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Microstructure evolution of a Cu-15Ni-8Sn-0.8Nb alloy during prior deformation and aging treatment

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ABSTRACT

The microstructure evolution of Cu-15Ni-8Sn-0.8Nb alloy during prior cold deformation by rotary swaging (RS) and subsequent aging treatment was investigated. Electron back scattered diffraction (EBSD) results indicated that the deformed microstructure mainly consisted of refined and elongated grains. Discontinuous precipitates appeared at previous grain boundaries (PGBs) and shear bands after deformation of 45 pct reduction. Transmission electron microscope (TEM) studies revealed that the transformation kinetics of both DO_{22} ordered phases and discontinuous precipitates were significantly accelerated by prior deformation, and the transformation from DO_{22} to $L1_2$ ordering was suppressed to a certain degree. The maximum yield strength of the specimens with 45 pct reduction reached to about 1230 MPa after aging treatment, but the corresponding ductility was poor due to the rapid growth of discontinuous precipitates.

1. Introduction

As one of the most prominent substitute for Cu-Be alloys, Cu-Ni-Sn alloys possess excellent age-hardening capabilities and exhibit an excellent combination of high strength, exceptional bearing properties, stress-relaxation resistance and corrosion-resistance properties after aging treatment [1–4]. The age-hardening capabilities of Cu-Ni-Sn alloys derive from the spinodal decomposition (SD), which occurs at the early stage of aging and produces a modulated structure [5], and DO_{22} ordering, which produces a homogeneous arrangement of fine-scale coherent DO_{22} ordered precipitates (Al_3Ti-type structure) throughout the matrix [6–8]. Discontinuous precipitates with a lamellar structure of gamma DO_3 precipitates ($(Cu_xNi_{1-x})_3Sn$) and equilibrium α phase usually appear in over-aged condition and lead to abrupt drop in both strength and ductility [9,10].

Since Plewes [11] found that the age-hardening of a Cu-9Ni-6Sn alloy could be significantly accelerated by prior cold deformation in the 1970s, many researches were carried out in attempts to achieve an optimum strength-ductility combination in Cu-Ni-Sn alloys through thermomechanical treatment. However, the Cu-Ni-Sn alloys with prior cold deformation showed brittleness after aging treatment. The adverse impact of prior cold deformation has not been effectively eliminated [12–14]. Up to now, detailed researches on the microstructure of deformed Cu-Ni-Sn alloys have not been reported and the mechanism of the accelerated age-hardening by prior cold deformation has not been thoroughly explained. To the author's understanding, an insight into the microstructure evolution during deformation process and subsequent aging treatment is essential for establishing a proper method to produce commercially applicable Cu-Ni-Sn alloys. Therefore, detailed electron microscope studies were needed to reveal the microstructure evolution during deformation process and subsequent aging treatment.

In the present study, Cu-15Ni-8Sn-0.8Nb alloy rods were deformed by rotary swaging (RS). A small amount of Nb was added into the alloy to improve the cold workability. The present study focuses on the effect of prior cold deformation on the microstructure evolution of Cu-15Ni-8Sn-0.8Nb alloy. Therefore, the effect of Nb on the microstructure and mechanical properties of this alloy will not be discussed in detail. The microstructure of alloys after swaging and aging treatment was investigated via orientation imaging microscopy (OIM) using electron back scattered diffraction (EBSD) and transmission electron microscope (TEM). The mechanical properties of swaged and aged alloys were investigated through microhardness and tensile tests.

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Table 1
Chemical composition of Cu-15Ni-8Sn-0.8Nb alloy(wt%).

Alloy	Cu	Ni	Sn	Nb
Cu-15Ni-8Sn-0.8Nb	Remain	15.8	7.94	0.78

2. Experimental

2.1. Materials and methods

The alloy rods for rotary swaging were produced by means of powder metallurgy followed by hot extrusion. The composition of the powders is listed in Table 1. The powders were first isostatic cool-pressed at 200 MPa for 20 min and vacuum-sintered (10^{-3} Pa) at 850 °C for 4 h. Hot extrusion was then performed at 830 °C using a backward extrusion method under an extrusion speed of 30 mm/s and

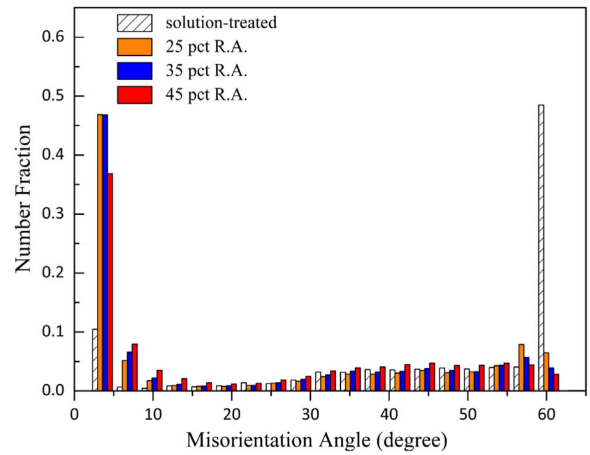

Fig. 2. Misorientation angles of Cu-15Ni-8Sn-0.8Nb alloys after solution treatment and 25, 35, 45 pct reductions.

