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# Influence of hydrostatic pressure on texture evolution in HPT deformed NiAl

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**Abstract.** NiAl is an intermetallic compound with a brittle-to-ductile transition temperature of about 300°C at ambient pressure. At standard conditions, it is very difficult to deform, but fracture stress and fracture strain are increased under hydrostatic pressure (HP). On account of this, deformation at low temperatures is only possible at high HP, as for instance used in high pressure torsion (HPT). In order to study the influence of HP on texture evolution, small discs of polycrystalline NiAl were deformed by HPT at different temperatures ranging from room temperature to 500°C and different HPs. The influence of HP is presented for deformation at room temperature and 500°C. It is found that HP affects the formability of the samples as well as texture and microstructure.

## 1. Introduction

Nickel-aluminium (NiAl) is an intermetallic compound with B2 structure. It has a low density of 5.85 $g/cm^3$ and a high melting point of 1638°C at stochiometric composition as well as a low coefficient of thermal expansion and good oxidation resistance [1]. These characteristics would make it a good material for high temperature applications, but it is hardly used in industry due to its low temperature brittleness. At ambient pressure, the brittle-to-ductile transition temperature (BDTT) lies at about 300°C. According to the von Mises criterion, five independent slip systems are needed for a homogeneous deformation of polycrystals, that means, the three primary {110}<100> slip systems in NiAl are not enough. Below the BDTT, the critical resolved shear stress for the necessary activation of the secondary slip systems {112}<111> or {110}<110> to fulfil the von Mises criterion is higher than the fracture stress and therefore the material breaks before plastically deforming. For temperatures above the BDTT, secondary slip on {110}<110> becomes easy, turning the material ductile. In order to achieve high strains in NiAl at temperatures below 300°C without fracture, high pressure torsion (HPT) [2] was used. In [3] it was shown that the fracture stress and fracture strain of polycrystalline NiAl drastically increase when applying a high hydrostatic pressure (HP) during tensile testing at room temperature (RT). Thus, the BDTT can be shifted below RT by application of a sufficient HP.

In the present work the influence of HP on texture evolution during HPT of NiAl at different temperatures is analyzed by evaluating the volume fraction of the texture components found.

## 2. Experimental

The polycrystalline NiAl investigated had a nearly stoichiometric composition ((50.2 ± 0.1) at%Ni). In the initial extruded sample, a homogeneous globular microstructure with an average grain size of about 50 µm and a weak <111> fiber texture was found [4, 5]. Small discs of the material with a height of 0.8 mm and a diameter of 8 mm were deformed at RT and 500°C by HPT at different pressures. According to [2], the shear strain γ in torsion is calculated by the relationship

$$\gamma = \frac{2\pi\ N\ r}{h}, \qquad (1)$$

with $N$ = number of rotations, $r$ = radius and $h$ = height of the sample. Two rotations were used adding up to a maximum shear strain of 60 at the edge of the sample. The rotation rate of 0.2 rotations/min leads to a maximum shear strain rate of 0.1 $s^{-1}$.
Texture measurements were done on small pins cut along the radial direction of the samples by spark erosion [see Fig. 1]. The investigated part considered here is a small volume at the

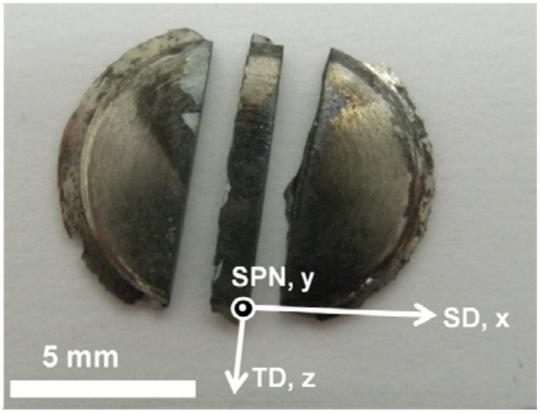


Fig. 1: Sample and crystal coordinate system of HPT deformed sample with cut pin. (SD = shear direction, SPN = shear plane normal, TD = radial direction, x = [100], y = [010], z = [001])

edge of the pin corresponding to γ ≈ 50. The experiments were performed at beamlines HARWI II and HEMS at DESY in Hamburg, Germany. For evaluation of the texture, the Debye-Scherrer rings corresponding to the {100}, {110} and {111} lattice planes were used. Pole figures (PFs) were calculated using the software StressTex [6]. For the calculation of the orientation distribution function (ODF), the software LaboTex [7] was employed. The volume fraction of the texture components was calculated with a Gaussian spread of 10°. More details on texture measurements with synchrotron radiation and data processing can be found in [8].

