Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Analysis of Boron Distribution in Steel using Neutron at HANARO

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1. Introduction

Boron is very useful element in steels to improve the mechanical properties. In steel matrix, boron exist several types such as solute, segregation in grain boundary and many kinds of precipitate, which influence the properties of the steel.

But, detecting of boron using X-ray or ion-beam is not easy because boron is very light atom than iron. However neutron gives the clear image of boron distribution from the particle tracking autoradiography (PTA) method[1-3]. The PTA method of boron uses the phenomenon that boron irradiated by neutron emits Li-ion and alpha particle. Boron distribution can be obtained by observing the traces of the emitted Li-ion and alpha particle.

At HANARO, the study for observing of boron distribution has been performed several years ago[4]. Recently, the experimental techniques were improved for the reactor power of 30 MW. In this paper, improved experimental techniques were described and some results for boron added low-carbon steel plate were introduced.

2. Experimental Methods

2.1 Sample Preparation

The low-carbon steel plate with 5 ppm boron was used. To analysis the boron distribution in a cross section of the steel plate, the sample was polished after molding in epoxy. Other samples were prepared as polishing the surface of the steel plate without molding.

Each sample was hold in an Al-cassette with a detector film as like Fig. 1. CN 85(Kodak) was used as a detector film. The detector film was just stacked in the sample without chemicals. The silicon wafers were used to adhere closely the sample and the detector film.

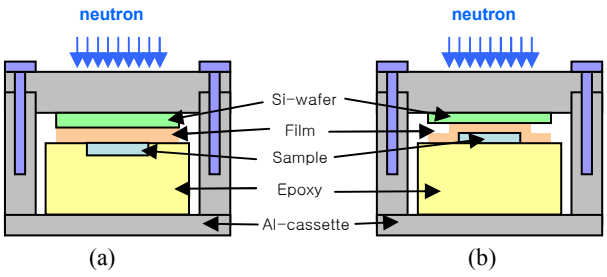


Figure 1. Sample preparation for neutron exposure, (a) is for the cross section and (b) is for the surface of steel plates.

2.2 Exposure of Neutron

The thermal neutron from the IR beam port in HANARO was used[5]. The neutron flux is about 10^9 n/cm^{2}s. The Cd-ratio is 104. The exposure time depends on the boron amount in samples. The samples used in this paper, the steel plate with 5 ppm boron, were exposed 6 hours.

2.3 Etching of Detector Film

For the etching of detector film, CN 85, the aqueous solution of NaOH with 2.2 N was used. The temperature of the solution was about 50^{o}C. Etching time depends on both the amount of boron in a sample and the exposure time of neutron. In this experiment, films were etched during about 15 min. After etching, films were washed by distilled water and dried.

2.4 Analysis

The etched films were investigated by using optical microscope. CN 85 film is transparent so that the microscope used in transmission mode. To evaluate quantitatively the boron distribution, the program of image analysis was used for the picture obtained from the microscope[6].

3. Results

Fig. 2 shows the boron distribution in the cross section of the steel plate. Boron was concentrated in surface of the steel plate. It looks like thick lines. Just behind this layer the clear region was shown. And in side, boron distribute as spherical spots.

Fig. 3 shows the boron distribution in surface layer, (a) is for the surface polished up 1 micrometer and (b) is that for 3 micrometer. More boron was observed in the surface polished up 1 micrometer than 3 micrometer. Most of boron is gathered in grain boundaries.

The area fraction of boron distribution obtained using Image analysis program was shown in Fig. 4. These are for the surface layers; 1, 3 and 5 micrometer mean the surfaces polished up 1, 3 and 5 micrometer thick. The spots in the size of 3~35 micrometer were used for the image analysis, and the spots were calculated as an ellipsoidal shape.

