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EBSD characterization of twinning in cold-rolled CP-Ti

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ABSTRACT

This work presents the use of a mechanical testing system and the electron backscatter diffraction technique to study the mechanical properties and twinning systems of cold-rolled commercial purity titanium, respectively. The dependence of twinning on the matrix orientation is analyzed by the distribution map of Schmid factor. The results showed that the commercial purity titanium experienced strong strain hardening and had excellent formability during rolling. Both the $\{11\bar{2}2\} < 11\bar{2}\bar{3} >$ compressive twins and $\{10\bar{1}2\} < 10\bar{1}\bar{1} >$ tensile twins were dependent on the matrix orientation. The Schmid factor of a grain influenced the activation of a particular twinning system. The specific rolling deformation of commercial purity titanium controlled the number and species of twinning systems and further changed the mechanical properties.

1. Introduction

The cold-rolled deformation of metals with a hexagonal close packed (hcp) crystal structure is primarily dominated by slip and twinning. The orientation of grains significantly influences the deformation mechanisms (slip or twinning) during rolling. In commercial purity titanium (CP-Ti), for instance, slip occurs via the activation of dislocations with <a> type Burgers vector mainly in prism planes[1,2]. Because <a> slip cannot provide five independent slip systems to accommodate an external strain imposed on the grains, other slip (such as <c+a> slip on pyramidal planes) or twinning must be activated [3,4]. It is proved that electron backscatter diffraction (EBSD) is a powerful technique for determining the grain orientation, twinning relationship and deformation texture of metals and alloys during deformation, and has achieved enormous success in researching the structure of hcp materials [5,6]. McCabe studied the contribution of twinning to the total plastic strain of zirconium compressed at 76 K [7]. Ahn comprehensively revealed the strain hardening behavior of α-Ti by using a constitutive model, which is based on dislocation mechanism and deformation twinning [8]. However, a detailed interpretation has not been developed to examine the influence of Schmid factor and critical shear

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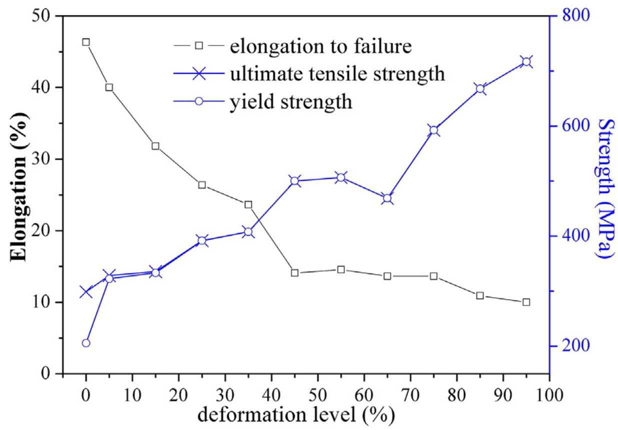

Fig. 1 – Mechanical properties of CP-Ti at different cold-rolled deformation levels.

stress on the microstructural evolution of hcp metals during deformation. In this work, the EBSD technique was employed to examine the activation of twinning systems and the dependence of twinning on the matrix orientation in CP-Ti during cold rolling.

2. Experimental

The raw material used in the experiment was CP-Ti ingot 20 mm in thickness, and its chemical composition is Ti-0.02Fe-0.008C-0.005N-0.005H-0.042O (wt.%). The ingots were rolled in a two-roller 480 mill at room temperature and to ten different thickness reductions from 5 to 95%, respectively. The tensile tests of as-rolled sheets were carried out by an MTS 810 machine with a strain rate of 10^{-3} S^{-1} at room temperature. Rectangular samples with a dimension of 5 mm × 10 mm were cut from the central areas of rolled sheets. The samples were mechanically polished and then electropolished in a solution consisting of 5% perchloric acid and 95% methanol at −30 °C and 50 V. The EBSD data acquisition was performed using a Sirion 200 Field Emission Gun Scanning Electron Microscope (FESEM) equipped with XM4-Hikari electronic backscatter signal collection system, with an accelerating voltage of 25 kV. The

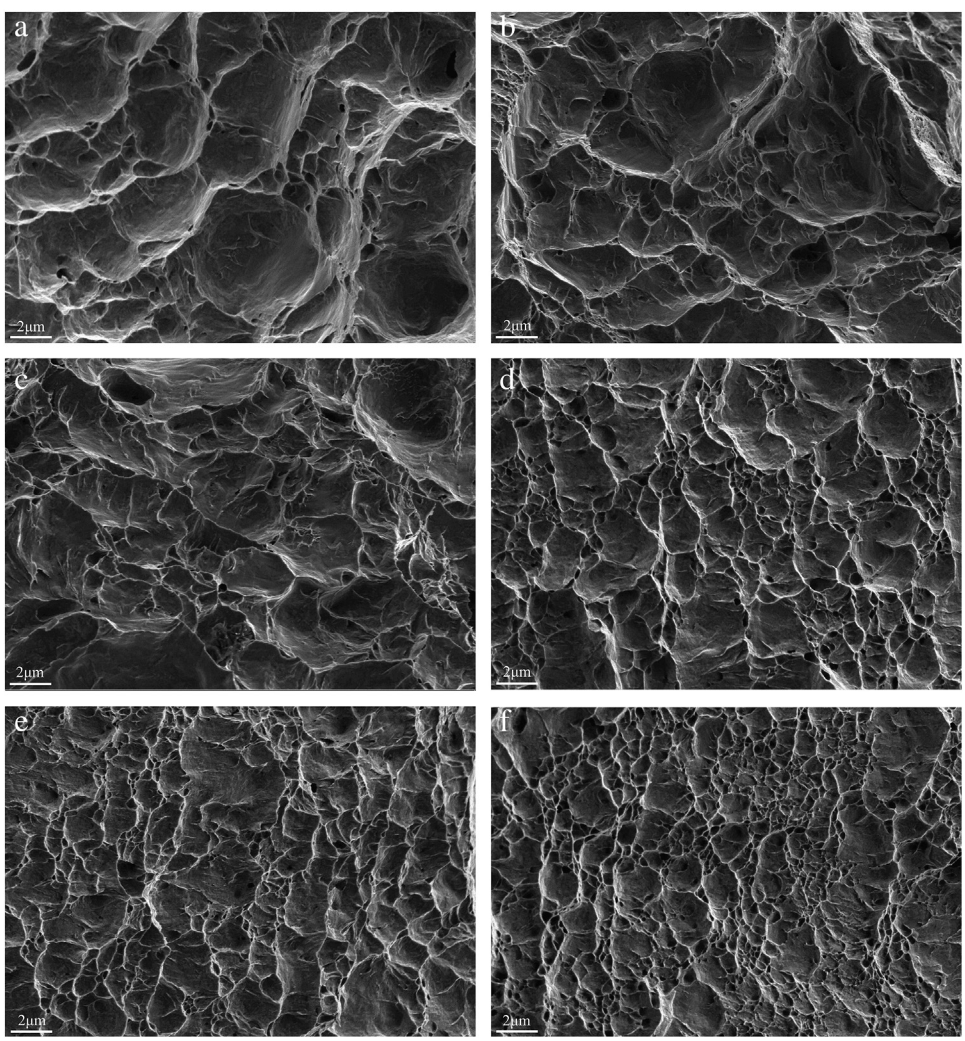

Fig. 2 – SEM images of fracture surface of cold-rolled samples at different deformation levels (a undeformed; b 5%; c 25%; d 45%; e 65%; f 95%).