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P076

MODELLING OF MICROSTRUCTURE EVOLUTION IN HCP POLYCRYSTALS ON NON-PROPORTIONAL STRAIN PATHS

K. Frydrych, K. Kowalczyk-Gajewska, S. Stupkiewicz

Institute of Fundamental Technological Research, Warsaw, Poland

1. Introduction

Microstructure evolution in hcp polycrystals subjected to severe plastic deformation, in particular in the KOBO extrusion [1] and the equal channel angular pressing (ECAP) processes [2], are examined in this work, using the crystal plasticity framework. The ECAP process consists in pressing a billet through the bent equal channel (without changing billet dimensions). Often there are many passes with rotations about the billet longitudinal axis. Standard sequences of such rotations are named routes A, Ba, Bc or C. Texture evolution in ECAP differs depending on the route and the number of passes [2]. The KOBO process consists in extruding material at room temperature with assistance of cyclic rotation of a die. Deformation paths in KOBO process are strongly position-dependent, which affects microstructure of obtained material. Both processes lead to considerable grain refinement, so they could be considered as tools enabling tailoring of material microstructure. In order to use these tools effectively, valid modeling approach is necessary.

2. Modelling framework

Modelling approach combines the large strain crystal plasticity model accounting for twinning [3] and the tangent variant of the self-consistent (SC) scale transition scheme [4]. Since elastic stretches are much smaller than plastic strains, elastic part of deformation gradient is neglected. Averaging responses of individual grains in the representative volume element (RVE) provides the response of polycrystalline aggregate. Calculations have been made using the VPSC code [4] with own procedures for the probabilistic twin volume consistent (PTVC) reorientation scheme and the hardening model accounting for slip-twin interactions [3] implemented into the program.

Simulations have been performed for two materials of high specific strength i.e.: titanium and magnesium alloys. Material parameters for titanium (Table 1) have been estimated by comparing pole figures, stress-strain curves and slip activity graphs with those shown in [5]. Four slip systems have been taken into account: prismatic $\{0110\}\langle 2110\rangle$, basal $(0001)\langle 2110\rangle$, pyramidal $\langle c+a\rangle\{1011\}\langle 1210\rangle$. Tensile twinning mode $\{1012\}\langle 1011\rangle$ has been also considered. Slip and twin systems and material parameters in AZ31B magnesium alloy have been taken from [3].

Table 1. Active slip and twinning modes for Ti and their parameters (notation as in [3]).

Slip/Twin mode	τ_{c0}	τ_r^{sat}	β	h_0^{ss}/h_0^{ts}	$f_{\mathrm{sat}}^{st}/f_{\mathrm{sat}}^{tt}$	h_0^{st}/h_0^{tt}	μ	$q_{rq}^{*\mathrm{pri}}$	$q_{rq}^{*\mathrm{bas}}$	$q_{rq}^{*\mathrm{pyr}}$	q_{rq}^{*tt}	$\gamma = c/a$
prismatic	30	70	1	50	1.0	10^{-5}	2.00	1	1	1	10	–
basal	40	42	1	86	1.0	10^{-5}	1.50	1	1	1	10	–
pyramidal $\langle c+a\rangle$	159	–	–	0	2.0	10^{-5}	2.00	1	1	1	2	–
tensile twinning	40	–	–	240	1.0	10^{-5}	0.75	1	1	1	10	0.514

3. Results

Selected results of texture simulation for initially untextured hcp materials are presented in Figs. 1–2. Microstructural changes have been investigated along the deformation trajectories according to the procedure described in [6]. The results will be compared with available experimental data.

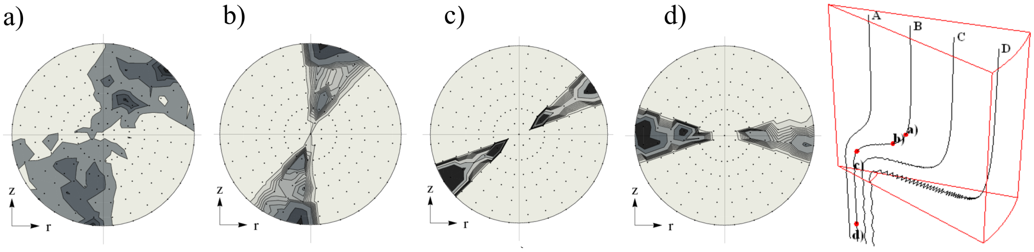

Fig. 1. (0001) pole figures of pure Ti in the KOBO process (process parameters $\phi_0 = \pm 6°$, $do : d = 35 : 8$ [mm], $f = 5$ [Hz], $V_0 = 0.5$ [mm/s]) for trajectory B ($r_0 = 8$ mm) for accumulated plastic strain: a) 0.26, b) 1.11, c) 3.26, d) 3.74.

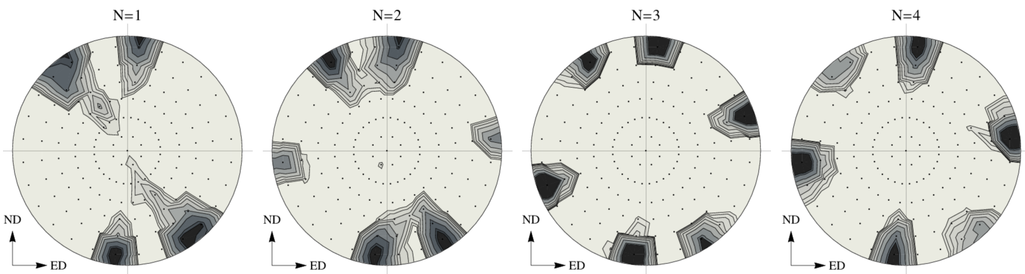

Fig. 2. (0001) pole figures of AZ31B Mg alloy after 1–4 ECAP passes (Route C).

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