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Names and affiliations of applicants (* indicates experimentalists):

Dr. Ellen Thiele *, Dr. Jörg Bretschneider *, Dr. Cesar Justino Buque *
Institute of Physical Metallurgy, Technical University Dresden
D-01062 Dresden
Germany

Report:

INFLUENCE OF THERMAL TREATMENT AND CYCLIC PLASTIC DEFORMATION ON THE DEFECT STRUCTURE IN ULTRAFINE-GRAINED NICKEL

Ellen Thiele[1], Jörg Bretschneider[1], Lutz Hollang[1], Norbert Schell[2] and Carl Holste[1]

[1] Institut für Physikalische Metallkunde, Technische Universität Dresden
[2] Institut für Ionenstrahlphysik und Materialforschung, FZ Rossendorf

Because of their unusual physical properties polycrystals with a mean grain size of some 100nm, so called ultrafine-grained (UFG) materials, are of a great interest for both, theoretical and experimental investigations. Compared with conventional polycrystals the material shows a relatively high yield stress and microhardness combined with a sufficient ductility. However, the structure is non-stable against thermal treatment. Furthermore, it is still open, how a cyclic deformation at different temperatures changes the structure, i.e. the internal strains and the distribution of the grain size and orientation. In the present paper we intend to describe quantitatively the structure changes induced by thermal treatment and cyclic deformation.

In order to produce ultrafine-grained nickel, billets of 99.992% purity were prepared by equichannel angular pressing (EAP)[1]. The thermal treatment experiments were carried out at different annealing temperatures on small blocks of the as produced UFG material. For the fatigue experiments samples with a rectangular cross section and with a loading axis parallel to EAP die axis were cut from the billets. The samples were cyclically deformed at room temperature and at 160°C at constant plastic strain amplitudes.

At room temperature deformation the stress amplitude didn't change significantly with the cycle number until macrocracks appeared. The mean stress always had a positive sign and decreased during cycling. As expected, the stress amplitude decreased with increasing deformation temperature.

The grain structure was observed using the orientation contrast in a scanning electron microscope. Recrystallization occurred even at temperatures significantly lower than that, usually required for recrystallization after cold rolling. The cyclic plastic deformation induced a slight grain coarsening already at room temperature.

To characterize the defect structure in the original UFG material as well as after thermal treatment and after fatigue, measurements of X-ray diffraction profiles were performed at the synchrotron radiation beamline ROBL of the Forschungszentrum Rossendorf at the European Synchrotron Facility in Grenoble[2]. Diffraction profiles with a negligible instrumental broadening were measured for different {hkl}-types of lattices planes parallel to the sample surfaces. Using the Williamson-Hall and the Krivoglaz-Wilkens plots, the size of coherently scattering regions, the root mean square strain and the dislocation density were calculated from the profile shape. These parameters depend in a characteristic way on the deformation and annealing state of the samples.

Finally, conclusions were drawn concerning threshold values of the deformation temperature and of the deformation amplitude for the thermal and mechanical stability of the ultrafine grain structure.

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