## 3. Results and discussion

Depending on temperature, respectively strength, a certain HP is needed to get a smooth HPT deformation without slipping of the sample. While it was possible to deform all samples at a HP of 8 GPa, at 2 GPa and RT the disc slipped. At a temperature of 500°C, HPT at all HPs was performed without problems. Thus, formability is enhanced by high HP. In accordance with the findings of Margevicius and Lewandowski [2], the fracture stress is increased by applying a high enough HP. Thus, activation of the secondary slip systems is possible.
In Fig. 2, PFs of the samples deformed with different HPs at RT and 500°C are shown. For the samples deformed at RT a shear texture with components typical of bcc metals is found (see key figure in Fig. 2b), while for the sample deformed at 500°C a weak F and strong oblique cube component developed. The differences in texture caused by different deformation temperatures are described in [9].

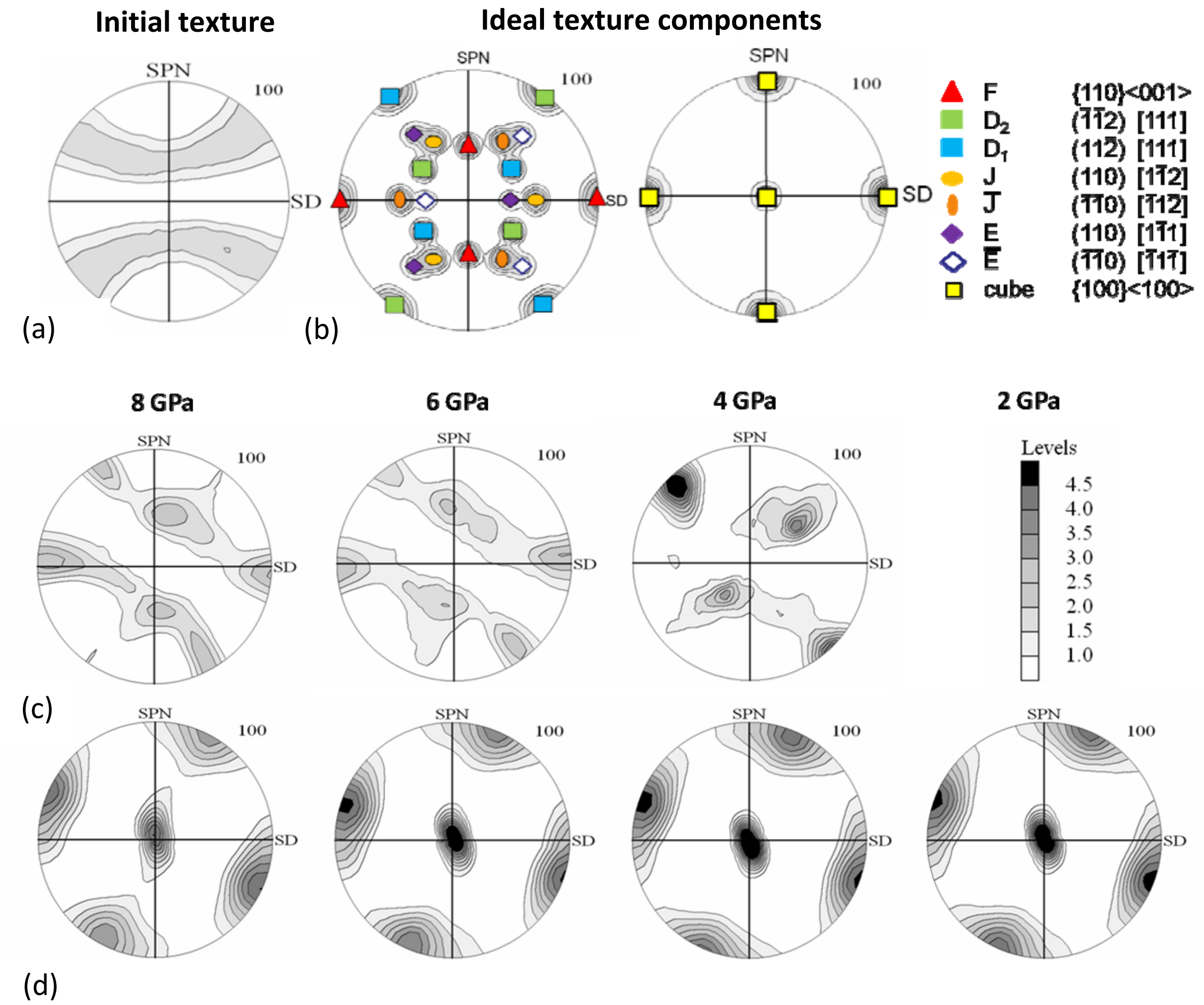


Fig. 2: {100} PFs of the initial texture (a), ideal texture (b) and samples HPT deformed at RT (c) and 500°C (d) at different HPs.

To analyze the texture changes quantitatively, the volume fractions of the texture components were calculated with LaboTex (Fig. 3). The ideal texture components for bcc metals deformed by simple shear can be found in [10].

