EBSP ANALYSIS OF MICROSTRUCTURE IN RECRYSTALLIZED AL-MG ALLOY AND ITS APPLICATION TO GRAIN GROWTH SIMULATION

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ABSTRACT The present study describes the analysis of the evolution of microstructure in Al-4mass%Mg alloy by utilizing the Electron Back-Scattering Pattern (EBSP) method and computer simulation of grain growth. EBSP analysis of a recrystallized specimen revealed equiaxed polycrystalline structure having a weak texture component around the cube orientation. Small angle boundaries were observed not to localize around particular grains. Monte Carlo simulation using the EBSP data showed a growth of grains containing low angle boundaries under the condition that these low angle boundaries increase their length, while the grains disappeared drastically when calculated using the different algorithm that every grain boundary has the same mobility.

keywords : grain growth, Monte Carlo simulation, grain boundary character distribution, EBSP, Al-Mg alloy

1. INTRODUCTION

Grain growth process is well known to show significant changes of microstructures such as distributions of grain size, grain orientation and grain boundary characters. Local distributions of these microstructural parameters such as grain boundary characters or grain size around each triple junction affect the migration behavior of each grain boundary which dominates the grain growth process. Since new grain boundaries are formed when two boundaries migrated to come into contact with each other, local distributions changes dynamically during grain growth and consequently wide varieties of microstructure are expected to appear. Thus, it is quite important to understand the grain growth process focusing on the local distributions of these parameters in order to establish the method to control microstructures of polycrystalline materials.

In the present study, local distributions of both grain orientation and grain boundary characters in a recrystallized Al-4mass%Mg alloy were investigated by the EBSP method(1). Monte Carlo simulation of grain growth was then performed utilizing the EBSP data(2) in order to make clear the dominant factors in the grain growth process.

2. EXPERIMENTAL PROCEDURE

Al-4mass%Mg alloy specimens were prepared by annealing at 773K for 10^3s after cold rolling with the reduction of 90% in thickness. These recrystallized specimens were then mechanically and electrolytically polished, followed by the analysis of microstructures by the EBSP method which was performed using a scanning electron microscope (JEOL JSM-6400) with the accelerating voltage of 30kV.

Two dimensional grain growth processes were simulated by means of the Monte Carlo method[(3)]. The area for the calculation consisted of 100 x 100 sites in hexagonal arrays, and the EBSP data were utilized as the initial grain structure of the simulation. Grain boundaries are classified into two groups depending on their misorientation angle : low angle boundaries having the misorientation angle less than 15 degrees and high angle boundaries. Two different algorithms for grain boundary migration were used in the present simulation. The first one is that low angle boundaries at triple junctions increase their length (***algorithm-1***), and the second one enables every grain boundary migrates with the same mobility (***algorithm-2***).

3. RESULTS AND DISCUSSION

3.1 Microstructure of a recrystallized Al-1mass%Mg alloy

Figure 1 shows an example of the OIM (Orientation Imaging Microscopy) image of a recrystallized Al-4mass%Mg alloy. It shows an equi-axed polycrystalline structure and no anomalous grains exist

