Crystal plasticity based modelling of strain hardening and creep in nanocrystalline freestanding Pd films

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Abstract

Crystal plasticity based finite element modelling (CPFEM) is used to study strain hardening and creep in freestanding nanocrystalline Pd films. The model accounts for the confinement of plasticity due to grain boundaries and to the presence of growth twins as well as for the significant viscoplastic effects associated to thermally activated mechanisms.

The model microstructure is a 2D periodic Voronoï tessellation that reproduces the grain size distribution. The finite element mesh conforms to the grain and twin boundaries. Periodic boundary conditions reproduce the initial loading and the subsequent slow relaxation occurring in the experimental test.

Numerical predictions are assessed based on experimental data gathered during a previously reported experimental campaign of tests on freestanding submicron Pd films using an on-chip technique [1]. The Pd films were deposited by e-beam evaporation which induces a microstructure exhibiting a columnar morphological texture with an ~30 nm in plane grain size. The films involve a large strain hardening capacity and a significant increase of the strength with decreasing thickness. Transmission electron microscopy has revealed the presence of a moderate density of growth nanotwins interacting with dislocations. Intense dislocation activity after deformation was detected and an increased twin density has been observed to enhance the ductility of the films.

As expected (e.g. [2]), the large apparent strain hardening at the onset of plasticity results from a gradual elastic-plastic transition. The largest grains yield much earlier than the softest ones and this effect is captured by the CPFEM approach. The model allows also the study of the creep behaviour of the Pd films and of the influence of the twin density on strain hardening.

[1]M.-S. Colla, B. Wang, H. Idrissi, D. Schryvers, J.-P. Raskin, T. Pardoen, Acta Mater 2012;60:1795-1806.
[2] L. Li, S. Van Petegem, H. Van Swygenhoven, P.M. Anderson, Acta Mater 2012 ; 60 :7001-10

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