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Microstructure evolution during deformation of a near-α titanium alloy with different initial structures in the two-phase region

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The effects of initial microstructure on the microstructure evolution of a Ti–1.5Fe (mass%) alloy during deformation in the ($\alpha + \beta$) two-phase region are studied at different deformation temperatures. Refining interlamellar spacing and colony size of the ($\alpha + \beta$) lamellar structure by quenching after β solutionizing results in promotion of dynamic recrystallization.

Keywords: Titanium alloy; Thermomechanical processing; Grain refining; Dynamic recrystallization

It is well known that hot deformation of α and near-α titanium alloys in the ($\alpha + \beta$) two-phase region can help to control and refine the microstructure [1–6]. The presence of relatively coarse second-phase particles promotes static recrystallization by increasing deformation inhomogeneity, whereas fine second-phase particles suppress recrystallization and grain growth by exerting a pinning effect on grain boundaries [7]. In $\alpha + \beta$ titanium alloys different microstructures can be obtained by changing the heat-treatment process. α lamellar structure starts to develop from β grain boundaries by cooling from the β solutionizing temperature [4]. $\alpha + \beta$ lamellar structure contains a characteristic group called a colony each of which consists of α lamellae of the same orientation. The final sizes of α lamellae and colonies can be controlled by changing the cooling rate [4,8].

Previous studies by the authors [9–11] have shown that refining the initial microstructure significantly affects the deformation behavior and microstructure evolution during warm deformation of low-alloy steels. It was noted that both critical strain for initiation of dynamic recrystallization and recrystallized grain size is decreased by refining the initial microstructure. Although many studies have been carried out to determine microstructure evolution during hot deformation of titanium alloys in the two-phase region [4,6,12–15], the effect of initial microstructure on deformation behavior has not been widely studied. Therefore, this study aims to clarify the deformation structure of a near-α titanium alloy in the ($\alpha + \beta$) two-phase region with different initial microstructures.

A Ti–1.5Fe–0.02O (mass%) alloy was used in this study. Cylindrical specimens 8 mm in diameter and 12 mm in height were machined from a hot forged bar and heat-treated via two different processing routes, referred to hereafter as the “furnace cooling process” and the “quench and reheating process”, in order to change initial microstructure. In the furnace cooling process, samples were solutionized at 1173 K in the β region for 1.2 ks and then furnace cooled to the deformation temperature and kept isothermally at that temperature for 0.9 ks. In the quench and reheating process samples were water quenched after the same solutionizing treatment as the furnace cooling process. The quenched samples were reheated to deformation temperatures (1108, 1073 and 948 K), and kept isothermally for 0.9 ks. Estimated equilibrium volume fractions of α phase are 15% at 1108 K, 50% at 1073 K, and 85% at 948 K. Uniaxial hot compression was conducted using a THERMEC-Master Z hot working simulator. All the samples were compressed for 50% at strain rates of

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10^{-2} s^{-1} followed by helium gas quenching. Initial microstructures of the alloy in both processing routes are obtained from the samples isothermally held for 0.9 ks at the deformation temperatures and then gas quenched just prior to the start of compression. α orientations were measured by electron backscatter diffraction (EBSD) method with scanning electron microscopy (SEM, Philips XL30FEG). Average interlamellar spacing was determined as the half of the average intercept length measured by the line interception method. Average α grain size was estimated as the average intercept length multiplied by a correction factor of 1.128.

Figure 1a–c show optical micrographs of the initial structure of the furnace cooled samples at 1108, 1073 and 948 K, respectively. The initial microstructure is α lamella in all cases. Since most of the β phase which existed at the processing temperatures was transformed to the α phase during quenching, it is not possible to reveal the exact two-phase initial structure at high temperature. However, it can be seen that the initial microstructure is refined by decreasing the processing temperature. For example, interlamellar spacing is decreased from 2 to about 1 μm in furnace cooled samples by the decreasing temperature from 1108 to 948 K. Quench and reheating process at 1108, 1073 and 948 K (Fig. 1d–f, respectively) results in formation of very fine α lamellar structures. It is clear that at the same temperature, the quench and reheating process results in finer α lamella colonies and α interlamellar spacing than the furnace cooling process. At 948 K the interlamellar spacing of the furnace cooled samples is about 1 μm, whereas it decreases to less than 0.5 μm in the quench and reheated samples.

