the right hand side and misorientation angles greater than 1.5° between adjacent pixels are revealed with black lines. The aim of this work is to separate on such an EBSD map, the orientations of the α_p grains and the α_s colonies, present in a bimodal microstructure. To achieve this separation in an automatic way, one has to find and use a physical feature very sensitive to the characteristics of primary α_p and secondary α_s microstructures.

2.1.1. Attempts to distinguish α_p and α_s orientations directly from EBSD data

The first attempts focussed on microstructural characteristics which could directly be deduced from the orientation data.

Obviously, the difference in morphology between primary α_p grains and secondary α_s colonies could be a good indicator. The primary α_p grains are in general

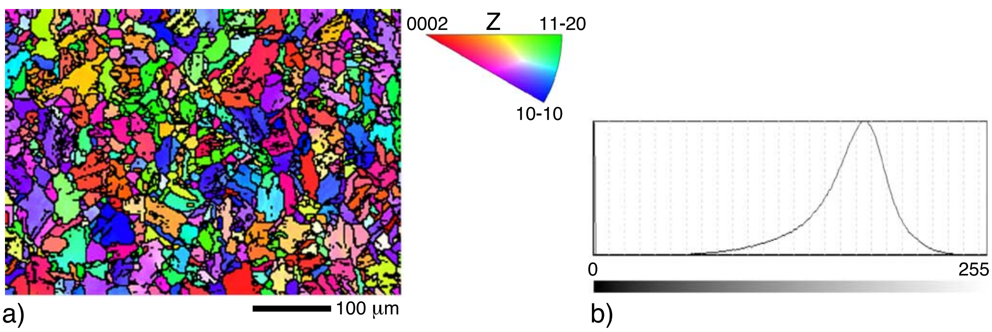

Fig. 1. (a) α EBSD map of a bimodal IMI 834 alloy. The pixels are colored according to the color key of the standard triangle, black lines reveal misorientations>1.5°. (b) Corresponding KPQ histogram.