Note

Formation of {001} Fiber Texture in Fe-3mass%Si Alloy during Uniaxial Compression Deformation at Elevated Temperatures

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Two of the authors found that {011} fiber texture formed at the early stage of the deformation was gradually replaced with {001} fiber texture with increasing strain in Al–Mg alloys at high temperature compression deformation.¹⁾ The texture transition proceeded by the preferential growth of grains having {001} fiber texture components.²⁾ It was concluded that the growth of {001} grains was attributed to the low stored energy relating to low Taylor factor as well as the uniform distribution of dislocations due to solute atmosphere, and the stability of this orientation for uniaxial compression.³⁾ It is expected that the mechanism works irrespective of the kind of alloys and crystal structures. Namely, the similar texture formation behavior in which the preferential grain growth plays an important role might occur in other solid solution alloys. In the case of BCC metal, orientations stable for uniaxial compression are {001} and {111}. In the case where the deformation is driven by pencil glide, Taylor factor for {001} and {111} is 2.121 and 3.182, respectively, according to Rosenberg *et al.*⁴⁾ Thus, it is expected that {001} appears as the main component of texture at high temperature compression.

In this paper, texture formation during high temperature uniaxial compression is studied on Fe-3mass%Si solid solution alloy with BCC structure. It is found that the strong {001} fiber texture develops at high temperature uniaxial compression deformation. Microstructure observation suggests that {001} fiber texture in Fe-3%Si alloy is also derived from the preferential growth of {001} oriented grains, which coincides with the understanding proposed before.³⁾

Fe-3mass% Si hot rolled plate provided by Nippon Steel Corporation was cold rolled (40%) and annealed for 30 minutes at 1 173 K. The annealing resulted in the equiaxed grain structure with the average grain size of 573 μm and nearly random distribution of crystal orientations.

Cylindrical specimens with a diameter of 12 mm and a height of 18 mm, or with a diameter of 10 mm and a height

of 15 mm were prepared from the plate. Uniaxial compression tests were conducted up to -1.0 in true strain with constant crosshead speed condition. Temperatures and initial strain rates for the tests were ranging from 1 023 K to 1 173 K and $4.6 \times 10^{-5} \text{ s}^{-1}$ to $5.6 \times 10^{-2} \text{ s}^{-1}$, respectively. An infrared-ray furnace was used for heating. After the deformation, the furnace was immediately opened and the specimen was taken out for the cooling in ambient air.

The compressed specimen was cut parallel to the compression plane and ground by emery papers in order to obtain the plane of thickness-center. X-ray texture measurement by Schulz reflection method followed by ODF calculation by Dahms-Bunge method⁵⁾ and EBSD measurement were conducted on this plane. Pole densities in the inverse pole figures derived from ODF calculation were normalized by the average densities.

As well known, the typical deformation texture of BCC metals for uniaxial compression is {001}+{111} double fiber texture at room temperature, in which both {001} and {111} are frequently oriented parallel to the compression planes.⁶⁾ **Figure 1** shows the {101} pole figure after the deformation at 1 173 K with a strain rate of $4.6 \times 10^{-3} \text{ s}^{-1}$ up to a strain of -0.96 . Pole densities are projected onto the compression plane. Mean pole density is used as a unit for drawing contours. Pole densities are distributed in a concentric circular manner, showing the formation of a fiber texture. In this case, the area of high pole density exists from 30 to 50 and from 80 to 90 degrees from the center; formation of {001}+{111} fiber texture is seen. The examination of inverse pole figures elucidated that pole density at {001} is quite high whereas that at {111} is quite low, which is different from the deformation at room temperature. This characteristic coincides with the prediction described above. In the extreme case, very high pole density of compression plane appears only at {001}, as shown in **Fig. 2**.

Crystal direction map obtained by EBSD measurement on the same specimen as **Fig. 2** is given in **Fig. 3**. In this map, regions within 10 degrees from {001} orientation are shown by dark gray color. High angle boundaries and low angle boundaries are depicted by the black and gray lines, respectively. Subgrains are seldom seen, suggesting that dislocations are distributed homogeneously. In **Fig. 3**, the {001} grains are obviously larger than the other grains. Furthermore, it can also be seen that high angle boundaries have complex curvatures. These facts indicate the boundaries have migrated during the deformation.

Fig. 1. {101} pole figure of the compression plane obtained from the specimen compressed at 1 173 K with the initial strain rate of $4.6 \times 10^{-3} \text{ s}^{-1}$ up to a strain of -0.96 .

Fig. 2. Inverse pole figure obtained from the specimen compressed at 1173 K with the initial strain rate of $4.6 \times 10^{-5} \text{ s}^{-1}$ up to a strain of -0.98 .

Fig. 3. Crystal direction map obtained from the specimen compressed at 1173 K with the initial strain rate of $4.6 \times 10^{-5} \text{ s}^{-1}$ up to a strain of -0.98 . The dark gray regions correspond to the regions in which the differences of crystal orientations from $\{001\}$ are within 10 degrees. Black and gray lines mean boundaries with misorientations higher than 15 and 2–15 degrees, respectively.

It was found that the uniaxial compression at higher temperatures and lower strain rates resulted in the high $\{001\}$ fraction. This trend suggests that high mobility of grain boundary and the long deformation time are important in order to make the effect of grain boundary migration obvious on the evolution of microstructure and texture.

In summary, texture formation by uniaxial compression deformation is examined on Fe-3mass%Si alloy at high temperatures. Development of $\{001\} + \{111\}$ fiber texture with high $\{001\}$ fraction and low $\{111\}$ fraction is seen. $\{001\}$ intensity becomes higher and $\{111\}$ becomes lower at higher temperatures and lower strain rates. In the extreme case, the texture having the pole density concentration only at $\{001\}$ is formed. These results agree with the prediction based on the understanding given in the study of Al–Mg, in which the specific orientation having stability against the deformation and low Taylor factor could be enhanced in the texture by preferential grain growth.

In addition, it should be emphasized that $\{001\}$ fiber texture which is achieved by the present method is important from the viewpoint of application to the production of electric steels.

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