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Research of textures of ultrafine grains pure copper produced by accumulative roll-bonding

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ABSTRACT

Deformation textures and recrystallization textures of ultrafine grains pure copper produced by asymmetrical accumulative roll-bonding (AARB) and symmetrical accumulative roll-bonding (ARB) respectively were investigated using X-ray diffraction (XRD). It was found that dominant deformation textures of copper after 98.4% strain are {1 0 0}<1 1 0> shear texture by AARB and {2 1 1}<1 1 1> copper texture by ARB, a mixed "deformation–recrystallization" texture is observed during the first stage of recrystallization, dominant recrystallization texture is {0 0 1}<1 0 0>cube texture in samples produced respectively by AARB and ARB. We suggest that deformation textures and recrystallization textures are controlled by the crystal structures and deformation methods of samples, some unusual properties in ultrafine grains pure copper are possibly unstable.

1. Introduction

A number of unusual properties have been reported in ultrafine grain materials produced by severe plastic deformation (SPD). In many cases the cause of the anomalous behavior has been attributed to the presence of non-equilibrium grain boundaries in the highly deformed materials [1,2]. Although the exact mechanisms of grain refinement are not completely understood, it is becoming obvious that grain-boundary mobility, including rotation, plays an important role during plastic deformation of ultrafine grained metals [3]. One of the SPD methods is an accumulative roll-bonding (ARB) [4,5]. The AARB method is brought forward by Professor Q.N. Shi which is evolution of ARB and is quite similar to ARB. The only difference between AARB and ARB is that one roller is bigger than another in AARB and two rollers are the same size in ARB. However, there are some shear strains in the two surfaces of a sample processed by AARB, and the shear strains are parallel to rolling direction (RD). In our recent study, results have indicated that when true strain is more than 4.2, deformation textures of surface layers of pure copper are {1 0 0}<0 1 1> shear textures for processed by AARB, and {2 1 1}<1 1 1> copper textures for processed by ARB, and that deformation textures of inner layers of all samples are dominant {2 1 1}<1 1 1> copper texture of which intensities are nearly homogeneous, and it is a symmetry distribution of deformation texture along the centre layer. Components and intensities of deformation textures do not vary obviously with increasing true strain. Interface of two adjacent layers confines the deformation range of grains which induces deformation textures more identity. If a sheet of copper with thickness 0.8 mm is rolled 10 passes by AARB or ARB, the space of two adjacent layers is only 780 nm. If there are only 5 grains between two adjacent layers, the average size of grains is 160 nm. The transition from the rolling texture to the cube texture during recrystallization of cold rolled copper is one of the most prominent examples of recrystallization-induced texture changes in metals [6]. For a cold rolling reduction greater or equal to 2.7, the {0 0 1}<1 0 0> cube texture is dominant after annealing in oxygen-free copper. Recrystallization textures are mainly composed of {0 0 1}<1 0 0> cube, {1 1 0}<0 0 1> Goss and {1 1 0}<1 1 2> Brass textures after 70% strain and of {0 0 1}<1 0 0> cube texture and S{1 2 3}<6 3 4> texture after 90% strain [7]. The S{1 2 3}<6 3 4> deformation texture has often been addressed to be responsible for the {0 0 1}<1 0 0> recrystallization texture in fcc metals [8]. The ultrafine grains coppers were produced by ARB or AARB [9]. Deformation textures and recrystallization textures of surface layers of pure copper with true strain more than 4.2 was studied in the paper. The hypothesis and interpretation of texture formation have been given.

2. Experimental procedure

2.1. Preparations of samples

The industry pure copper sheets with thickness 0.8 mm, whose chemical components are showed in Table 1, are starting mate-

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Table 1
The chemical components of copper sheet (wt.%).

Element	Content
Cu	99.95
Bi	0.002
Sb	0.002
Fe	0.005
Pb	0.005
S	0.005
P	0.003
O	0.003
$\sum$	0.05

rials. Table 1 lists the chemical components of copper sheet (wt.%).

The copper sheets were cut into samples with size 30 mm × 300 mm × 0.8 mm, which were annealed at 600 °C for 1 h with heating up rate 20 °C/min, then cooled in furnace. The samples were washed with hydrochloric acid solution ($VHCl:VH_2O = 1:3$), then polished by a steel wire brush in order to get rid of the oxide on surface.

After the above pretreatment, the samples were rolled respectively by AARB and ARB with 50% thickness reduction per pass. In AARB process, the diameter ratio of two rollers is 1.08. The samples were annealed at 120 °C for 0.5 h every 2 passes until they were rolled 6 passes. After rolled 6 passes (98.4% thickness reduction), the specimens were annealed at 240, 260, 300, 340 and 380 °C for 0.5 and 1 h respectively.

