Materials and Design 32 (2011) 1948–1956

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Severe plastic deformation of copper and Al–Cu alloy using multiple channel-die compression

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ARTICLE INFO

Article history:
Received 2 April 2010
Accepted 30 November 2010
Available online 4 December 2010

Keywords:
A. Non-ferrous metals and alloys
A. Nano material
F. Plastic behavior

ABSTRACT

Severe plastic deformation studies of copper and Al–Cu alloy by multiple channel-die compression tests were investigated. The materials were tested under plane strain condition by maintaining a constant strain rate of 0.001/s. Extensive grain refinement was observed resulting in nano-sized grains after severe plastic deformation with concomitant increase in flow stress and hardness. The microstructural investigation of the severely deformed materials was investigated using optical microscope and scanning electron microscope. Shear band formation was identified as the failure mechanism in the two phase Al–Cu alloy. The results indicate difficulty in obtaining severe plastic deformation for alloys having two phase micro-structure.

1. Introduction

In recent years, bulk nano-structured materials (NSM) processed by the methods of severe plastic deformation (SPD) have attracted interest among material scientists and engineers. Using SPD approach, materials can be deformed to very large strains thereby enhancing the physical and mechanical properties. Valiev et al. [1] carried an extensive research on different methods of SPD for obtaining NSM. The advantages of these methods being that ultra-fine grained materials with enhanced strength, higher thermal stability, increased fatigue life, high damage tolerances, absence of porosity high strain rate super plasticity can be obtained. Applications of these materials include light weight structures for automotive and aerospace industries, sports goods like tennis rackets having high strength to weight ratio, medical implants, high strength micro springs and gears, etc.

Saito et al. [2] studied the accumulative roll-bonding process for producing ultra-fine grained bulk aluminum. Vorhauer and Pippen [3] studied the influence of type and path of deformation on the microstructural evolution during severe plastic deformation. They used plane strain compression technique in cyclic/multiple channel compression die similar to plane strain rolling condition. They imparted SPD through repeated pressing of pure Al and Cu through a channel-die. Becker and Lalli [4] studied the texture evolution and the effect on grains in channel-die compression process. Salishchev et al. [5] investigated the micro-structure evolution and mechanical behavior of the commercial pure titanium. Multiple channel-die compression tests were carried out at warm deformation ($T = 400\,^{\circ}C$) up to a true strain of 6.0 and reported the following unusual behavior. (a) The yield stress dependence was non-monotonic. (b) The yield stress of each subsequent deformation step was always less than the flow stress at the end of the previous one. (c) The strain hardening as a function of strain in each deformation step was similar.

Li and Blum [6] used multiple uniaxial compression technique along three orthogonal axis to impart SPD in copper up to a true strain of 7.8. The increased strength and strain rate sensitivity by this technique was similar to that obtained through ECAP process. Li et al. [7] studied the strain rate sensitivity of copper at 373 K as a function of prestrain by multiple uniaxial compression technique. The deformation behavior of ultrafine-grained (UFG) and coarse-grained (CG) copper produced by severe plastic deformation was reported by Li et al. [8]. Kundu et al. [9] used multiple compression technique in a channel-die to impart severe plastic deformation to copper at ambient and elevated temperatures up to an equivalent strain of eight. Zhu et al. [10] reported the properties like strength, ductility, toughness, fatigue strength, wear resistance, thermal stability, corrosion resistance, magnetic and optical properties of different nanostructured materials obtained by SPD. Sauvage et al. [11] investigated the role of interphase boundaries on the grain size reduction mechanisms in a Cu–Cr composite. Experiments on 70–30 brass in a channel-die by Nourbakhsh and Vujic [12] indicated work hardening rate to be high for low and high strains whereas for medium strains the rate of work hardening was low. The influence of the micro-structure and the misorientation relationship between grains on the mechanical properties in the Cu specimens processed by equal-channel angular extrusion up to 16 passes was investigated by Torre et al. [13]. Ghosh [14] deformed precipitation hardened aluminium alloys along three

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doi:10.1016/j.matdes.2010.11.074