Grain Boundary Engineering of an Austenitic ODS alloy

T.K. Kim,[a] C.S. Bae,[b] D.H. Kim,[b] C.H. Han,[a] J. Jang [a]
[a] Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, 305-353, tkkim2@kaeri.re.kr
[b] Dept. of Metallurgical Engineering, Yonsei Univ., 134 Schinchon, Seodaemun, Seoul 120-749

1. Introduction

Among many candidate alloys for Gen IV reactors, the oxide dispersion strengthened (ODS) alloy is widely considered as a good candidate material for the in-reactor component, like cladding tube. The ODS alloy is well known due to its good high temperature strength, and excellent irradiation resistance [1-3]. For the previous two decades in the nuclear community, the ODS alloy developments have been mostly focused on the ferritic-martensitic (F-M) steel-based ones. On the other hand, the austenitic stainless steels (e.g. 316L or 316LN) have been used as a structural material due to its good high temperature strength and a good compatibility with a media. However, the austenitic stainless steel showed unfavorable characteristics in the dimensional stability under neutron irradiation and cracking behavior with the media.

From this point of view the application of Grain boundary engineering (GBE) technique to austenitic ODS steel has become a subject of concern. In this study the ODS steel sheets were fabricated, and the effects of a thermomechanical treatment (TMT) on the CSL (coincidence site lattice) boundaries were investigated.

2. Methods and Results

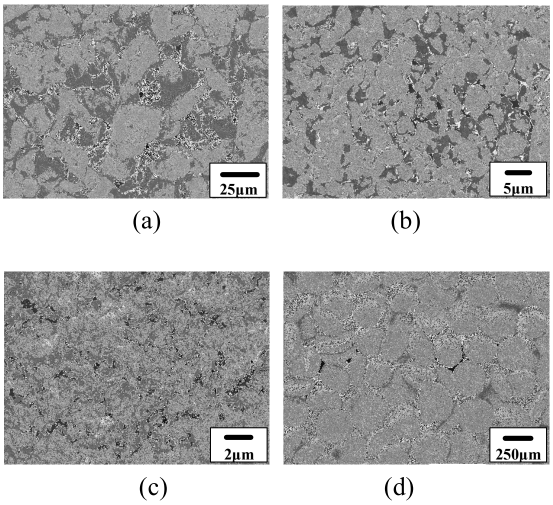
2.1 Experimental procedure

99.4 wt% of type 316L stainless steel powders were mechanically alloyed with 0.3 wt% of Ti powders and 0.3wt% of Y_2O_3 powders. The austenitic ODS alloy sample was hot rolled to 4 mm in thickness, followed by annealing at 1150℃ for 1 h. The hot rolled plate was cold rolled to 1 mm in thickness followed by a recrystallization heat treatment at 1200℃ for 1 h. In order to attain the optimum TMT conditions, one-step cold rolling was performed with the reduction ratios of 3, 6 and 24% in thickness, respectively. For each rolling reduction ratio, the annealing was carried out at 950, 1000 and 1150℃ for 72 h.

The powders and mechanically alloyed lumps were observed by using a scanning electron microscope (SEM), The frequency of CSL boundaries were determined by using an electron backscatter diffraction (EBSD) attached to a SEM. The microhardness was also measured using a microhardness tester under the load of 0.5 kgf.

2.2 Morphology of the powders

Figure 1 shows the SEM images of 316L stainless steel, Ti, Y_2O_3 powders and mechanically alloyed lumps. The 316L stainless steel, Ti and Y_2O_3 powders revealed an irregular morphology and their average particle sizes were determined to be about 20 μm, 3 μm and 30 nm, respectively. On the other hand, the mechanically alloyed lumps exhibited a nearly disk-type morphology.



(a) (b) (c) (d)

Figure 1. SEM images of (a) 316L stainless steel, (b) Ti, (c) Y_2O_3 powders and (d) mechanically alloyed lumps.

