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ANALYSIS OF TEXTURE FORMATION HOMOGENEITY PROCESSES DURING EQUAL-CHANNEL ANGULAR PRESSING

ANALIZA PROCESU TWORZENIA JEDNORODNOŚCI TEKSTURY PODCZAS WYCISKANIA W KANALE KĄTOWYM O PRZEKROJU KWADRATOWYM

Experimental investigations of texture formation processes were conducted in selected zones of cross section of bulk billets, subjected to equal channel angular (ECA) pressing. Pure Cu and Ti with *fcc* and *hcp* lattices, respectively were chosen as investigated materials. There was considered a case of 12 ECA pressing passes (route B_c). The angle of channels' intersection during ECA pressing was 90°. ECA pressing rate was 6 mm/s. In the case of Cu deformation was carried out at room temperature and in the case of Ti it was elevated to 450°C.

Experimental tests were carried out by means of X-ray diffraction technique. For both investigated materials, the incomplete back-reflection pole figures in selected areas of prepared samples were registered. The texture functions calculated on the basis of such incomplete pole figures enabled to calculate both the complete and inverse pole figures, and to perform the qualitative and quantitative texture analysis.

Conclusions on texture homogeneity during ECA pressing of bulk Cu and Ti ingots were drawn.

Keywords: Crystallographic texture, texture homogeneity, equal-channel angular pressing, Cu, Ti

Eksperymentalne badania procesu tworzenia tekstury przeprowadzono w wybranych obszarach przekroju poprzecznego litych próbek poddanych wyciskaniu w kanale kątowym (ECA) o przekroju kwadratowym. Materiałami wybranymi do badań były Cu i Ti o strukturze odpowiednio *fcc* i *hcp*. Rozważano przypadek 12 przepustów wyciskania (droga B_c), przy czym kąt zakrzywienia kanału wynosił 90°. Szybkość wyciskania wynosiła 6 mm/s. W przypadky Cu deformację przeprowadzono w temperaturze pokojowej, podczas gdy Ti w 450°C.

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Badania tekstury uzyskanych materiałów przeprowadzono metodą dyfrakcji rentgenowskiej. Wyznaczono niekompletne figury biegunowe wybranych obszarów próbek. Obliczone na podstawie niekompletnych figur biegunowych funkcje tekstury umożliwiły obliczenie kompletnych i odwrotnych figur biegunowych oraz pozwoliły na jakościową i ilościową analizę tekstury. Wyciągnięto wnioski o jednorodności tekstury podczas wyciskania ECA prętów Cu i Ti.

1. Introduction

Equal channel angular (ECA) pressing is a perspective technique of the severe plastic deformation (SPD) method, which allows processing nanostructured billets of different metals and alloys [1]. The processed material is characterized by attractive physical and mechanical properties. However, the process of ECA pressing is relatively complicated. The stress-strain state of the deformed material depends on the deformation rate, temperature of pressing, number of passes, route and geometry of the die-set, etc. The process of ECA pressing in this connection may lead to heterogeneity in the distribution of the accumulated strain, microstructure and resulted mechanical properties.

It is well known that SPD is accompanied with formation of the developed crystallographic textures [2]. As a result of the complicated character of the strain-stress state the distribution of the preferred orientations in bulk ECA pressed billets could be heterogeneous [3, 4].

The aim of the current paper is to investigate the type of the crystallographic texture and its homogeneity in the cross section of the bulk ECA pressed billets subjected to 12 passes by route B_C [1]. Such processing typically results in the development of ultrafine-grained (UFG) states in bulk Cu and Ti ingots [1]. However, homogeneity of the UFG structure and texture developed in these materials are still a subject for investigations.

2. Experimental technique

Pure Cu (99.9%) and Ti (99.95%) being typical metals with *fcc* and *hcp* lattices, respectively were used as investigated materials. The size of the billets subjected to the ECA pressing was 60×8×8 mm^3. In this work the study of the crystallographic texture homogeneity after 12 passes by ECA pressing by the route B_C (90° clock-wise rotations of the ingot around it longitudinal axis between the passes) is presented. Temperature of the ECA pressing in case of Ti was equal to 450°C and in case of Cu — to the ambient one. The deformation rate was 6 mm/s. A lubricant — rosoil-angelina Nr. 0258-022-06377289-2001 was used. The angle of channels' intersection during ECA pressing was 90°.

