Texture Evolution in NiAl Deformed by High Pressure Torsion

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In recent years, a lot of research has been done on the topic of severe plastic deformation (SPD). Severely deformed materials exhibit an ultrafine-grained microstructure and significantly higher yield stress compared with their coarse grained counterparts. High pressure torsion (HPT) is beside equal channel angular pressing (ECAP) and accumulative roll bonding (ARB) one of the most important SPD processes [1]. In the present study HPT was applied to NiAl which is an intermetallic compound with B2 structure and has a brittle-to-ductile transition temperature (BDTT) at about 300°C. Characteristics like low density, high melting point and very good oxidation resistance are advantageous for high temperature applications, but processing at low temperatures is difficult because of brittleness [2]. However, with HPT it was successfully managed to severely deform NiAl samples at low temperatures in order to study texture and microstructure evolution below and around the BDTT. To do that, small discs of polycrystalline NiAl (diameter about 8 mm, thickness about 0.8 mm) were deformed by HPT at temperatures ranging from room temperature up to 500°C and pressures from 2 GPa to 8 GPa. At the edge of the samples very high local shear strains of about 70 were achieved leading to a large shear strain gradient from the center to the edge of the sample.

The texture of the torsion deformed material was measured by diffraction of high-energy synchrotron radiation (100keV) using the HARWI II (W2) beam line at DESY in Hamburg, Germany. The high penetration depth of the synchrotron radiation allows to measure small volumes (1.1 mm × 0.5 mm × 0.8 mm) of the sample in transmission in order to get a good grain statistics. Measurements were done on three or four positions along a pin from the edge to the center of the sample. During the measurements because of monoclinic sample symmetry the pins were rotated 180° about the longitudinal axis. This was done by continuously rotating the sample and integrating the intensity of the Debye-Scherrer rings in intervals of 5°. The orientation distribution function (ODF) was calculated from the measured pole figures (\{100\}, \{110\}, \{111\}) using LaboTex software version 3.0. The ODFs were used to determine volume fractions of the texture components and changes in intensity or position. The texture components observed were compared with the ideal texture components found in simple shear deformed bcc metals [3].

As expected, for all samples a texture gradient from center to edge was found due to increasing shear strain. In the pole figures, an increasing intensity of the texture components is seen. A strong change of texture is induced by different processing temperatures (see Fig.1). Lower intensity maxima correspond to lower temperature.
At room temperature, the texture is a typical shear texture with a strong F and D₁ component. From 100°C onwards an oblique cube component (clockwise rotated around the transverse direction) develops leading to an almost pure cube texture at 500°C. This is usually explained by discontinuous dynamic recrystallization, but has not been confirmed so far by microstructure investigations. Varying the pressure does not change the texture much for successfully deformed samples. However, as only high pressures enable to deform the samples without slipping or crack formation, accurate textures could not be obtained for all samples.

Fig.1: {111} pole figures measured at the edge of the sample (γ ≈ 60) with a pressure of 8 GPa. The temperature changes from room temperature to 500°C. (SPN = shear plane normal, SD = shear direction)

References