For the samples deformed at RT shear texture components of different intensities are found. With increasing HP, the volume fraction of the components increases apart from the $D_2$ component, which shows the opposite effect. The change in volume fraction of the shear texture components may be due to a change in activity of the different secondary slip systems. Simulations to check this are planned.

At 500°C, only a weak F component and a strong oblique cube component are found. The volume fraction of the F component increases with pressure while that of the oblique cube component, which usually develops by discontinuous dynamic recrystallization, decreases. Thus, HP enhances the formation of the shear texture by impeding recrystallization and grain growth due to restrained diffusion [see e.g. 11,12].

These results can be linked to microstructure and microhardness measurements not shown here. According to these measurements, the grain size decreases with increasing HP, whereas microhardness increases which also indicates a slower recrystallization and grain growth process.

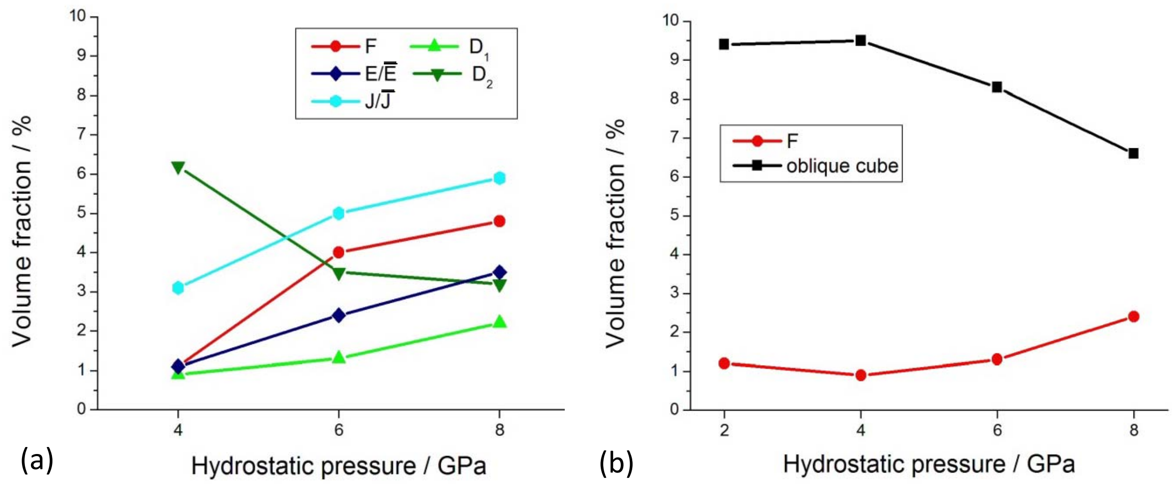


Fig. 3: Volume fraction of texture components for the samples HPT-processed at RT (a) and 500°C (b)

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