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EFFECTS IN THE TEXTURE AND MICROSTRUCTURE IN SOME METALS OF CUBIC AND HEKSAGONAL SYMMETRY CAUSED BY THE CHANGE OF THE ROLLING DIRECTION

WPŁYW ZMIANY KIERUNKU WALCOWANIA NA TEKSTURĘ I MIKROSTRUKTURĘ W WYBRANYCH METALACH SIECI REGULARNEJ HEKSAGONALNEJ

In the present paper texture and microstructure effects which are released after the change of the deformation path in metals are displayed. The effects are characterized by experimental results selected from earlier studies for some metals of cubic and hexagonal symmetry. The observed effects result directly from the instability of the texture and microstructure with respect to the modified geometry of deformation. A consequence of the change of the geometry of deformation is at the same time a reduction of the global strain hardening which causes that the observed changes are rapid and dynamic. The presented results which were obtained in the rolling process of copper, copper alloy and magnesium alloy show strong effects of destabilization after the change of the rolling direction and after a relatively small amount additional deformation. The performed investigations, were inspired by works published in the 1990s mainly by A.Korbel.

Keywords: copper, copper alloy CuGe8, magnesium alloy AZ31, texture, microstructure, deformation, deformation path

Prezentowane są efekty w teksturze i mikrostrukturze metali wywołane zmianą drogi plastycznego odkształcenia. Są one charakteryzowane wynikami eksperymentalnymi, które wybrano z wcześniejszych prac dla niektórych metali sieci regularnej i heksagonalnej. Obserwowane efekty wynikają bezpośrednio z niestabilności tekstury i mikrostruktury względem zmienionej geometrii odkształcenia. Skutkiem zmiany geometrii odkształcenia jest równocześnie redukcja globalnego umocnienia, co powoduje, że zachodzące zmiany są szybkie i dynamiczne. Przedstawione wyniki, które uzyskano w procesie walcowania miedzi, stopu miedzi i stopu magnezu, pokazują efekty destabilizacji po zmianie kierunku walcowania, po względnie małych dodatkowych odkształceniach. Wykonanie eksperymentów inspirowane było pracami A.Korbla w latach 90-tych.

1. Introduction

It is known that plastic deformation is accompanied by definite microstructure and texture changes which for a given metal depends on the geometry of deformation. With increasing amounts of deformation decomposition of the initial texture and simultaneous formation of new texture components and reorganization of the microstructure take place. The change of the geometry of deformation leads to considerable effects of destabilization in the texture and microstructure. Decomposition of the texture and simultaneous back formation of the former components occurs. The change of the rolling direction leads to a change of the active slip systems. Consequently, there is a drastic destabilization of the dislocation structure and a decrease in global strain hardening. Plastic deformation becomes heterogeneous by inducing localizations in the form of deformation band or shear bands. The changes in the texture and microstructure caused by the change of the plastic deformation path are rapid and characterized by strong dynamics. The effects of destabilization are observed with a relatively little amount of additional deformation. If during the rolling process the deformation path is not changed the development of the texture proceeds relatively slowly. In this paper some results of earlier investigations [1, 2, 3, 4, 5] show how the texture and microstructure in some metals of cubic and hexagonal symmetry are influenced by the change of the deformation path. The investigation are mainly based on results of individual grain orientation measurements performed by EBSD in the SEM [7, 8] on relatively large sample areas.

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2. Effects of destabilization in polycrystalline copper

The texture is described by the ODF and is usually presented in the Euler Angle space. The ODF describing the texture of cold rolled copper with its typical components C = {112}<111>, S = {231}<634> and B = {110}<112> is plotted on Fig. 1a. The ODF of the same texture is shown in Fig. 1b after rotating the sample 90° around ND which changes the RD into the TD. The profile of the rolling texture of copper presented in the ODF has the form of a fiber (β-fiber) connecting its main components.

