Mechanical properties and structure of microcrystalline materials

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Abstract

In the present work, high temperature deformation of an Al – 4,5 Mg – 0,2 Zr – 0,2 Sc alloy produced by equal-channel angular pressing (ECAP) was studied. The aim of the investigation was to find a correlation between the mechanical properties of the material at elevated temperatures and its specific microstructure resulting from the severe plastic deformation during ECAP. Special attention was devoted to the stabilizing effect of the Zr and Sc additions on the ultra-fine grained (UFG) microstructure at elevated temperatures and its possible consequences for the occurrence of superplastic behavior.

The material with 6 passes of ECAP at 523 K, route B_C, was studied using the methods of light microscopy (LM), transmission electron microscopy (TEM) and atomic force microscopy (AFM). A series of tensile tests were performed at temperatures between 573 and 823 K.

The grain size after ECAP was found to be < 1 μm and remained < 10 μm up to a temperature as high as 798 K. This outstanding stability of the UFG microstructure can be attributed to the presence of $Al_3(Zr_xSc_{1-x})$ precipitates. Consequently, the studied alloy exhibited high strain rate superplasticity over a broad interval of temperatures ranging from 573 to 798 K. Exceptionally high elongations to failure were achieved at an initial strain rate of $4.5 \times 10^{-2}\ s^{-1}$ – 2130 % at 773 K and 1950 % at 798 K. At these conditions, the strain rate sensitivity parameter m exceeded the value of 0.6.

LM and AFM observations identified grain boundary sliding as the dominant deformation mechanism during superplastic deformation of the material. AFM was used to document grain rotation as well as sliding. The displacements at individual boundaries were found to be roughly proportional to the grain size corresponding to a given straining temperature. The grain boundary sliding did not occur in a homogeneous manner – it was preferentially concentrated to bands with the finest grains.