Local Recrystallization Treatment in Pure Aluminum by Means of Laser Spot Heating†

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1. Introduction

Polycrystalline materials are described by parameters such as types of phase, shape and size of grains, grain orientation and grain boundary structure. Spatial distributions of these microstructure parameters are known to be heterogeneous and were revealed by Electron Back-Scattering Pattern （EBSP）analysis[1].

Conventional heat treatments utilizing homogeneous temperature fields that have been commonly performed in industry change these parameters in all material areas. Thus some important local distributions of microstructure parameters may have disappeared or become passive and disabled and fail to contribute to the evolution of microstructures as in texture development.

Meanwhile, taking into account the heterogeneity of spatial distribution, a spot heating method would become a candidate method to control evolution processes of microstructure as compared with homogeneous heat treatment since only some selected areas are heated without affecting to the other regions.

In the present study a fiber laser-aided spot heating system has been developed, and spot heating of pure aluminum plate has been tried to investigate microstructure changes by local heating.

2. Experimental

Figure 1 illustrates schematically the ray diagram of a laser heating system that has been newly developed in the present study. The system utilizes a fiber laser generator (YLR-100SM) provided by IPG Photonics Co.Ltd., with a wave-length and maximum power of 1076nm and 100W, respectively. A well-designed system of optics aims to focus the beam into less than 10 μm in the focal plane. The beam profile of the laser is shown in Fig.2, presenting a Gaussian distribution that satisfies the required properties for spot heating experiments in the present study. This fiber laser-aided spot heating system is called “*FLASH*” in the present study.

The microstructure of the irradiated specimen was evaluated by means of optical microscopy and scanning electron microscopy (SEM) and SEM-EBSP methods. The EBSP measurement was performed on laser-irradiated specimens after polishing the surface to about 100 μm using an alkali suspension containing oxide particles.

3. Results

3.1 Local recrystallization

Figure 3 shows an inverse pole figure (IPF) map of an irradiated area together with its surrounding area of specimen. Each color in the IPF map corresponds to crystallographic orientation represented in the unit triangle as shown additionally in the figure. Grain boundaries having misorientations larger than 15 degrees are denoted with black lines. White grain boundaries have the misorientation ranging from 2 degrees to 15 degrees.

Some large grains are present in the center region of the IPF map. Since the specimen was cold rolled prior to the laser-heating, these grains should have been recrystallized in the vicinity of the irradiated position and grown towards the outside along the temperature gradient. In addition, the recrystallized area is clearly observed indicating that a sufficient amount of energy was

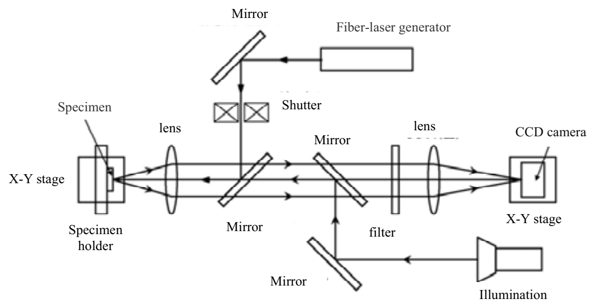

Fig. 1 Schematic illustration of laser spot heating system.

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consumed for the recrystallization during spot heating in this region.

As for the normal direction of each recryatallized grain, grains A, B and C denoted in Fig.3 have orientations close to (001), (110) and (114), respectively. Grain A and B contains few small angle boundaries, suggesting discontinuous recrystallization took place in the deformed structure. However grain C contains larger amounts of small angle boundaries, so continuous recrystallization might have proceeded in this area.

The FLASH method can generate a peculiar microstructure such as heterogeneous grain size distribution in any small area. The size advantage of a grain would lead to a preferential growth during homogeneous annealing.

