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The evolution of cold-rolled deformation microstructure of {0 0 1}⟨1 1 0⟩ grains in Ta–7.5 wt%W alloy foils

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ABSTRACT

The deformation structure of {0 0 1}⟨1 1 0⟩ grains in cold-rolled Ta–7.5 wt%W alloy foils has been investigated by transmission electron microscopy (TEM) and electron backscattering diffraction (EBSD). The results show that there are two kinds of {0 0 1}⟨1 1 0⟩ grains formed during the cold-rolled deformation process. Type A grains are surrounded by α-fiber, while type B grains are surrounded by γ-fiber. Dislocation analysis reveals a continuous evolution of dislocation substructures from dislocation arrays, to high dense dislocation walls, and to microbands in type A grains, while in type B grains from dislocation mesh to dislocation cells as a function of plastic strain. By both the analysis of EBSD and TEM, a new deformation mode in type A grains is developed.

1. Introduction

Ta and Ta–W alloys are used in a number of industrial applications because they provide a good combination of properties, such as high density, excellent formability, high melting point, and a moderately high elastic modulus, etc., which are not found in many other refractory metals [1–11]. Due to these unique features, they have become one of the most promising materials for applications in power, aerospace and nuclear engineering fields [8]. As a result, many available studies were focused on the mechanical behavior of Ta and Ta–W alloys [9,10,11]. However, few researchers have correlated properties with deformation microstructures and crystal orientation in them. Since Ta and Ta–W alloys are bcc materials, the well-developed rolled texture of Ta and Ta–W alloys can be represented as two fibres, α and γ. In α fibre, ⟨1 1 0⟩ parallels the rolling direction and in γ fibre ⟨1 1 1⟩ parallels the rolling plane normal direction [12]. For deformation structure in BCC metals and alloys, there are many articles about steels. For example, many authors have reported that there is a correlation between the deformation microstructure and the crystal orientation in IF steels [13,14,15]. Chen et al. [16] suggested that during cold-rolled deformation, the α fiber grains in IF steels can use as many as seven independent slip systems, which allow homogeneous deformation in them. They also indicated that under such circumstances, dislocation structures in grains belonging to α fiber must constantly evolve during cold deformation, but how they do so remains unclear. It is essential to study microstructure evolution during cold deformation of metals for which is important in its relationship to deformation mechanisms, mechanical properties, and texture formation. Furthermore, the characteristics of deformation microstructures affect the way in which materials behave during recovery and recrystallization. As an important kind of refractory alloy it is important and meaningful to correlate deformation structures with orientation in Ta–W alloys and to study the evolution of the deformed structures during cold rolling process. However, not sufficient attention has been paid on this topic in Ta–W alloys, especially when the strips are very thin. The objective of this article is to investigate how deformation microstructures evolve during cold rolling at medium reduction levels in most common grains of {0 0 1}⟨1 1 0⟩ in Ta–7.5 wt%W alloy foils.

2. Experimental procedure

Ta–7.5 wt%W alloys were prepared by a powder metallurgy method for a fine grain structure in original materials. The sintered plates of 50 μm average grain size were processed by cold rolled to 50% by 10% reduction per pass, and then the plates were annealed at 1473 K for 1 h with a uniformly recovered condition. The annealed plates were cold rolled to 50% again and then annealed at 1473 K for 1 h. By repeating this process, a 150 μm plate was obtained. After annealed at 1473 K for 1 h, the 150 μm plates were cold rolled in the range from 10 to 50% and the deformation microstructure has been analysed by TEM. Since the plates are very thin, TEM observation was conducted on rolling planes with a JEOL 2010 transmission electron microscope. The specimens were twin-jet polished in a mixing solution of HF, H_2SO_4 and CH_3OH with ratio of 1:5:94 at 273 K. EBSD investigations were also done on the rolling planes of the 100 μm foils.

3. Results and discussion

For bcc metals, in the Bunge version of Euler space, the full orientation distribution function needs not be shown because the

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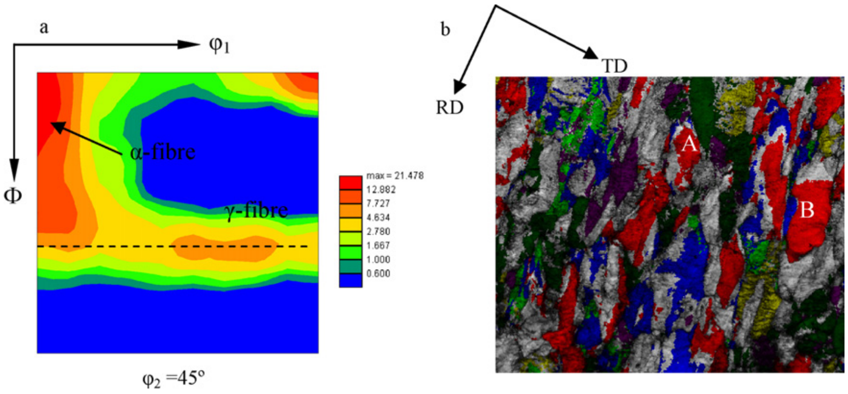

