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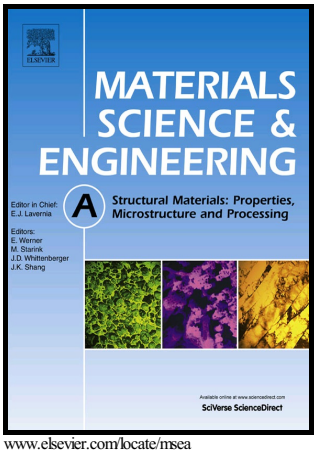

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High-pressure torsion of aluminum with ultrahigh purity (99.9999%) and occurrence of inverse Hall-Petch relationship

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Abstract

Severe plastic deformation through the high-pressure torsion (HPT) method was applied to pure aluminum with a wide range of purity levels such as 99% (A1100), 99.5% (A1050), 99.99% (4NAl), 99.999% (5NAl) and 99.9999% (6NAl). The hardness of 6NAl decreased with straining and saturated to a level below the hardness level of the annealed sample. This softening behavior, which was similar to the behavior of metals with low melting temperatures such as indium, tin, lead and zinc, was not observed in 5NAl or less pure Al. It was found that the grain-size dependence of hardness became less significant with increasing the purity level, while the HPT-processed 6NAl followed an inverse Hall-Petch relationship. In 6NAl with large grain sizes, dislocations accumulated in the grains in the form of dislocation cells and enhanced the hardness, but when the grain size was small, the dislocations moved fast and disappeared in high-angle grain boundaries.

Keywords: severe plastic deformation (SPD); ultrafine-grained (UFG) materials; high-pressure torsion (HPT); homologous temperature; reverse Hall-Petch relationship; strain softening.

1. Introduction

Severe plastic deformation (SPD) techniques are now receiving significant attention to produce ultrafine-grained (UFG) structures in different kinds of materials [1,2]. Within the last 3 decades, the most widely studied topic has been hardening of metals by SPD processing