INFLUENCE OF THE GRAIN SIZE AND OF THE ROLLING DEGREE ON THE RECRYSTALLIZATION TEXTURE OF LOW-ALLOYED BRASS

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INTRODUCTION

The development of microstructure and texture during deformation and annealing of low-alloyed brass has been oft studied and is quite well understood¹⁻³. However most investigations on the recrystallization texture development were carried out at high rolling degrees and only few publications exist over a large range of deformation². Furthermore, the influence of initial grain size on the annealing texture were seldom investigated⁴⁻⁶, especially using the ODF-analysis^{5,6}. In this paper the recrystallization texture of cold rolled Cu-2%Zn alloy with three different initial grain sizes prior deformation (15μ , 120μ and 150μ) are investigated over a large range of deformation (40%-99% rolling degrees).

EXPERIMENTAL PROCEDURES

A Cu-2%Zn ingot was cast under argon atmosphere from high purity copper and zinc (>99.995%). The coarse-grained samples were obtained from the fine-grained specimens after annealing treatment at elevated temperature. Mean linear intercept values for grain size were 15μ , 120μ and 150μ . These starting samples with different grain sizes were cold rolled to various reductions (40%-99%) and subsequently annealed in order to achieve primary recrystallization.

For the determination of textures the ODF's were calculated from four incomplete pole figures {111}, {002}, {022} and {113} using the series expansion method. The ODF's are represented in φ_2 -sections ($\Delta\varphi_2=5^\circ$). For a quantitative evaluation of the texture as well as a reduction of ghost effects, a model ODF consisting of a few Gauss type scattering components was fitted with the experimental ODF. Model ODF's were used for the calculation of volume fractions (M_i)⁷. Scanning electron microscopical investigations of shortly annealed specimens were carried out with the help of a special etching⁸ that enables direct orientation measurements.

RESULTS

Fig.1 shows examples of the recrystallization texture of Cu-2%Zn at 85%-reduction for two initial grain sizes (15μ and 150μ). The strongest effect of increasing grain size is an important decrease of the Cube-orientation $\{001\} \langle 100 \rangle$ and of the rotated Cube around the rolling direction $\{025\} \langle 100 \rangle$ (Cube-RD) and the arising of the Transition component (U) $\{418\} \langle 744 \rangle$ at intermediate reductions. Fig.2 shows the volume fractions of the main recrystallization components for two initial grain sizes (15μ and 150μ) in function of the rolling degree. The recrystallization components are again represented in Fig.3 in function of the

grain size (95%, 99% reductions), where values of 1500μ are taken from Zhang⁶.

For small grained specimens one observes a strong increase of the Cube up to 97% rolling degree followed by a slight decrease. First generation- $\{122\}\langle 212\rangle$ and second generation (sum of $\{447\}\langle 184\rangle$, $\{148\}\langle 841\rangle$ and $\{148\}\langle 474\rangle$) twins (Tw) of the Cube reach a maximum at 85% reduction and decrease at higher deformations. Also a relative strong Cube-RD is found at high rolling degrees (>95%). Additionally the BR- (Brass Recrystallization) $\sim\{236\}\langle 385\rangle$ and the P- $\{011\}\langle 377\rangle$ are observed above $\sim 80\%$ reduction.

For coarse grained specimens the Cube is strongly suppressed and reaches 10% volume fraction above 98% reduction only. Its twins, especially of the second generation are much stronger than the cube itself. On the other hand, the BR- and P-component develop stronger as in the fine grained samples. The Transition (U) component with some of its twins and the Goss (G) $\{011\}\langle 100\rangle$ orientation arise significantly only in coarse grained samples.

DISCUSSION

The strong presence of the Cube after annealing of rolled fcc metals of medium SFE has been thoroughly investigated¹⁴ according to the oriented nucleation mechanism after the Dillamore and Katoh (D-K) theorie⁹ and subsequent growth selection^{3,10}. Fig.4a represents a Cube orientated nucleus which spreads in large areas of the rolling structure with different orientations. This shows the strong compromise character of this high symmetrical orientation.

The decrease of the Cube at high reductions in fine grained samples, which is observed in pure copper¹¹, is explained as followed: 1- By the extension of Cube orientated areas in divergent zones along the rolling direction according to the D-K-theorie, the Cube orientated subgrains are decreasing at high reductions as they rotate away. 2- When the sample thickness reached a value below $100\mu\text{m}$, a weakening of the Cube was observed in Al¹². This was interpreted through a reduction of Cube nuclei with decreasing the specimen thickness. 3- By the extension of deformation inhomogenities in the rolling structure (shear bands and twins), which disturb (shear bands) and destroy (twins) preferentially the Copper-(C) orientation $\{112\}\langle 111\rangle$, wherein most Cube oriented nuclei occur¹⁰.