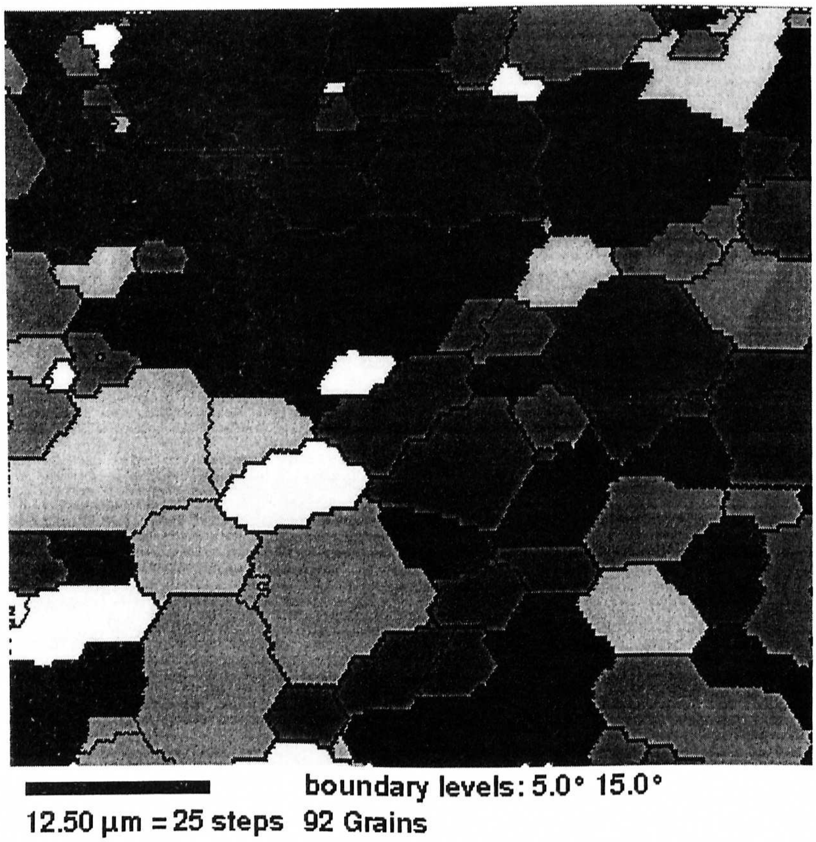

Figure 1 An example of the OIM of Al-4mass%Mg alloy annealed at 773K for 10^3s.

indicating a normal grain growth are proceeding, and there also observed no significant localization of low angle boundaries. Macro-texture or pole figures are shown in Fig. 2. The figures indicate that no strong texture has developped for the present specimen, but weak component around the cube orientation is observed.

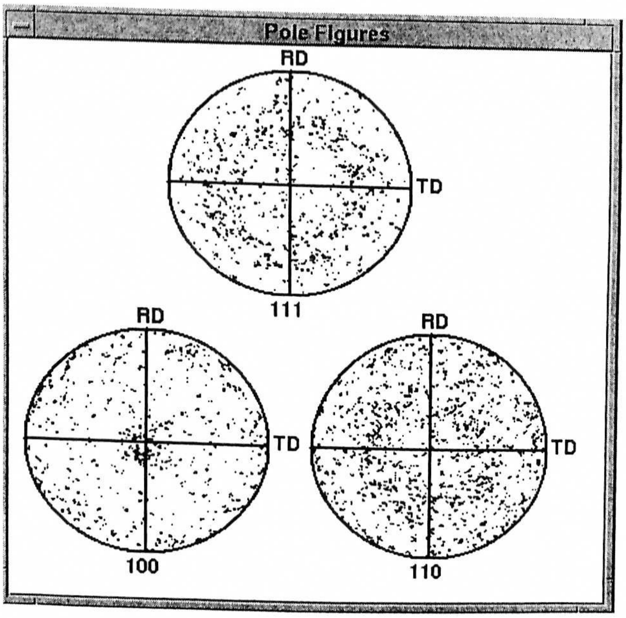

Figure 2 Pole figures

3.2 Grain growth simulation utilizing the EBSP data

Initial microstructure for the grain growth simulation was prepared by transforming the EBSP data

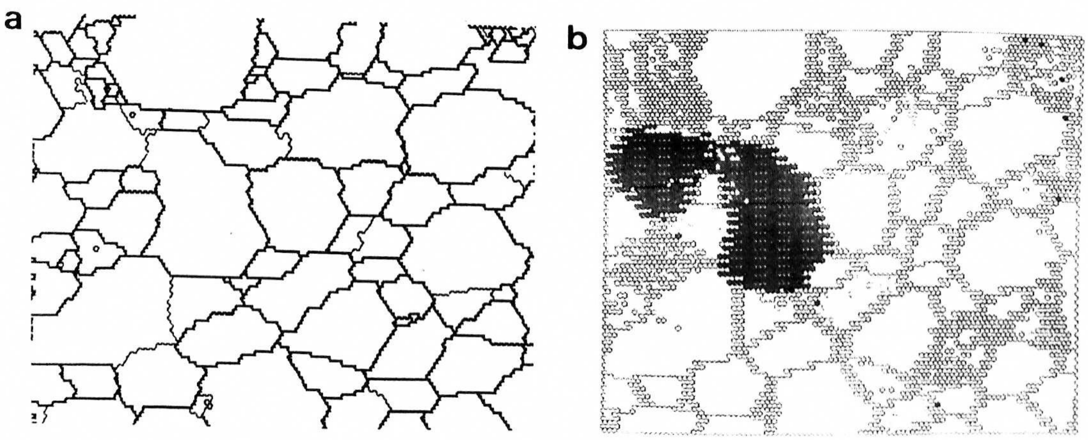

Figure 3 Comparison of an OIM image (a) with the translated microstructure (b) used as the initial structure of the grain growth simulation.

in Fig. 1, and both the OIM image and the microstructure drawn using the transformed data are shown in Fig. 3. These two figures are in consistent with each other, while many grain boundaries showed rather irregular shape as seen in Fig.3(b).