2.3 CSL boundary

Fig. 2 shows the effects of the rolling reduction ratio and TMT temperature on the frequency of the CSL boundaries in the sample. There appeared little effect of the rolling reduction ratio on the frequency change of the CSL boundaries. However, the TMT temperature seemed to have significant effect on the CSL frequency change. The maximum CSL frequency was always observed at 950℃ of TMT temperature in the 3, 6 and 24% pre-strained specimens. It is thus concluded that the frequency of the CSL boundaries depends more on the TMT temperature rather than on the rolling reduction ratio.

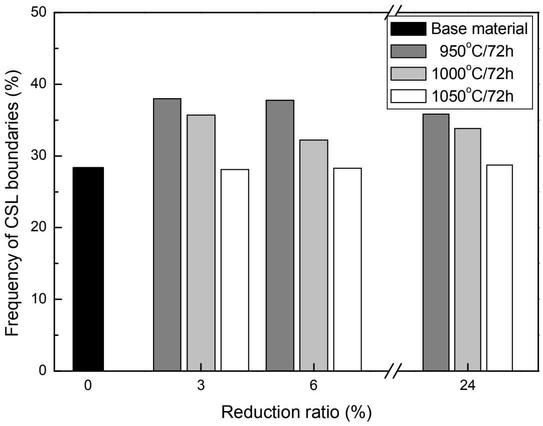


Figure 2. Effects of rolling reduction ratio and TMT temperature on the frequency of CSL boundaries in the austenitic ODS alloy.

2.4 Microhardness

Fig. 3 shows the effects of the rolling reduction ratio and annealing temperature on the microhardness of the ODS sample material. The microhardness appeared in general to increase with an increasing reduction ratio, and to decrease with an increasing TMT temperature. The highest microhardness was observed with the reduction ratio of 24% and TMT temperature of 950℃.

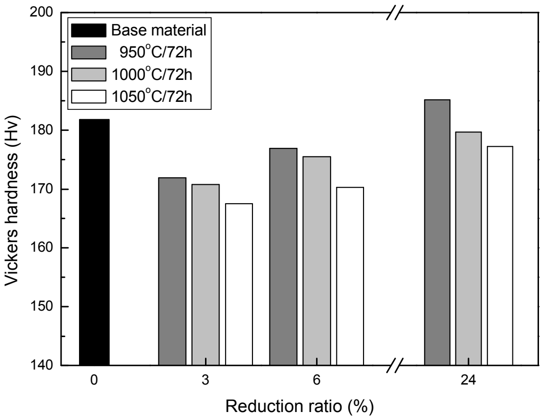


Figure 3. Effects of rolling reduction ratio and TMT temperature on the microhardness of the austenitic ODS alloy.

3. Conclusion

In order to attain the optimum TMT conditions in terms of the frequency of the CSL boundaries, the cold rolled austenitic ODS alloy specimens were TMT treated. The frequency of the CSL boundary was mostly decided by the TMT temperature, and the highest frequency of the CSL boundaries was obtained with the rolling reduction ratio of 3% and TMT temperature at 950℃. It is expected that the high frequency of the CSL boundaries would be effective to improve material properties, especially grain boundary related ones.

Acknowledgements

This study was supported by the Korea Science and Engineering Foundation (KOSEF) and the Ministry of Science and Technology (MOST), Korean government, through the National Nuclear Technology Program.

REFERENCES

[1]A. Alamo, V. Lambard, X. Averty, M.H. Mathon, J. Nucl. Mater. Vol. **329-333**, p. 333, 2004.

[2] T. Yoshitake, Y. Abe, N. Akasaka, S. Ohtsuka, S. Ukai, A. Kimura, J. Nucl. Mater. Vol. **329-333**, p. 342, 2004.

[3] S. Yamashita, N. Akasaka, S. Ohnuki, J. Nucl. Mater. Vol. **329-333**, p. 377, 2004.