The texture analysis was conducted based on the X-ray diffraction technique. The adequate back-reflection pole figures $P_{(hkl)}(\alpha, \beta)$ were registered in the range of the pole angle α varying from 0° to 75° and the azimuthal angle β - from 0° to 360°. Measurements were performed with application of the Philips X'Pert system equipped with the texture goniometer ATC-3. The filtered X-ray radiation CoKα (λ = 0.179026 nm) and CuKα (λ = 0.154183 nm) in the case of Ti and Cu samples, respectively were used. The applied collimated incident beam had a diameter of 0.6 mm. It means that each measurement point marked by 1, 2, 3, 4 and 5 symbols in the square cross-sections with the edge of 8 mm is representative for the indicated area of the ingots (see Fig. 1).

The complete pole figures (100), (110) and (111) for Cu and (001), (011) and (102) for Ti were analyzed for the selected measurement points.

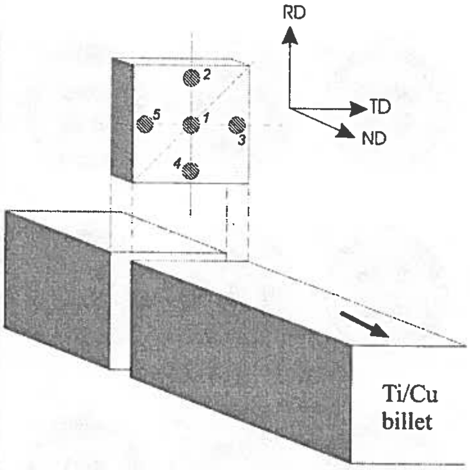

Fig. 1. Location of investigation areas in deformed Ti- and Cu- billets

The texture functions (ODFs) calculated on the basis of the experimental incomplete pole figures enabled to calculate the complete pole figures, and the inverse ones of normal direction (ND) as well as performing the qualitative and quantitative texture analysis.

In the calculation procedure, a discrete ADC method has been used [5]. The numerical analysis has been performed with the use of the LaboTex software package [6].

3. Results and discussion

In the case of Cu billet the observed crystallographic texture for all considered control areas is characterized by the developed textural maxima observed on the pole figures (Fig. 2).

Crystallographic texture in the 1-, 4- and 5-points is similar one to the other and it is characterized by one dominant component {110}<111> (Figs. 2, 3). At the same time the texture in 2- and 3-point exhibit enhanced background intensity in vicinity of component {110}<111> and local texture maxima which can be described by {331}<212>

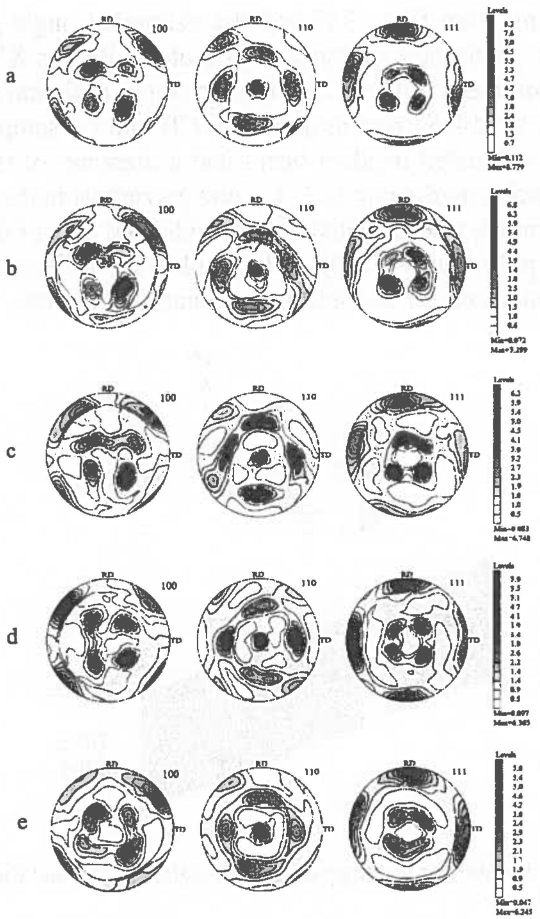

Fig. 2. Complete pole figures (100), (110), (111) for the selected areas in Cu billet denoted as *1*(a), *2*(b), *3*(c), *4*(d), *5*(e) measurement points, respectively

and {210}<122> ideal components are observed. Most intensive texture (intensity = 4.6) is formed in the central part of the billet (see Fig. 3). The second billet's zone of intensive texture is typical for points 4 and 5 with maxima of 4.2 and 4.1, respectively (Fig. 3). Minimal texture intensity is observed in points 2 and 3.