The rotation of the sample puts the components that have been formed while rolling into positions C90 = {112}<110>, S90 ≈ {123}<542> and B90 = {110}<111>, respectively, which are unstable with respect to the transverse rolling process [2].

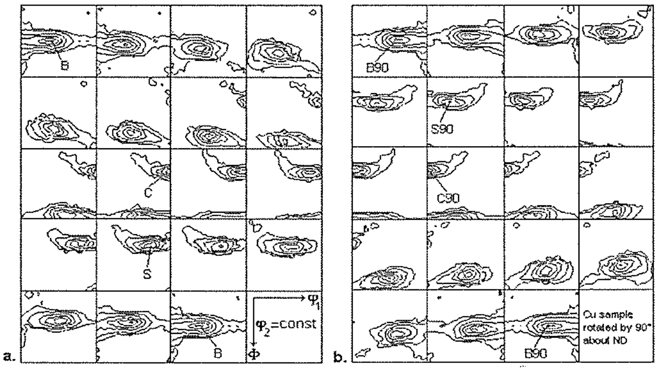

Fig. 1. Orientation density function (ODF) of a polycrystalline copper, a) after cold rolling up to 70%, b) the same ODF after rotating the sample 90° around ND

While rolling in the transverse direction, according to the findings illustrated on Fig. 2 by β-fibers, a small amount (10%) of additional transverse deformation releases great changes in the texture. The orientation density of the components became weaker with the exception of the brass component near B90 which became stronger and shifted towards the stable B position.

Other examples for copper with different grain sizes are shown in Fig. 2. They demonstrate the strong texture changes after a small amount of additional deformation and show that the effect of texture disintegration depends on grain size.

3. Some results obtained for single crystals

A copper single crystal {112}<110> was deformed by the channel-die in two different ways [3]: with predeformation (i.e. with the change of the deformation path) and without predeformation. The {112}<110> orientation is not stable and the deformation of the crystal in both cases leads to the brass orientation {110}<112>.

The predeformation was carried out on the {112}<111> oriented crystal up to 20.7% reduction (Fig.3a) and the deformation was continued after rotating the sample 90° about the ND, i.e. for the orientation near {112}<110>, up to further 28.7%. An important feature of the predeformed {112}<110> single crystal is the appearence of a specific fragmentation of the structure (see Fig.3b). The microtexture of the fragmented structure consists of a set of alternately complementary oriented lamenae, (20-60 μm in thickness), which is close to the complementary brass texture components (011)[2-11] and (011)[21-1]. The decomposition of the initial orientation (the fragmentation) was caused by a rotation of opposite signs about an axis parallel to the transverse direction, connected with the fact that different slip systems operate in each of the fragments. The formation of two sets of layers with complementary components {011}<211> of textures in these banded structures of the predeformed samples is similar to the transition banding.