This type of "*mis-transformation*" is attributed to the roughness of the surface and/or the local changes of the orientation in the vicinity of grain boundaries. The former problem would be solved by preparing quite smooth surface. The latter reason suggests that the present method enables the simulation to deal with local change of the orientation which will be very important for the calculation of grain growth behavior in slightly deformed materials or the simulation of grain boundary migration where a dynamic change of the grain boundary misorientation occurs . In the present study, grain growth calculation with a few Monte Carlo steps was performed in order to make smoother grain boundaries.

Figure 4 shows an example of grain growth process using the "*algorithm-1*". The shaded grains have almost the same orientation and a low angle boundary exists in between these grains. In this calculation, low angle boundaries are settled to increase their length preferentially. As grain growth proceeds, the shaded grains grew consuming surrounding grains, but the reversed tendency appeared after calculation of 500MCS.

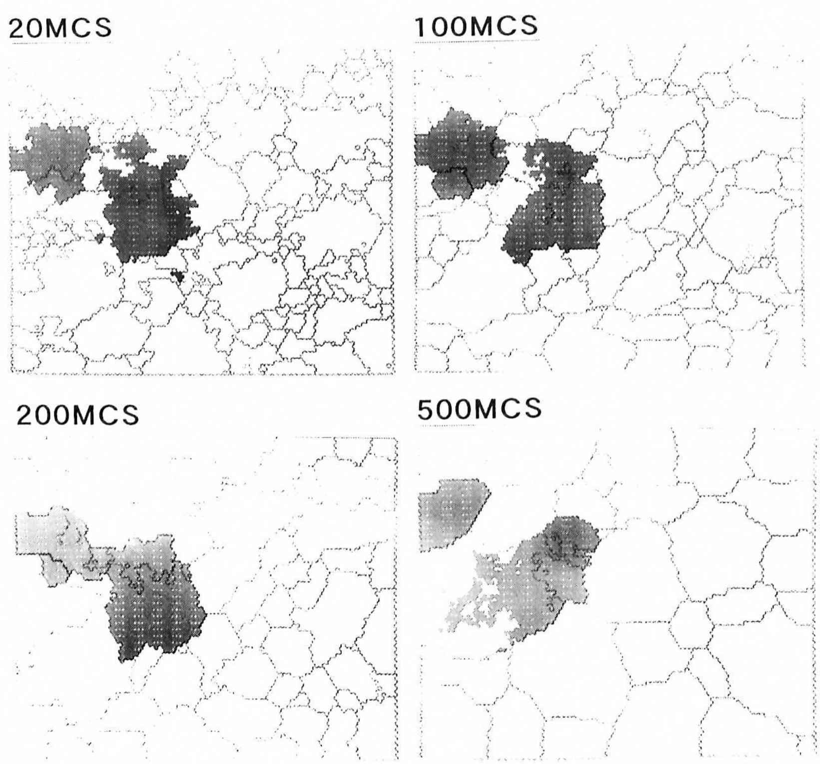

Figure 4 An example of grain growth process using the *algorithm-1*

These changes in the evolution of microstructure were also observed in Al-0.3mass%Mg alloy [(4)]. According to the paper, "clusters" of grains in the same orientation group tended to contain low energy boundaries, and formation of the cluster is important for the preferential growth. In the present simulation no significant clusters were observed and consequently no drastic change of grain growth such as anomalous grain growth or formation of texture was concluded to occur.

