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INVESTIGATIONS OF PREFERRED ORIENTATIONS IN ZINC AND ZINC-BASED ALLOYS OBTAINED BY MEANS OF ROTATING MILL DEVICE

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Introduction

Preferred crystal orientations are subject of considerable interest due to their strong influence on the mechanical and other properties of commercially produced materials. They are also very important in the study of the physical properties of polycrystalline alloys. The purpose of this investigation was to determine the influence of rapid quenching by the use of the rapidly rotating mill device[1)] on the crystal orientations in a pure zinc and several zinc-based alloys which were used in the earlier investigations of the electrical resistivity[2)] and the thermoelectric power[3)].

The investigation of the preferred orientations was particulary important in order to find out whether rolling which is inherent to that particular quenching technique[1)] influences the texture and thus affects the physical properties of these alloys.

Experimental

Preferred crystal orientation was studied in pure zinc and the following zinc-based alloys: Zn 0.11 at% Fe, Zn 0,3 at% Fe, Zn 0.5at%Fe, Zn 0.11at%Co, Zn 0.22at%Co and Zn 4at%Ag. The concentrations of the master alloys (prepared by the use of standard procedures for obtaining zinc-based alloys[4)] were predetermined by the weight analysis and verified by the use of electron microprobe investigation. The actual samples were prepared by rapid quenching because of very low equlibrium solid solubilities of these metals in zinc. We used the rapidly rotating mill device for rapid quenching where the molten alloy solidifies by passing between two rollers (Fig.1) and therefore there is a possibillity of rolling already solidified sample which may influence the texture of the crystal grains. The samples were usually 5-15 cm long, 5-10 mm broad and 20-50 μm thick.

For the x-ray diffraction studies we cut foils 2 cm long in the ("rolling direction") and 3 mm broad. In order to determine preferred orientations we used standard x-ray goniometer (UNICAM-S25-6 cm). The difraction patterns were taken rotating the sample around the "rolling direction" from 0^o to 90^o and around transverse direction perpendicular to the "rolling direction" from 0^o to 30^o in the steps of 10^o. The film exposure varied from 4 to 14 hours depending on the sample thickness, impurity and its content. Ni filtered $Cu_{K\alpha}$ radiation was used. Pole figureswere constructed for reflections (0001), $(10\bar{1}0)$ and $(10\bar{1}1)$ on which no splitting of $Cu_{K\alpha}$ doublet occurs.

Results

X-ray patterns have shown that the crystal grains are the biggest in the pure quenched zinc and then decrease in the following order: Zn 0.11at%Fe, Zn 4at%Ag, Zn 0.11at%Co, Zn 0.22at%Co, Zn 0.3 at%Fe and Zn 0.5at%Fe. Therefore the grain size depends both on kind and content of impurity.

From the pole figures (some of which are shown on Fig.2-6) one can draw the following conclusions.

1) No sample has preferred crystal orientation in the "rolling direction".

2) In all the samples together with randomly oriented ceystal grains which give rise to a continous Debye-ring there is also a rather strong tendency for the planes (0001) to be oriented parallel to the "rolling plane". Therefore this texture can be characterized with a simple fiber texture [0001] oriented perpendicular to the "rolling direction" (i.e. in the cooling direction). Scattering of hexagonal axis from this ideal texture is up to 15-25^o in transverse direction and 10-15^o in longitudinal direction ("rolling direction") and depends on impurity and concentration of impurity. Only in Zn 4% Ag alloy scattering is bigger in longitudinal direction.

3) In the alloys Zn 0.3at% Fe and Zn 0.5at%Fe together with the orientations of grains described above there is also a less prominent $\langle 10\bar{1}0 \rangle$ texture appearing again in the cooling direction.

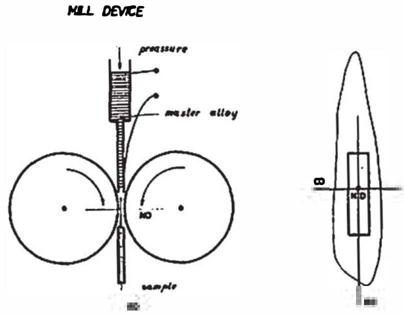

Fig.1 Principle sketch for "mill device" (and sample)
RD-"rolling direction"
ND- normal direction (cooling direction)
CD- transverse direction

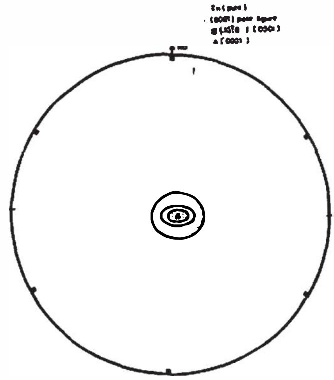

Fig.2 (0001) pole figure for pure zinc.
Shaded areas on the projection indicate concentrations of orientations deduced from x-ray line intensities (▦ -strong; ▥ -medium; ▤ -weak)

