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QUANTITATIVE STUDIES OF RECRYSTALLIZATION IN POLYCRYSTALLINE MATERIALS

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ABSTRACT

The results are reported on quantitative studies of continuous and discontinuous recrystallization in polycrystalline α-Fe. The described changes in the geometry of the grain boundaries give better insight into the processes taking place in the microstructure of polycrystal as a result of straining and annealing.

Key words: Quantitative description of grains, plastic deformation, recrystallization, grain growth.

INTRODUCTION

Polycrystalline materials constitute a significant fraction of functional and structural materials of technical importance. This group includes not only metals but also ceramics, intermetallics and other advanced materials developed for specific applications. Grains in annealed polycrystals form a 3-dimensional honeycomb structure characterized by the presence of 3-fold common edges and 4-fold points of contact. Individual grains differ in their size and shape. As a result geometry of grains may be described by a distribution function of grain volume, f(v). It can also be characterized in terms of:

a) E(v) the mean volume,
b) N_V, the average number of grains in unit volume,
c) S_V the grain boundary density,

Plastic deformation changes the geometry, microstructure and, as a result, properties of materials (see for example Cahn et al, 1983). In polycrystals deformed at a low temperature, the major change is an increase in the density of lattice defects and the rearrangement of the grain boundaries. Upon annealing the deformed microstructure releases stored energy. This is usually accompanied by a reestablishment of some of the properties. During the annealing the grain boundaries act as sinks for the lattice dislocations and the point defects

(Kurzydłowski et al, 1990). This is associated with the movement of the pre-existing grain boundaries (continuous recrystallization) or the newly formed ones (continuous recrystallization). These two phenomena were recently investigated in a pure α-Fe (Kurzydłowski et al, 1993; Ralph et al, 1993) from the point-of-view of quantitative description of the size of nuclei and grains.

The studies have been performed on α-Fe with an initial grain size of approximately 30 μm. In first series of experiments specimens were compressed at room temperature to give a total reduction in thickness of 50%. The deformed material was annealed at 400°C for 30 minutes to 8 hrs. These annealing conditions resulted in continuous recrystallization of the material. In the second series, the material has been hydrostatically extruded and subsequently annealed at 500°C for annealing times from 15 minutes to 6 hrs. Discontinues recrystallization has been observed in this series of specimens.

Measurements of the earlier listed parameters were carried out on the microstructures of the deformed and annealed specimens with the help of an automatic image analysis system. The measurements of S_v, due to the anisotropy of the microstructure, were made using the procedure based on vertical sectioning employing a system cycloids (see for example Cruz-Orive and Hunziker, 1986). The volume distribution functions were obtained using the methods described by Bucki and Kurzydłowski (1992).

RESULTS

Figure 1 shows micrograph characteristic of the microstructure of the recrystallized material and Fig.2. after 50% compression. Figures 3 and 4 exemplify binary images of grain boundary networks in the material after the 0.5 hour anneals employed in the first and second series of experiments.

It can be noted that the sections of the grains in the deformed material are clearly elongated in the direction perpendicular to the axis of straining. The microstructures revealed in the successive stages of grain boundary rearrangement in the process of continuous recrystallization show that the grain boundaries quite fast loose preferential orientation along the direction perpendicular to the axis of straining. At the same time, the grain boundary area per unit volume, S_V,

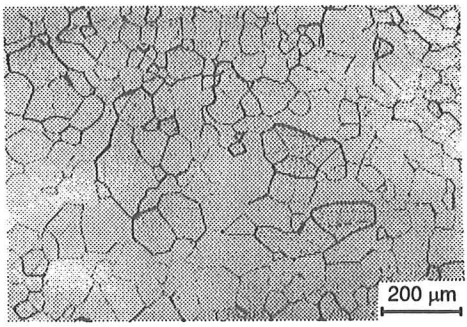

FIG.1. A microstructure characteristic of an annealed α-Fe

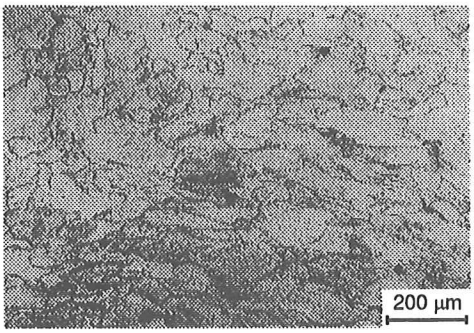

FIG.2. Grain boundary network revealed on a longitudinal section of α-Fe after 50% reduction in compression

increases in value by approximately 5% and then gradually drops by 20% after an 8 hrs of annealing (see Fig.5.).

The results of the measurements on the second series of the specimens (discontinues recrystallization) are plotted, as a function of the annealing time in Figures 6 and 7. These figures show that process of discontinues recrystallization is characterized by an increase in the mean grain volume, E(v), and/or decrease in the density of grains/nuclei, N_V.

