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Role of deformation temperature on the evolution and heterogeneity of texture during equal channel angular pressing of magnesium

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ABSTRACT

Investigations on texture evolution and through-thickness texture heterogeneity during equal channel angular pressing (ECAP) of pure magnesium at 200 °C, 150 °C and room temperature (RT) was carried out by neutron, high energy synchrotron X-ray and electron back-scatter diffraction. Irrespective of the ECAP temperature, a distinctive basal (B) and pyramidal (C_2) <c + a> II type of fibers forms. The texture differs in the bottom 1 mm portion, where the B-fiber is shifted ~55° due to negative shear attributed to friction.

1. Introduction

Equal channel angular pressing (ECAP) is a severe plastic deformation technique that leads to ultra-fine grain sizes in bulk metallic materials [1,2]. Such fine grain sizes are highly desirable due to their obvious effect on strengthening. In magnesium based materials, which show poor ductility at room temperature due to insufficient number of slip systems, ultra-fine grain size imparts ductility [3–5]. Magnesium and its alloys have been subjected to ECAP process at temperatures >200 °C, where non-basal slip also contributes to deformation. However this does not lead to ultra-fine grain size [6–9]. Recently, it has been found that strategically reducing the ECAP temperature after certain passes could lead to ultrafine grain size (0.25 μm < d < 1 μm) [3–5]. An important attribute of ECAP process is the development of characteristic shear textures [5,10–13]. These textures have been found favorable for imparting plasticity in magnesium [5,6]. On the other hand, considerable heterogeneity in the microstructure and texture has been reported from the top to bottom portion of the ECAP processed face centered cubic metals/alloys [14–18]. Thus in ECAP processed materials, the property attributes could be location sensitive. In case of magnesium, the texture has a prominent effect on the property due to its hexagonal closed packed structure [4–6]. In order to adequately address the texture–property correlation in magnesium alloys processed by ECAP, it is important to investigate the texture heterogeneity.

The present study is aimed at examining the role of deformation temperature on the evolution and heterogeneity of texture during ECAP. Texture heterogeneity has been accessed by measuring the local texture using synchrotron X-rays and electron backscatter diffraction (EBSD) and comparing with global texture measured by neutron diffraction.

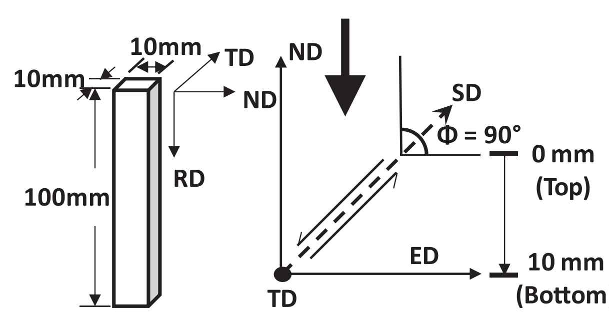

Fig. 1. Reference systems of the initially hot rolled billet and for the ECAP process; RD = rolling direction, ED = ECAP direction, ND = normal direction, TD = transverse direction and SD = shear direction.

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Table 1
Deformation temperatures for different ECAP passes.

No. of pass	1st case	2nd case	3rd case
1–4	250 ± 5 °C		
5	200 ± 5 °C	200 ± 5 °C	200 ± 5 °C
6			150 ± 5 °C
7		150 ± 5 °C	100 ± 5 °C
8			RT

2. Experimental

Rolled Magnesium billets of dimension 100 mm × 10 mm × 10 mm were subjected ECAP up to 8 passes following route A in a 90° die, thus imparting $\varepsilon_{von\text{ - }Mises} = 1.16$ and shear strain $\gamma = 2$ per pass [19]. The reference directions in the as-received material with respect to the ECAP reference direction is depicted in Fig. 1. ECAP was carried out so as to obtain the final pass at 200 °C, 150 °C and room temperature (RT). The temperatures of deformation during each pass are given in Table 1.

Global textures were measured by neutron diffraction on a ~10 mm × 10 mm × 10 mm cube at GKSS Research Centre (Geesthacht, Germany). Local textures were measured on a pin of ~1 mm × 1 mm × 10 mm along ND taken from the center of the billet by high-energy synchrotron radiation using beam line W2 (≈50 keV) at DESY-HASYLAB in Hamburg, Germany. Microtextures were measured by electron backscattered diffraction (EBSD) technique in a field emission gun (FEG) scanning electron microscope (SEM) (FEI Sirion) using the TSL OIM version 5.2 software. The TD planes of ECAP billets were irradiated to observe the effect of shear (Fig. 1).