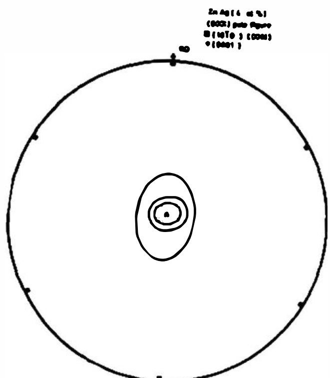

Fig.3 (0001) pole figure for ZnAg(4 at%)

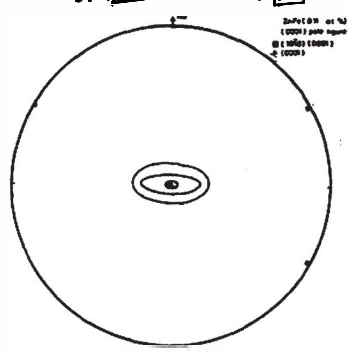

Fig.4 (0001) pole figure for ZnFe (011at%)

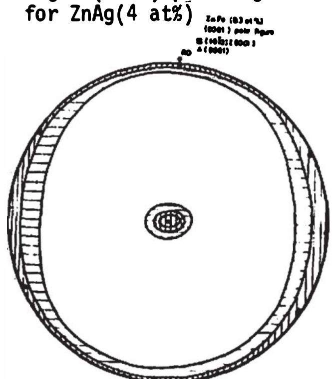

Fig.5 (0001) pole figure for ZnFe (0.3at%)

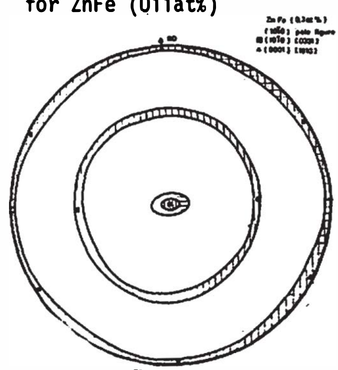

Fig.6 (10$\bar{1}$0) pole figure for ZnFe(0.3at%)

Discussion

Earlier investigations[5] have shown that zinc (c/a=1,856) has rolling textures in which little material has the basal plane in the plane of sheet. The hexagonal axis is found most frequently inclined 20 to 25^{o} toward rolling direction. Textures in our samples are different and one can conclude that they are not caused by rolling.

Furthermore close-packed hexagonal metals usually have (0001) paralel to the mold wall in chilled zone. In the columnar zone zinc has $[10\bar{1}0]$ normal to the mold wall[6]. Due to the rather small thickness of our samples and because of the efficient cooling from both large surfaces almost all their volumes can be regarded as a chill zone and practically all the texture should have planes (0001) parallel to the planes of cooling.

For larger contents of iron in zinc probably a columnar zone also appears so that one can also detect less prominent $\langle 10\bar{1}0 \rangle$ texture in the direction of cooling. As a tentative explanation of this phenomenon we recall that an increase in impurity content usually decreases the crystal grain size probably due to an increase in the number of centers of nucleation and also because some impurities in certain matrices increase the rate of the growth of crystallites[7] in the direction of cooling by constitutional supercooling effect. Thus, by increasing the Fe content in ZnFe the crystal grains become smaller and columnar zone forms. We note that the constitutional supercooling effect is bigger if an increase in the impurity content increases the liquidus temperature in the phase diagram. As the liquidus line appears to be steeper in Zn-Fe system than in Zn-Co and Zn-Ag[9] systems, this may possibly explain the appearance of the columnar zone and therefore of additional texture in Zn 0.3at%Fe and Zn 0.5at%Fe alloys.

At this stage it is not possible to give a more detailed explanation of the processes which occur during the cooling of the samples and of those which cause the steepness of the liquidus line and which finally predetermine the particular texture. It seems clear however that there is some correlation between the electronic structure of the impurity and of the matrix with the above phenomena. For instance the results for residual resistivity ratio (RRR) of our alloys[2] indicate (via the linearity of RRR with the impurity content) that all our alloys except for Zn 0.5at%Fe were proper solid solutions (in that case the presence of the phase was also detected by x-ray investigation) and that the additional texture appears only in those alloys with RRR 0.6 regardless to particular kind and content of the impurity.

(We note that RRR values were not determined accurately enough to show also the influence of the crystal grain sizes and texture whose contribution to the resistivity is expected to be much smaller than that of impurities).

Conclusion

Our results of the investigation of preferred orientation in the zinc-based alloys produced by rapid quenching by the use of rapidly rotating mill device indicate no significant influence of rolling on the texture of these alloys which turns out to be caused by the cooling processes.

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