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Report:

CHANGE OF INTERNAL STRAINS AND STRESSES IN ULTRAFINE-GRAINED NICKEL DUE TO CYCLIC PLASTIC DEFORMATION

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Ultrafine-grained (UFG) materials with a mean grain size of some 100nm, prepared by equal channel angular extrusion (ECAE) from compact material are of a great interest for theoretical and experimental investigations due to their outstanding physical properties. They show a very high yield stress and microhardness in comparison with conventional polycrystalline samples. However, the structure and the defects, responsible for the mechanical behaviour, are non-stable against thermal treatment. Corresponding to the application fields of the materials, also the stability against cyclic deformation at different temperatures should be investigated.

To carry out fatigue experiments, samples with a rectangular cross section were cut from UFG nickel billets of 99.99% purity. The loading axis of the samples was parallel to ECAE die axis.

The cyclic plastic deformation of the samples was performed at room temperature and at 200°C in a servohydraulic materials testing machine at a constant plastic strain amplitude $\varepsilon_{pa} = 5 \cdot 10^{-4}$. A cyclic softening was observed till the stress amplitude σ_a remained nearly constant. As expected, σ_a decreased with increasing deformation temperature. To achieve a symmetric plastic strain amplitude, in the tension half cycle a higher amount of maximum stress was required than in the compression half cycle.

The grain structure was observed using the orientation contrast in a scanning electron microscope. No significant changes of the grain size distribution were detected after the cyclic deformation.

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. The basic instrument was a 6-circle goniometer. Applying monochromatic synchrotron radiation with an energy of 8.05 keV, the instrumental broadening was negligible in comparison with the strain induced broadening of the profiles measured at the UFG samples.

To estimate the spectrum of internal strains, diffraction profiles were measured for different {hkl}-types of lattices planes parallel to the sample surface. From the shape changes of the profiles one can conclude that the width of the strain spectrum is reduced by the cyclic plastic deformation especially for higher temperatures though no recrystallisation occurs. Taking into account the variation of the profile shape with the {hkl}-type of the reflection as well as the dependence of the profile position on the measuring direction, long-range granular stresses should be present. The mean dislocation density, calculated on the basis of the Krivoglaz-Wilkens theory, was found to be correlated with the deformation state of the samples.

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