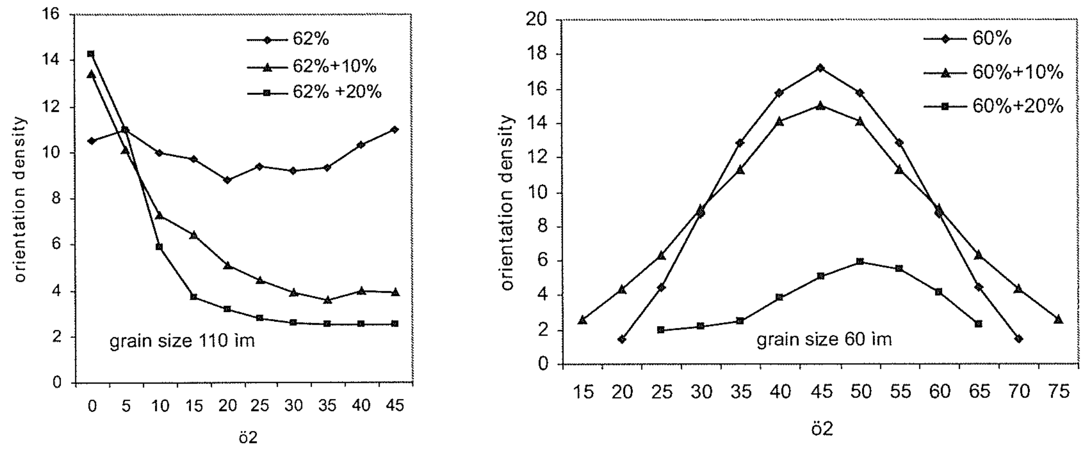

Fig. 2. ODF values along the profiles of the main texture components of copper samples with different grain sizes

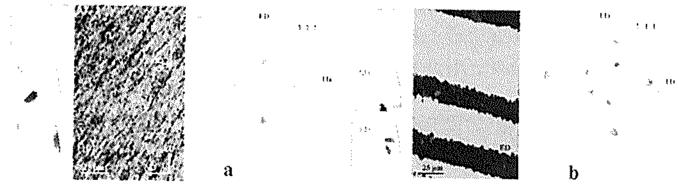

Fig. 3. Microstructure images in the plane of the ND-ED, inverse pole figures of the ND and ED axes and the {111} pole figures of a (112)[1-10] single crystal deformed by channel-die compression, a) predeformed in the TD up to 20.7%, b) next deformed up to 28.7%

Such a fragmentation of the structure is not observed in the case of non predeformed single crystal (see Fig. 4).The deformation behaviour of the non predeformed single crystal is significantly different from the predeformed sample. The transition process during deformation proceeds at a slower rate and with less dynamism. In the range of small reductions below 20% (Fig. 4a) the changes of the initial orientation are rather small, although a distinct tendency of rotation towards the main brass type component can be observed. The orientation changes become intense above 20%. In partcular, a sample deformed to 41.9% attains an orientation shift in the direction of the (011)[2-11] position (see Fig. 4b), corresponding to one of the complementary components of the micostructure of a predeformed sample.

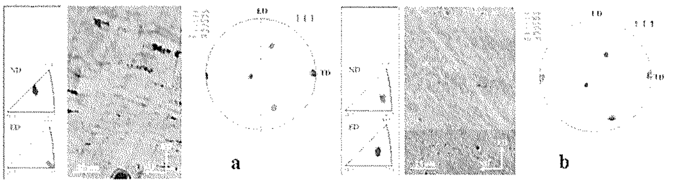

Fig. 4. Microstructure images in the plane of the ND-ED, inverse pole figures of the ND and ED axes and the {111} pole figures of a (112)[1-10] single crystal deformed by channel-die compression, a) deformed up to 20%, b) next deformed up to 41.9%

4. Effects of the change of the rolling direction in copper-germanium alloy

In Fig. 5 some results of the destabilization effects in the structure and texture observed in rolled samples of copper alloy with a wt 8% of germanium are demonstrated [1]. These are the observations of the shear bands in the optical microscopy and corresponding texture functions (ODF) in the Euler angle space prior and after additional transverse rolling, are shown in Fig. 5a and Fig. 5b, respectively. The observation plane of the shear bands is perpendicular to the transverse direction of the final rolling.

Fig. 5a shows the geometry of shear bands SB_1 formed during unidirectional rolling and Fig. 5b indicates the shear bands SB_2 formed during additional transverse rolling. It is clearly seen that additional transverse rolling with a small reduction introduces shear bands SB_2 (of two intersecting families) visible together with the trace (parallel to RD_2) of old shear bands SB_1 formed during unidirectional rolling. Fig. 5a (below) shows a typical rolling texture of fcc metals with low stacking fault energy in the range of medium reduction. This texture is characterized by a strong component in the B = {110}<211> position and by twin areas originating from the components C = {112}<111> and S = {213}<346> around the {111}<uvw> positions in which the twin planes have become parallel to the rolling plane.The addition of small amount (10%) of transverse rolling (Fig. 5b) lead to a strengthening of the B component and simultaneously to a shift towards the {011}<322>($\varphi_1 \approx 45°$) position which is symmetric with regard to both the unidirectional and transverse rolling geometry. Microscopic observations indicate a considerable strengthening and broadening of areas of twin positions.