2.2. Textures measurement and hardness test

After electrochemistry erosion, all samples were cut in size 20 mm × 20 mm, they were tested using a Japan Rigaku D/max-rc X-ray diffractionmeter. The diffraction data were collected using Schulz back reflection method with a special texture attachment. A copper target was used, the tube voltage was 40 kV, the tube current was 1 0 0 mA, the size of deliver slit (DS) was 3 mm × 1.2 mm, the width of solar slit (SS) was 4°, the width of receiver slit (RS) was 3 mm. The 3 part pole figures of (1 1 1), (2 0 0) and (2 2 0) plane were tested (α is from 20 to 90°, β is from 0 to 360°, $\Delta\alpha = \Delta\beta = 5°$). Hardness tests were performed with 200 g load using a Japan Shimadzu type M micro hardness tester.

3. Results

The initial texture of samples annealed at 600 °C for 1 h is cube texture in accord with literature [6]. The deformation textures of samples rolled 6 passes by AARB and ARB process respectively were

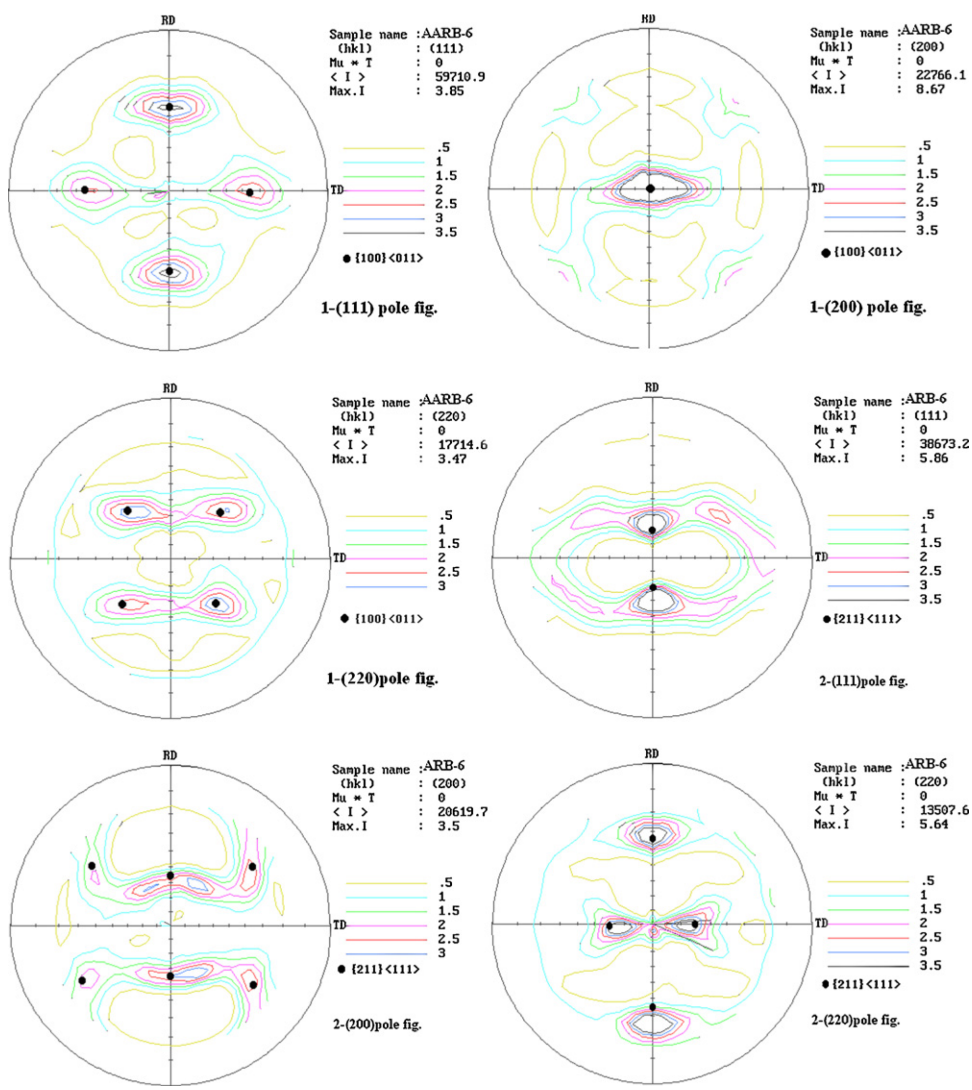

Fig. 1. (1 1 1), (2 0 0) and (2 2 0) pole figures of samples rolled 6 passes by (1) AARB, (2) ARB.