3.2 Control of recrystallization process by FLASH method

Figure 4 represents an example of recrystallized region occupied by almost single grain. The heating condition was 30W for 20s. The IPF map of the deformed matrix containing the recrystallized region indicates a band-like alteration of orientation. A dashed-rectangle highlights deformed matrix containing the recrystallized grains, and its corresponding (111)-pole figure clearly indicates that this area has a strong deformation texture of (112)<111>, which is called "C-orientation". This texture component is typically observed for cold rolled aluminum. The recrystallized grain and its vicinity area, which is surrounded by black square, has a similar orientation to that observed in the deformed matrix as shown in the corresponding pole figure.

Recrystallization starts from a relatively low dislocation density area (*baby grain*) in a heavily deformed structure, and the baby-grain can grow and become a recrystallized grain if it can satisfy the growth condition. Since the laser-spot heating can enhance the growth behavior in a very limited area, some peculiar recrystallized structures, having quite different texture, would be fabricated if the system can search out the target grains and lock-on to it.

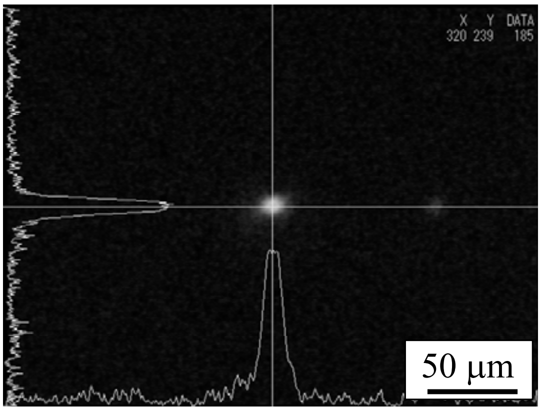

Fig. 2 Beam profile.

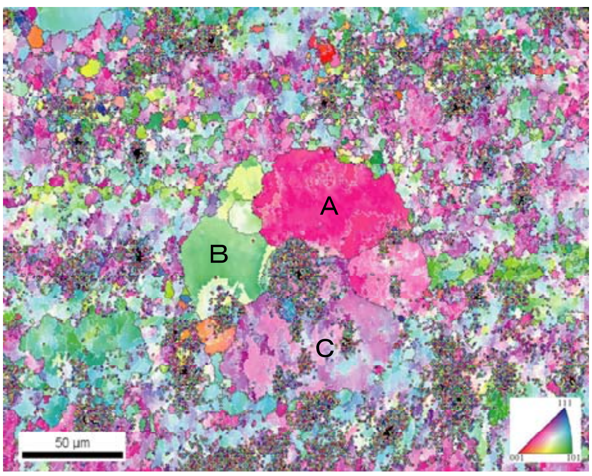

Fig. 3 Inverse pole figure map of laser spot heated specimen.

4. Summary

The present study succeeded in the development of a fiber-laser aided spot heating system with a minimum spot diameter of 10µm. The system produced some recrystallized grains in small region around 120µm diameter or less on the surface of commercially pure aluminum which was cold rolled. The laser-spot heating system can generate peculiar grain structures and is a promising technique for microstructure control.

5. Acknowledgement

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Reference

[1] V.Randle, "*Microtexture Determination and its application*", The Institute of Materials, 1992.

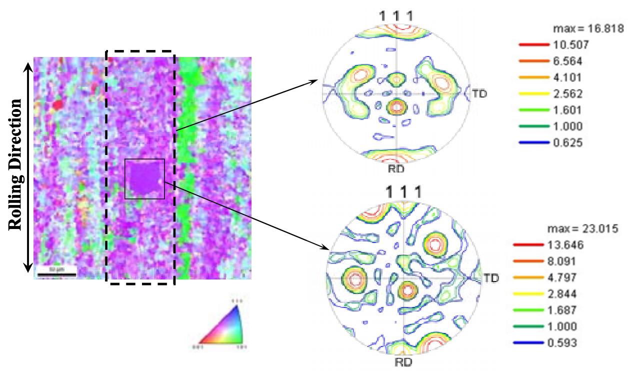

Fig. 4 Orientation distribution map and (111)-pole figures of pure aluminum laser spot-heated at 20W for 10s.