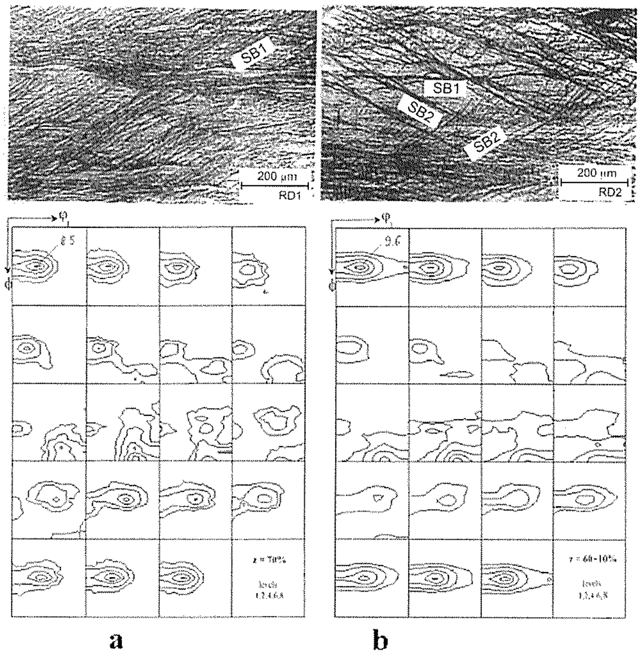

Fig. 5. Shear bands and the texture functions of the samples CuGe8 rolled up to 70%, a) unidirectional rolled and b) 60% unidirectional rolled and additionally 10% transverse rolled

5. Investigations of the magnesium alloy

The material was a magnesium alloy AZ31 (3%Al,1%Zn) in the form of an ingot after squeezing and annealing. The AZ31 samples were rolled uni-directionally up to 65% reduction at 380°C, and next additionally rolled transversely up to 11% reduction at 180°C. Details are published in [4, 5].

The results of this investigation are presented by pole figures (0002) and ODFs in Fig. 6. The ODF is plotted in the space of Euler angles ($\varphi_1, \Phi, \varphi_2$) in sections of constant angles φ_2, every 5 degree. For a distinct presentation of the specific texture of magnesium alloy in the space of the Euler angles the reference system of the sample was rotated 90° around the ND. The texture of the rolled magnesium alloy AZ31 up to 65% shown on Fig. 6a has the form of a strongly exposed fiber with the c axis aligned almost parallel to the normal direction of the sheet. The fiber contains a maximum near (0001)<10-10> which, together with the fiber axis, deviates by 15° from the RD. The basic lattice plane is thus slightly declined from the rolling plane.