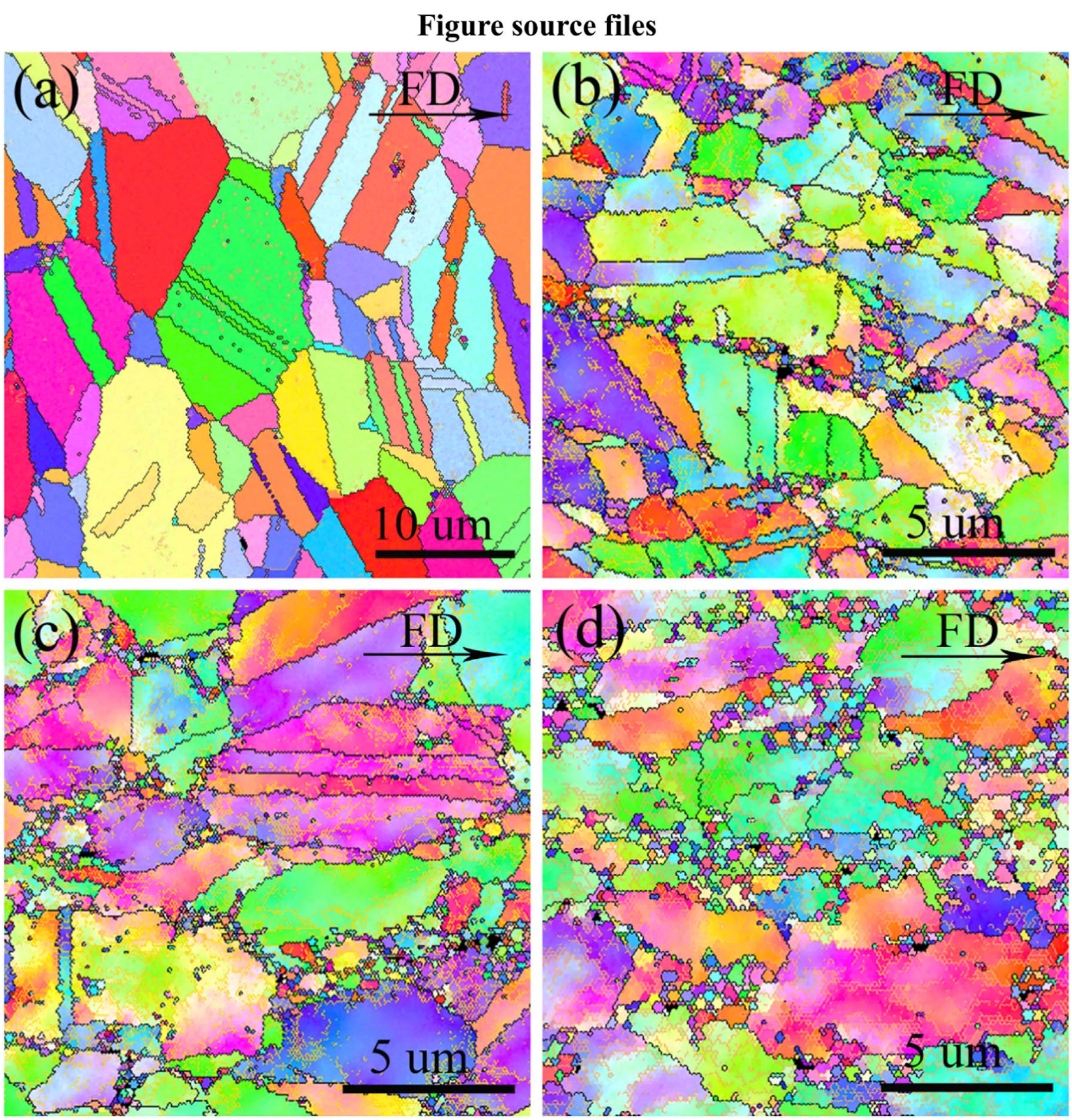

Fig. 1. EBSD maps of Cu-15Ni-8Sn-0.8Nb alloys after (a) solution treatment at 850 °C for 1 h; and (b) 25; (c) 35; (d) 45 pct reductions. The feeding direction of the swaging process is marked in each image.