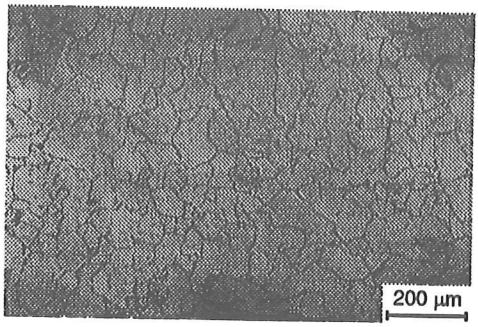

FIG.3. Image of the grain boundary network of the material after extrusion and the annealing at 400°C for 0.5 hour

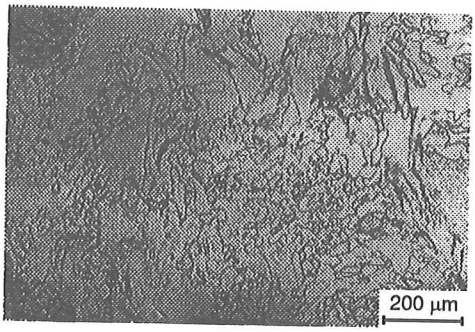

FIG.4. Image of grain boundary network of the material after extrusion and the annealing at 500°C for 0.5 hour

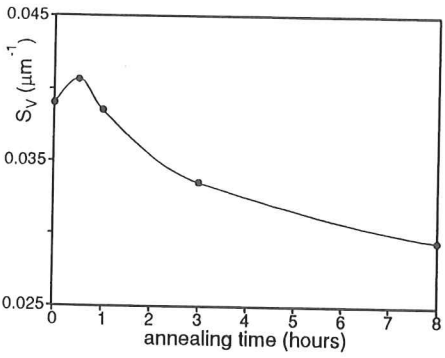

FIG.5. The dependance of S_V on the annealing time for the process of continuous recrystallization observed during annealing at 400°C

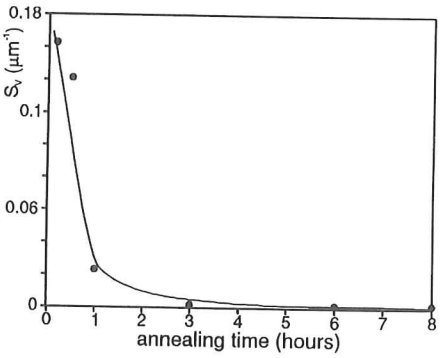

FIG.6. The dependance of S_V on the annealing time for the process of discontinuous recrystallization observed during annealing at 500°C

DISCUSSION

The results of the measurements show that the processes of continuous recrystallization is characterized by a significant activity of the pre-existing grain boundaries. The discontinues recrystallization has been found to be characterized by increasing mean volume of nuclei/grains and decreasing density of the number of nuclei/grain in unit volume.
These findings are in contradiction to the commonly accepted views on the process of recrystallization. Further works towards their explanation are in progress.

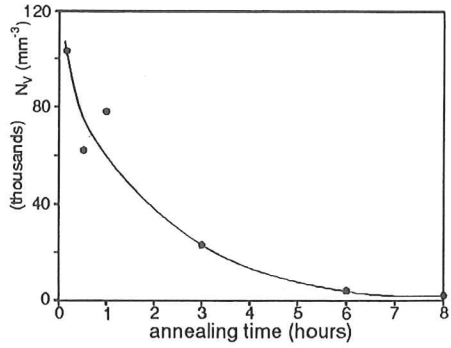

FIG.7. The dependance of N_V on the annealing time for the process of discontinuous recrystallization observed during annealing at 500°C

REFERENCES

Bucki JJ, Kurzydłowski KJ. Analysis of the effect of grain size uniformity on the flow stress of polycrystals. Part I: Studies of the relationship between the variance of grain volume and the variance of the grain area on polycrystal cross-section. Materials Characterization 1992; 29: 365-374.

Cahn RW, Recovery and recrystallization. In: Physical Metallurgy. Ch. 19. Amsterdam: North-Holland Publishing Company, 1983.

Cruz-Orive L, Hunziker E. Stereology for anisotropic cells: application to growth cartilage. J Microscopy 1986; 143: 47-80.

Kurzydłowski KJ, McTaggart KJ, Tangri K. On the correlation of grain geometry changes during deformation at various temperatures to the operative deformation modes. Phil Mag A 1990; 61: 61-83.

Kurzydłowski KJ, Bucki JJ, Chojnacka A. Studies of recrystallization and grain growth in a high purity α-Fe, submitted to Acta Metall et Mater 1994.

Ralph B, Kurzydłowski KJ, Chojnacka A. Studies of the changes in the geometry of grain boundaries and grains during recovery/continuous recrystallization in α-Fe. J Mat Sci 1994, in press.