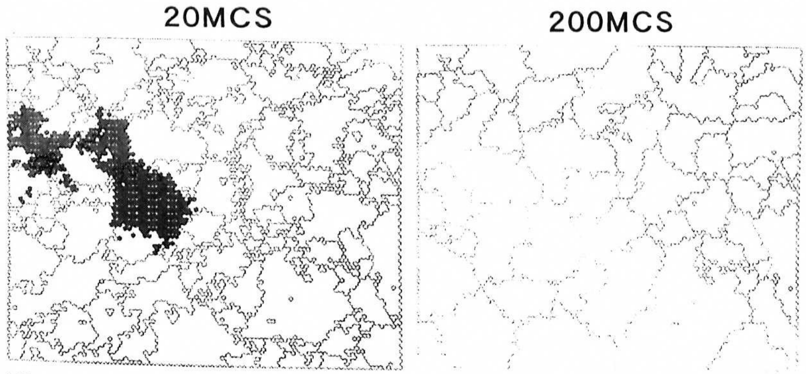

Figure 5 An example of grain growth process using the *algorithm-2*

Figure 5 shows the different type of grain growth process calculated for the same initial microstructure as that used in Fig.4. This simulation was performed using the "*algorithm-2*" for the grain boundary migration, *i.e.* all the boundaries have the same mobility. In the early stage of the grain growth the shaded grains disappeared, showing different process of the evolution of microstructure from that shown in Fig.3.

Analysis of microstructure for each snap shot of the grain growth was then performed focusing on the local grain boundary character distribution, *i.e.* the fraction of low angle boundaries around the

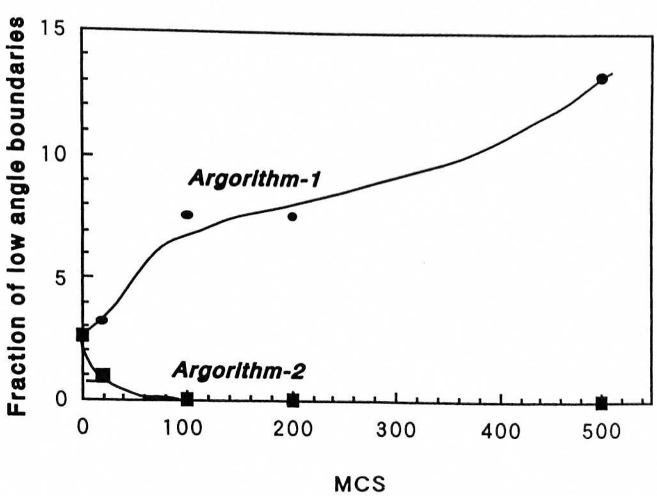

Figure 6 Changes of the fraction of low angle boundaries around the shaded grains in Figs. 3 and 4 during grain growth.

shaded grains indicated in Figs. 3 and 4, and the result is shown in Figure 6. Simulation using the *algorithm-1* yielded an increase in the fraction with grain growth, while a drastic decrease occurred when calculated using the *algorithm-2*.

These results suggest that migration behavior of each grain boundary plays quite important role in grain growth process. Grain boundary migration is known to be caused by an imbalance of grain boundary energies at each triple junction. In addition, grain boundary energy is functions of both the intrinsic factors such as grain boundary structure or segregation and the extrinsic factors such as annealing temperature, pre-strain and so on. Therefore, grain boundary migration and grain growth process should be affected and wide variety in microstructure would appear by these factors which can be controlled by some heat treatment methods.

The present results indicate that different processes of grain growth appear depending on the behavior of grain boundary migration even for the same microstructure or the same local grain boundary character distribution. In other words, the extrinsic factors are also important in grain growth process as well as the factors associated with microstructure and the properties of grain boundaries.

Effects of these intrinsic and extrinsic factors should be made clear systematically in order to understanding the grain growth process perfectly and to find the most suitable condition for controlling microstructure for given materials. Computer simulation of grain growth based on real microstructure is one of the effective methods for this purpose and detailed works would yield many fundamental data which would be summarized as "*data base of microstructure*" in future.

4. SUMMARY

Microstructure of recrystallized Al-4mass%Mg alloy specimens were analyzed by means of the EBSP method, and two dimensional grain growth simulation was performed utilizing the EBSP data. The specimen showed weak cube texture but no significant localization of grains with particular orientation. Low angle boundaries were also observed not to localize preferentially around particular grains. Monte Carlo simulation of grain growth process using the EBSP data revealed that different ways in the changes of microstructure occurred depending on the algorithm of grain boundary migration. That is to say, development of the clusters or the texture evolution would be controlled by the behavior of grain boundary migration at each triple junction, and grain growth simulation using real microstructure is useful for the classification and elucidation of grain growth processes.

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