The reduction of the C-orientation due to mechanical twinning leads to the occurrence of the rolling texture transition and thus of an increase of the Brass-(B) orientation $\{011\}\langle 211\rangle$ in which the Cube-RD component and not the Cube itself finds best growth possibilities due to the good $40^\circ\langle 111\rangle$ orientation relationship between both B- and Cube-RD-orientations. The occurrence of the Cube-RD at high deformations seems thus to be controlled by selected nucleation (rotation of the Cube along RD during rolling) and oriented growth¹³.

The observed reduction of the Cube with increasing initial grain size is connected to the occurrence of more developed deformation inhomogenities (especially shear bands) in the rolling structure which destroy the Cube orientated zones⁴. Furthermore, numerous shear bands in coarse grained samples act as preferential nucleation sites, that produce more randomly orientated new grains, which suppress the growth of the Cube.

As only a weak Cube arises in coarse grained samples, also other, less favo-

rable oriented nuclei can find growth possibilities. Furthermore, the large amount of shear bands produces several nuclei that can grow significantly, if they have a good orientation relationship with the deformed matrix. This is particularly the case of the U-orientation which becomes stronger with increasing grain size. Fig.5a and 5b show the U-orientation which originates in or near a shear band. Due to its good $40^\circ \langle 111 \rangle$ orientation relationship with the Goss- (which is an important shear band orientation¹⁴) and with the C/S-orientation $\{538\} \langle 475 \rangle$ (in which shear bands mostly occur^{13,14}), the U-orientation can grow easily in shear bands (Fig.5a,6a) and in the surrounding matrix (Fig.5b,6b). The increase of the Goss-, P- and BR-orientations with increasing grain size can be explained in the same way, since they originate at least partly in shear bands^{10,13,15}.

The annealing twins of the Cube in small grained samples (Fig.4b) reach their maximum at $\sim 85\%$ reduction and then decrease, although the Cube itself in this deformation range always increases. Due to an augmentation of the frequency of Cube nucleus formation with increasing deformation, the size of the new grains decreases. The probability of growth accident¹⁶, which can be seen as the origin of annealing twins, becomes weaker leading to a reduction of the twin density. On the other hand, due to weak Cube nucleation in coarse grained specimens, the formation of Cube twins is never suppressed.

CONCLUSION

The stronger presence of shear bands with increasing grain size and thus the greater proportion of randomly oriented new grains lead to the suppression of the Cube and an increase of the background. The recrystallization texture becomes more random and can be explained as a process of growth selection. Since in fcc metals the $40^\circ \langle 111 \rangle$ orientation relationship is strongly preferred, the rolling texture of the 85% rolled coarse grained sample was statistically transformed by all possible $40^\circ \langle 111 \rangle$ rotations and compared with the corresponding annealing texture (Fig.7). The good concordance between the experimental and the calculated ODF's demonstrates the dominance of orientated growth in coarse grained specimens at least at intermediate reductions, while the recrystallization texture of fine grained specimens is more controlled by the nucleation of the Cube.

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Fig.1 ODF's of the recrystallization texture of 85% cold rolled Cu-2%Zn. (a) fine grained sample (15 μ); (b) coarse grained sample (150 μ).

Fig.2 Volume fractions M_i of the main recrystallization components in Cu-2%Zn as function of the rolling degree. (a) fine grained samples (15 μ); (b) coarse grained samples (150 μ).

Fig.3 Volume fraction M_i of the main recrystallization components in Cu-2%Zn as function of the grain size at (a) 95% reduction ; (b) 99% reduction.

Fig.4 Scanning electron micrograph of partly recrystallized 95% cold rolled fine grained Cu-2%Zn, showing Cube-oriented grains (W). (x2000)
 T_1 = Twin first generation {122}<212>.

Fig.5 Scanning electron micrographs of partly recrystallized 85% cold rolled coarse grained samples showing the Transition-orientation. (x1000)
(a) Cu-2%Zn; (b) Cu-5%Zn. T_1 = Twin first generation $\{538\} \langle 391 \rangle$.

Fig.6 Orientation relationship between the Transition-orientation (U) and the:
(a) Goss-orientation (G) ; (b) C/S-orientation.

Fig.7 (a) Recrystallization ODF of the 85% cold rolled coarse grained Cu-2%Zn;
(b) Transformation ODF.