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Effect of initial cube texture on the recrystallization texture of cold rolled pure nickel

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ABSTRACT

High-purity nickel samples with different volume fractions of initial cube textures were cold rolled to 96% reduction and subsequently annealed at different temperatures. The survived cube orientation fractions in the cold-rolled samples were found to be in proportion to the volume fraction of the initial cube texture. The initial cube fraction could affect the recrystallization process significantly, which showed some huge differences in the case of low temperature annealing from that of high temperature annealing.

1. Introduction

The recrystallization texture has been a research subject by metallurgist for several decades. It is usually found that the cube texture ({001}⟨100⟩) is the strongest recrystallization texture component after annealing for most deformed face-centered cubic (FCC) metals. For metal-based substrates for coated superconductors (i.e. Ni and Ni–W alloys), the cube texture should be controlled. A very sharp cube texture is needed for metal substrates to overcome the "weak link" behavior so that YBCO coated conductors can get a high critical current density [1]. With respect to the origin of the cube texture both theories of oriented nucleation and oriented growth were given strong supports [2–4]. Oriented nucleation maintains that cube-oriented grains nucleate from a deformed matrix more frequently than grains with any other orientations [5]. There is a substantial evidence that in the cold deformed microstructure, cube orientation regions are located in some thin bands, which are parallel to the rolling direction (RD), these regions are called cube bands [6–9]. These cube bands are formed within cube oriented grains in pre-deformed metals undergoing deformation and retention [8]. It has been reported that cube orientation is metastable, a large orientation gradient develops during plastic deformation [8–10] and dislocation cells of cube oriented regions have larger size. All these characters lead to a larger nucleation rate of cube orientation grains and thus the cube bands become very potent nucleation sites during recrystallization annealing. In contrast, the oriented growth theory emphasizes that the origin of sharp cube texture lies in the selective growth of cube nuclei. That is to say, cube oriented grains grow faster than non-cube oriented grains during the recrystallization process [2], which is due to the high migration mobility of boundaries between cube grains and their surrounding deformation matrix. It is also suggested that certain misorientation relationships such as 40° around ⟨111⟩ have a high mobility. It is found that misorientation between the cube-orientation and the S-orientation ({123}⟨634⟩) conforms to this relationship. S is one of the dominating components of deformation texture in FCC metals. Since cube oriented grains in the cube bands grow faster than non-cube oriented grains [2,11], cube bands in the deformation microstructure were developed from cube-oriented grains in pre-deformed materials, therefore the content of cube-oriented grains in the pre-deformed materials plays an important role in the recrystallization cube texture component.

It is well known that many factors influence the recrystallization cube textures. For polycrystalline nickel, numerous studies have focused on the effects of nickel purity, alloying elements, rolling reduction and annealing temperature on the recrystallization textures [11–17]. However, effect of initial cube texture has been paid little attention for nickel substrate. The initial cube texture prior to cold deformation is one of the structural parameters affecting the evolution of the microstructure and the texture of nickel during deformation and subsequent annealing. It is important to study the effect of initial cube texture on the as-deformed and recrystallized textures of pure nickel which is critical for texture control of nickel-based superconducting substrates. Not

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only does it play an important role in enriching the theory of metal-based substrates but also it contributes to industrial production of metal-based substrates production.

2. Materials and methods

The starting material used in the present investigation was high-purity nickel (99.999%), its thickness was 10 mm. It was processed to give an average grain size of 50 μm and a fairly random texture. A two-step rolling procedure was used to investigate the effect of initial cube texture on the recrystallization texture of the cold-rolled pure nickel. Firstly, the samples were rolled by a reduction of 80% to 2 mm in thickness, and two types of initial samples with different fractions of cube texture were prepared by different annealing procedures, marked as samples A and B. Then, they were cold rolled by 96% reduction to 80 μm in thickness. Finally, the samples were annealed at certain temperature (300 °C, 700 °C or 900 °C) for 30 min in reducing atmosphere of argon and 4% hydrogen (heating rate of 300 °C per hour, water quench).

The microstructures and textures of the deformed and recrystallized samples were characterized by a Channel 5 Electron Back-Scattering Diffraction (EBSD) detector attached to a FEI Nova 400 Nano scanning electron microscope (SEM). The measuring surface is RD-TD (RD is rolling direction and TD is transverse direction) and an area of 400 × 400 μm^2 was characterized on each sample. At least three maps were taken for each condition. The horizontal direction is RD in all EBSD orientations maps.

