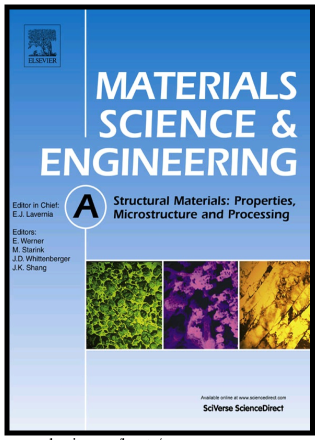

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PII: S0921-5093(16)31499-X
DOI: http://dx.doi.org/10.1016/j.msea.2016.12.017
Reference: MSA34448

To appear in: *Materials Science & Engineering A*

Received date: 13 November 2016
Revised date: 2 December 2016
Accepted date: 3 December 2016

Cite this article as: S.P. Iliev, X. Chen, M.V. Pathan and V.L. Tagarielli, Measurements of the mechanical response of Indium and of its size dependenc in bending and indentation, *Materials Science & Engineering A* http://dx.doi.org/10.1016/j.msea.2016.12.017

Measurements of the mechanical response of Indium and of its size dependence in bending and indentation

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Abstract

Tension, compression, three-point bending and indentation experiments are conducted on high purity Indium at room temperature and low strain rates. The material displays a ductile viscoplastic response, found to be size-independent in tension and compression. Simple analytical models are constructed to aid interpretation of the test results and detection of a size effect in bending and indentation, associated to a length-scale of order 50-100 µm.

Keywords: A. creep; plastic collapse; strengthening mechanisms; B. elastic-viscoplastic material; C. mechanical testing.

1. Introduction

Indium has wide applications in the electronics industry and potential uses as a propeller in Field-Emission Electric Propulsion micro-thrusters; it was a strong contender for use in the ESA Pathfinder mission [1]. Pure polycrystalline Indium at room temperature is a soft and ductile metal with a low melting point (157°C) and strength of order of few MPa. This metal is not suitable for structural applications at mm scale and above, and as a consequence there are only a few published studies focusing on the mechanical properties of Indium. At room temperature (22°C) Indium is at a homologous temperature of 0.69 and deforms by power-law creep. This paper will report measurements of the mechanical response of the material in its power-law creep regime and of the dependence of such response upon specimen size.

Ashby [2] has proposed that geometrically necessary dislocations (GND) associated with gradients of plastic strain enhance material strength and lead to size effects in the micron range. This has led to a large number of investigations into size effects in plasticity. For example, an increased yield strength with decreasing specimen size has been observed in torsion of thin metal wires by Fleck et al. [3] and in microbending experiments Stolken and Evans [4]. Likewise, an increase in the hardness of metals with decreasing indentation depth has been observed by several authors ([5]-[8]). Strain gradient plasticity theories have also been developed by several authors to account for the observed size effects (e.g. [9]-[13]). These theories contain one or more material length scales and typically predict a strength elevation when the specimen size is comparable with such length scale. The studies above focused on metals at either room temperature; some studies included the effects of higher temperatures, but not sufficiently high to activate creep mechanisms (e.g. [14]); other studies investigated the effect of ageing ([15]) on material length-scales, reporting small variations of these.