Combining nano-DIC and ACOM TEM to study the grain boundary mediated plasticity of aluminium films

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Abstract

The viscoplastic response of metallic nano-crystalline films has been widely studied in the literature by means of nanomechanical testing, such as with in situ TEM experiments (1), (2) or dedicated on chip test methods (3). The enhancement of ductility (as compared to large grain samples) has been attributed to different mechanisms, including grain boundary sliding, grain growth or kinematic hardening due to dislocation pile up (2), (4). However, observations of the polycrystal deformation are challenging due to highly refined grain sizes. The correlative methodology developed in this work allows probing the relationships between the microstructural changes and the total strain field, at a scale never resolved before – i.e. sample size of 2.5 x 25 μm and strain field resolution of 50 nm. The aluminium films deposited by sputtering (210 nm thickness) are mechanically loaded with an on chip method (3) and then observed after deformation in the transmission electron microscope (TEM). Nanoscale digital image correlation (nano-DIC) reveals multiple necking regions appearing at low plastic strains and further spreading along the sample gauge without leading to critical failure. Automated crystal orientation mapping (ACOM TEM) indicates that strain localization bands correspond to grain boundaries (GB) and that the global texture remains unchanged. The local shear amplitude achieved by such GB sliding correlates, to some extent, with the GB character. The complementary results obtained by both techniques shed some new light on the link between GB mediated plasticity and enhanced macroscopic ductility (5).

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