3. Results and discussions

Fig. 1 shows the microstructures and misorientation distribution of initial samples. EBSD analysis gives crystallographic orientation map for identifying orientations of each grain. Different

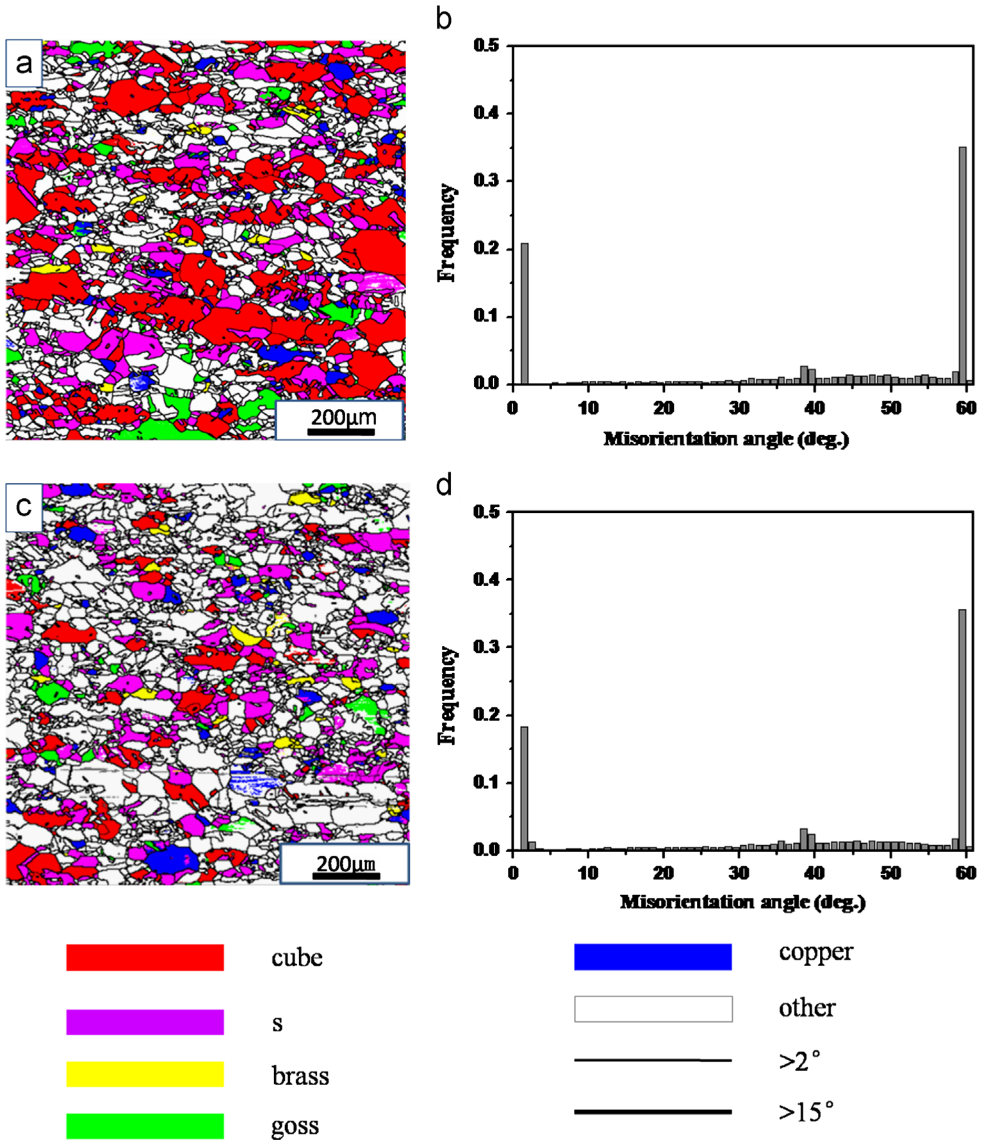

Fig. 1. (a) EBSD orientation map for initial sample A with initial texture (fraction of cube texture is 25.4%); (b) misorientation distribution of initial sample A; (c) EBSD orientation map for initial sample B with initial texture (fraction of cube texture is 9.1%); (d) misorientation distribution of initial sample B. In this EBSD map, grains in red have the orientation of cube texture (within a 15° deviation from {100}⟨001⟩), grains in purple are S orientation ({123}⟨634⟩), grains in green are goss texture ({011}⟨100⟩), grains in yellow are brass texture ({011}⟨211⟩), grains in blue are copper texture ({112}⟨111⟩), grains in white have random orientation, thin black lines refer to low angle grain boundaries, and thick black lines refer to high angle grain boundaries. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)