Fig. 1. (a) The φ_2 45° section of ODF maps showing the major components of the α and γ fibers in Ta–7.5 wt%W alloys foils cold-rolled to a reduction of 50%;(b) OIM micrographs showing the major grains distributed in Ta–7.5 wt%W foils, color code in OIM: Red-(0 0 1)[1-1 0], blue-(1 1 2)[1-1 0], green-(1 1 1)[1-1 0], violet-(1 1 1)[1 1-2], deep green-(1 1 1)[0-1 1]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

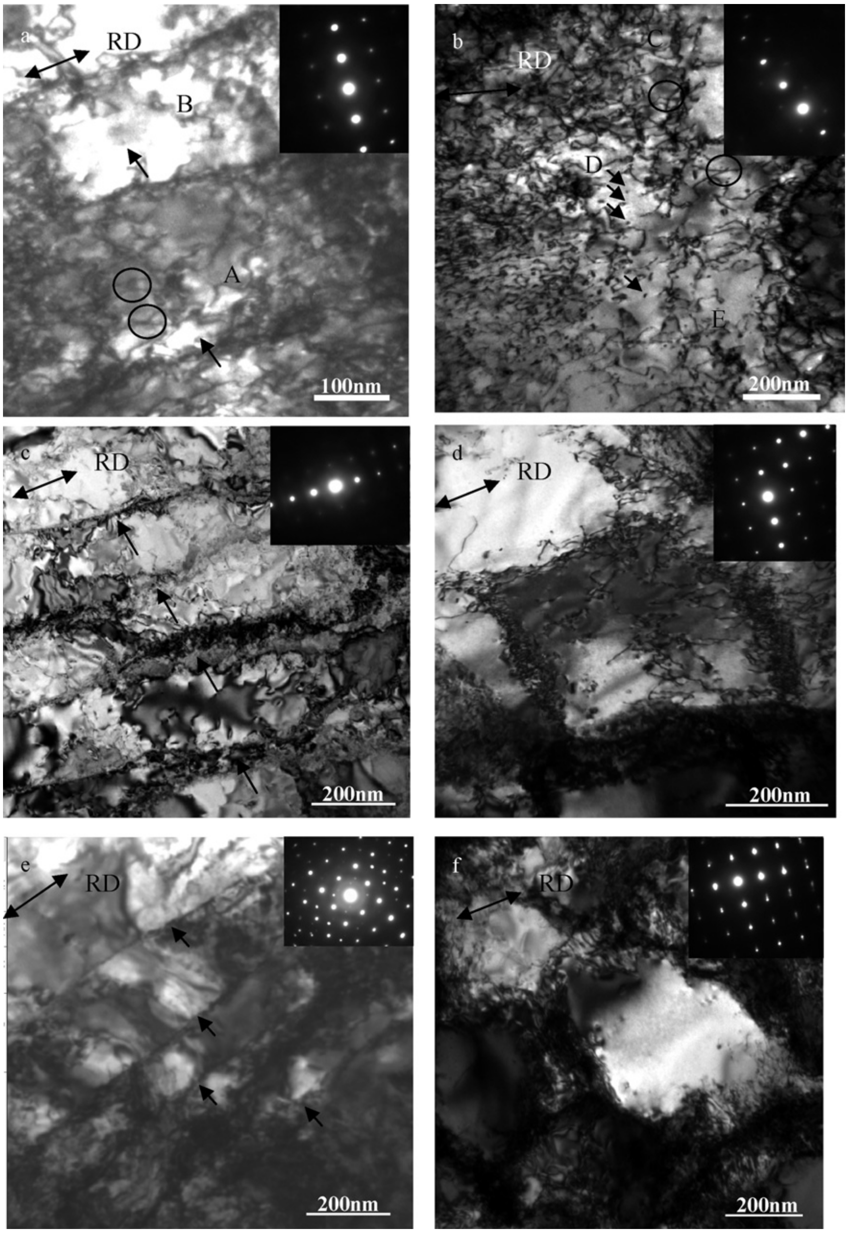

Fig. 2. Typical dislocation structures and the corresponding SADPs of Ta–7.5 wt%W alloy foils. (a), (c) and (e) show the typical deformation structures in type A grains with reductions of 10%, 20% and 50%. (b), (d) and (f) show the typical deformation structures in type B grains with reductions of 10%, 20% and 50%. The rolling direction is marked by RD.