Figure 2a–c show α orientation maps of the deformed samples obtained via the furnace cooling process at

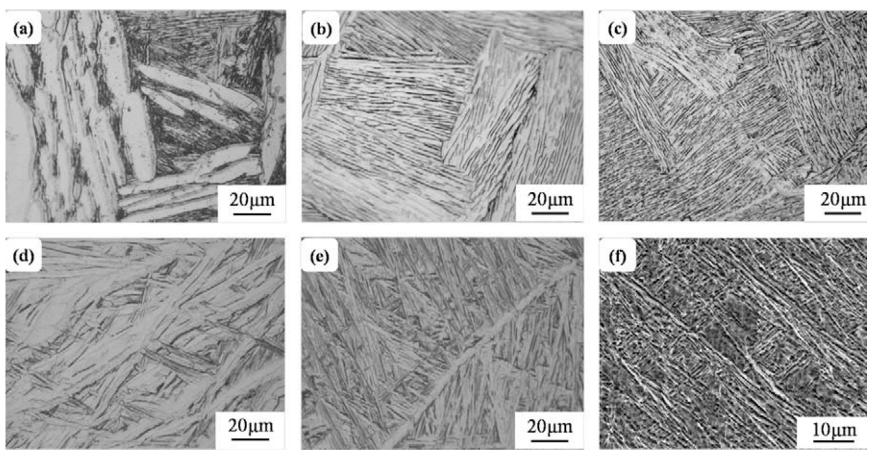

Figure 1. Optical micrographs of the initial structure of the alloy prior to deformation processed by (a–c) furnace cooling at 1108, 1073 and 948 K, and (d–f) quench and reheating at 1108, 1073 and 948 K, respectively.

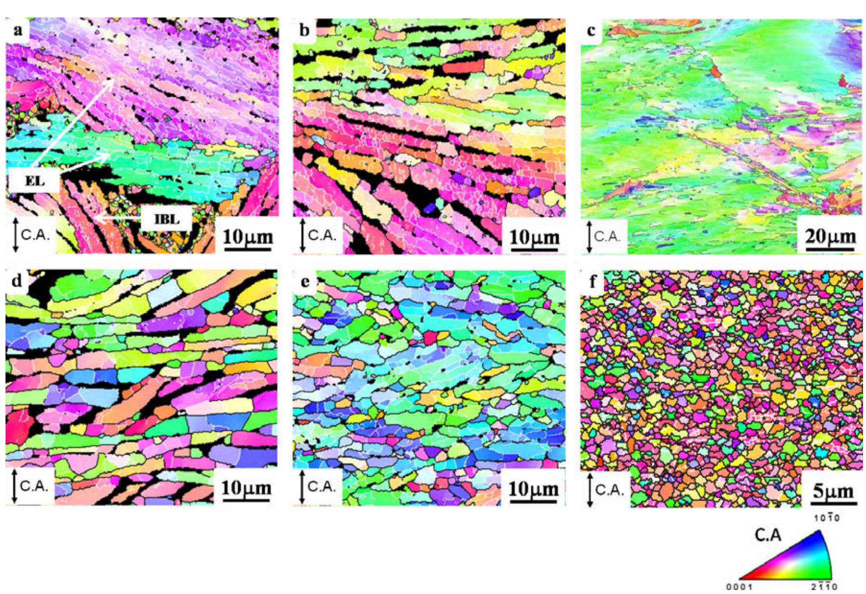

Figure 2. (a–c) α orientation maps of the alloy deformed at 1108, 1073 and 948 K by the furnace cooling process, and (d–f) α orientation maps of the alloy deformed at 1108, 1073 and 948 K by the quench and reheating process, respectively. Black thick lines correspond to high-angle grain boundaries with misorientation over 15° while thin white lines represent low-angle boundaries with misorientation between 1 and 15°. White arrows show irregular bent lamellar (IBL) and elongated lamellar (EL) structures. CA shows the compression axis.