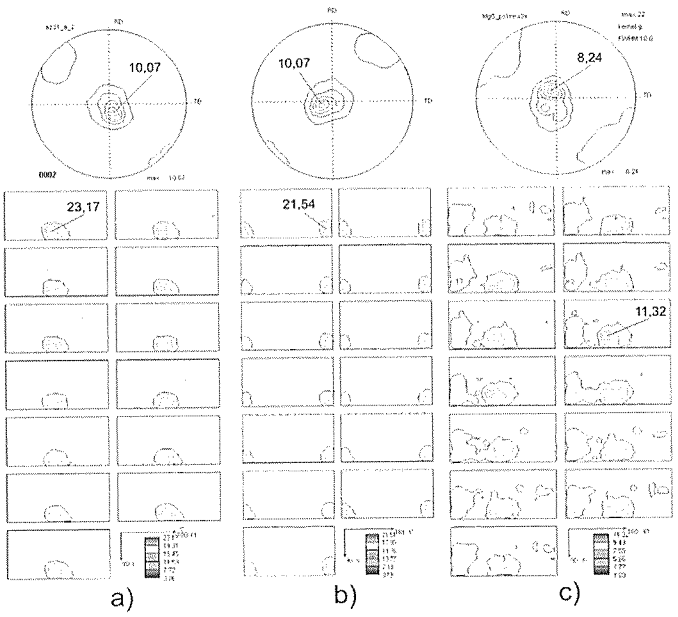

Fig. 6. Pole figures (0002) and ODFs of an AZ31, a) after rolling up to 65% reduction at 380°, b) the same ODF after rotating the sample by 90° about the ND, c) after rolling up to additional 11% reduction at 180°C

The ODF of the same texture is shown in Fig. 6b after rotating the sample 90° around ND which changes the RD into the TD. In Fig. 6c the ODF after additional rolling of the sample along the TD up to 11% is plotted. The result shows that the texture has returned to the previous form of a fiber, the same type of texture as before the change of the deformation path. In successive plots demonstrate that additional transverse rolling, which was carried out at 180°C, led to dramatic texture effects. The result shows that only traces of the initial texture outlast additional rolling. In the texture transition from b) to c) at a slightly elevated temperature of 180°C only new basal slip could be activated, either in a <11-20> (single slip) or in a <10-10> (double slip) direction. In Fig. 7 also the microstructures before and after additional rolling are shown. The microstructures are fine-grained, but after additional rolling there are some indications of dynamic recrystallization visible.

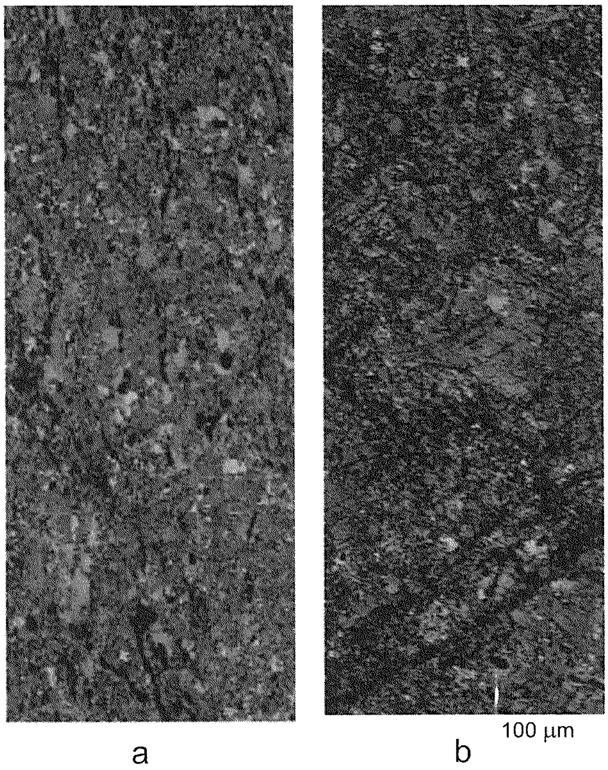

Fig. 7. The microstructure images of an AZ31 samples presented by crystal orientation maps: a) after rolling up to 65% reduction at 380°C, b) after transverse rolling up to 11% reduction at 180°C
1 cm corresponds to 100 μm

6. Conclusion

Texture and microstructure, stabilized in unidirectional (or reverse) rolling of a polycrystalline material, become unstable after the change of the rolling geometry due to the change of the active slip systems and to the reduction of the global strain hardening. Consequently a reorganization of the microstructure and a distinct change in texture is observed. This effects observed after a relatively little amount of additional deformation are rapid and of high dynamic. The end orientation of the same rolled metal pre-deformed as well as non pre-deformed is of the same kind. The effects of destabilization are the higher the higher the initial deformation the sample and the larger the grain size of the material are.

Acknowledgements

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