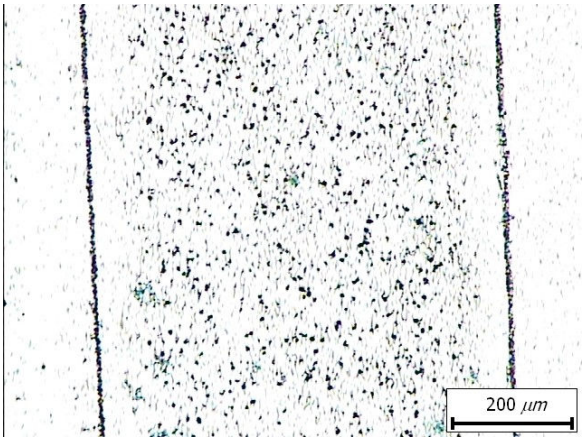
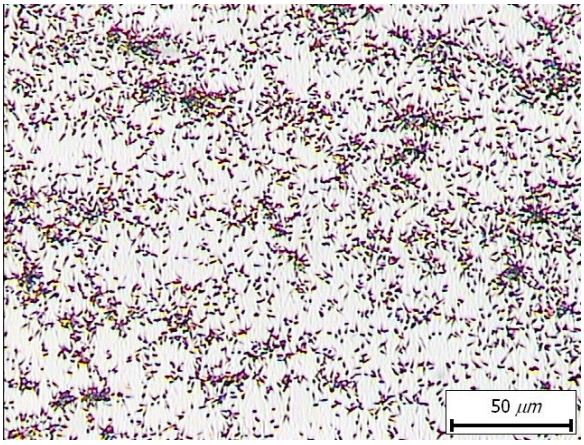
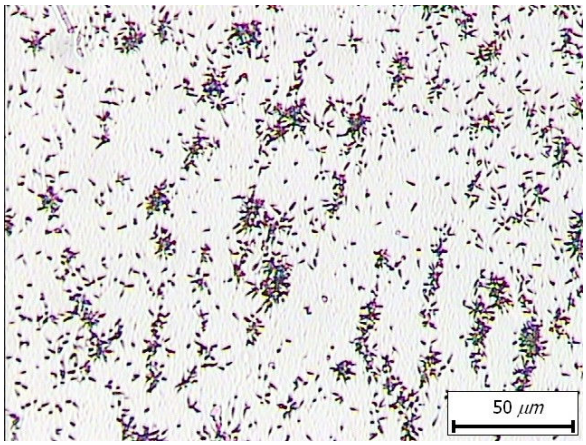


Figure 2. Boron distribution in the cross section of the low-carbon steel plate



(a)



(b)

Figure 3. Boron distribution in the surface layers of the low-carbon steel plate; (a) is the surface polished up 1 micrometer and (b) is for 3 micrometer.

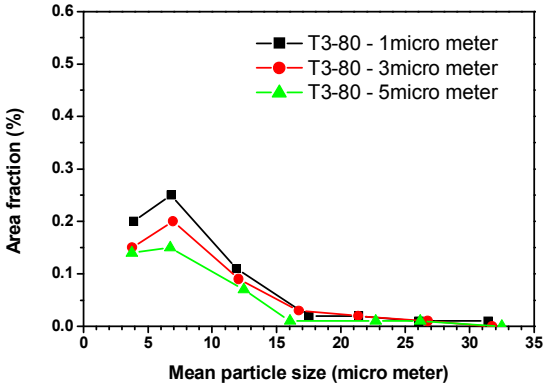


Figure 4. Area fraction of boron distribution in the surface layers of the low-carbon steel plate; ■ is after polishing up 1 micrometer, ● is for 3 micrometer and ▲ is for 5 micrometer.

4. Summary

The boron distribution in the low-carbon steel plate added 5 ppm boron was investigated using neutron at HANARO. The improved experimental techniques give the clear image of boron distribution. And the quantitative analysis was performed by using Image analysis program. In the low-carbon steel plate, boron was concentrated in surface layer and appeared as spherical spots in center.

ACKNOWLEDGEMENT

Part of this work was supported by the HANARO Nuclear R & D Program of the Ministry of Science and Technology.

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