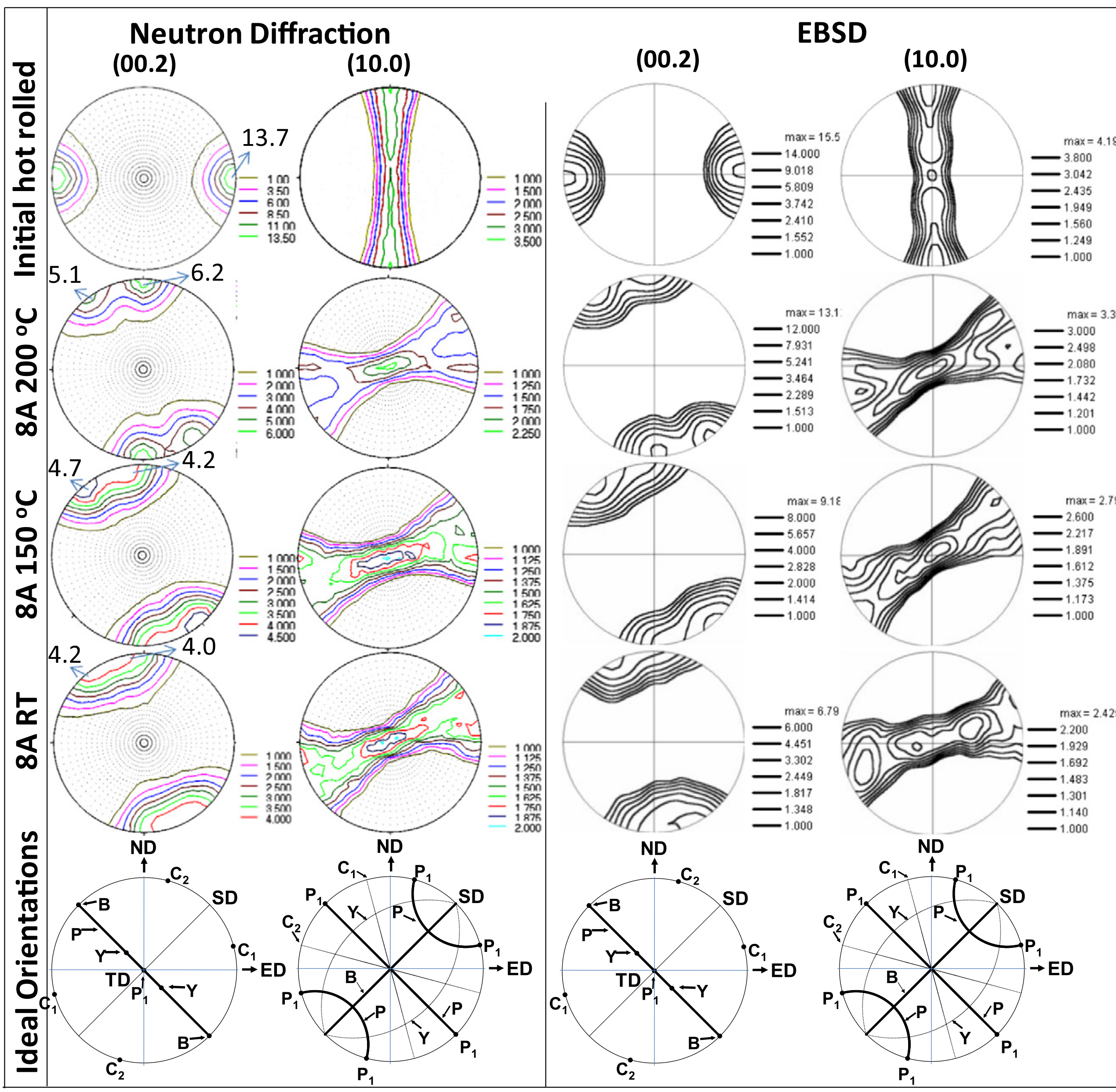

Fig. 2. (0002) and $(10\bar{1}0)$ pole figures generated by Neutron and electron backscatter diffraction (EBSD–SEM) for the initial and the 8th pass ECAP processed pure magnesium. Ideal orientations for magnesium under simple shear at 45° to the ED and ND as they appear in the (0002) and $(10\bar{1}0)$ pole figures [9]. The fiber names are: B — basal; P — prismatic; Y — pyramidal-<a>; C_1 and C_2 — pyramidal <c + a>-I and II.