In the case of Ti billet the presented results allow identifying {101}<*hkl*> texture component (Fig. 4). Depending on localization of the measurement point in the billet's cross-section, different extent of spreading of the texture components around the given nominal orientations is observed. Texture of the tested Ti billet is generally weakly developed when compared to the Cu one. The most intensive texture is identified in the central point (1), whereas in other points (2-5) its intensity is significantly weaker (Fig. 5).

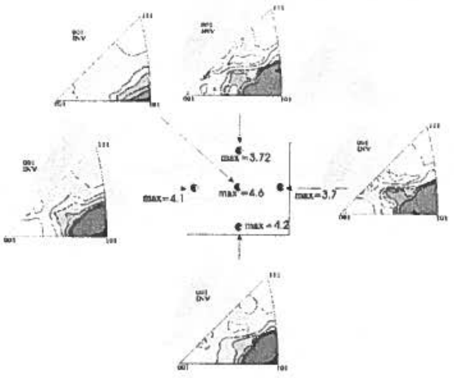

Fig. 3. Inverse pole figures of ND for Cu billet at the selected areas with the maximal texture intensity value being pointed out

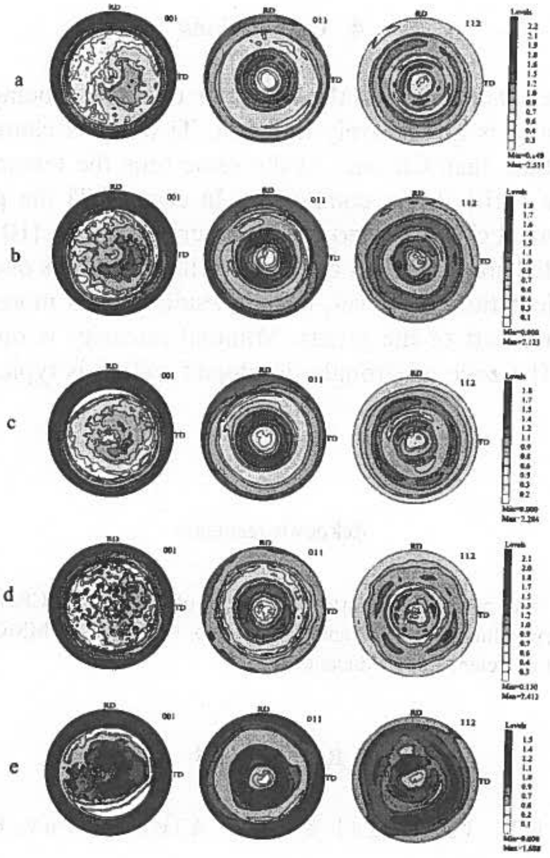

Fig. 4. Complete pole figures (100), (110), (102) of Ti billet denoted as *1*(a), *2*(b), *3*(c), *4*(d). *5*(e) measurement points, respectively

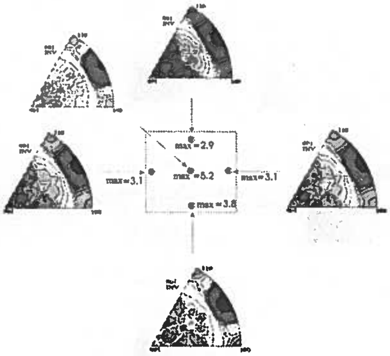

Fig. 5. Inverse pole figures of ND for Ti billet at the selected areas with the maximal texture intensity value being pointed out

4. Conclusions

The obtained results show, that the character of texture, being formed in Cu and Ti after ECA pressing is qualititavely different. Ti billet is characterized by weaker development of texture, than Cu one. At the same time the texture in case of Cu can be described by the {110}<111> component. In case of Ti the preferred orientation distribution has an axial character and can be described by the {101}<hkl> component.

In the investigated cross sections of Cu, as well as Ti billets one may observe rather strong preferred orientation. However, in both studied cases more intensive texture is formed in the central part of the billets. Minimal intensity is observed in the upper part of the billets. The zone of strongly developed texture is typical for the lower part of the billets.

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