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Micro-texture Analysis of 2nd Pilgered Zirconium Alloys by Electron Backscatter Diffraction

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1. Introduction

Texture controlling with crystallographic orientation is one of important techniques to produce seamless zirconium tubes for nuclear fuel cladding materials. The texture of the zirconium alloys can be analyzed by several methods such as X-ray, neutron and electron diffraction. Each method has its advantages and disadvantages for texture analysis, respectively.[1-3] Since the thin seamless zirconium tubing was usually prepared with thick TREX by pilgering process, the grains near outer and inner surfaces have different deformation force during pilgering, which resultantly gives critical crystallographic orientation with position of grains in a tube. In this study, micro-texture analysis of pilgered zirconium alloys was carried out by electron backscatter diffraction (EBSD) to give a information for optimum fabrication condition. Emphasis is on the analysis of crystallographic orientation with position of 2nd pilgered zirconium tubings.

2. Experimental Method

The zirconium alloy tube formed by 2nd pilgering was supplied by the Korea Nuclear Fuel Company. In order to removing surface strain, specimen with a size of 3x3x3 mm was cut and polished followed by electro-chemical etching. Microstructure of the tube was observed by scanning electron microscopy (Jeol 35C). Micro-texture as orientation maps of the 2nd pilgered zirconium tube was determined by the electron backscattering pattern method using a scanning electron microscope (Jeol JSM 2400-EBSP, Oxford).

3. Results and Discussion

Fig. 1 shows scanning electron micrographs of 2nd pilgered zirconium tubes. As shown in Fig. 1, grains in center and inner areas have equiaxed shape with similar grains size in cross section view. Average grain size of the 2nd pilgered tube is about 6.7 μm in cross sectional view.

Fig. 2 is pole figures of basal plane (0002) in a grain in center region and a grain near inner surface region, respectively. As shown in Fig. 2, crystallographic orientation depends on the position of grains in the zirconium tube. The (0002) poles of a grain at center region tend to be mainly distributed in radial and transverse directions, whereas, those of a grain at inner surface region are relatively uniformly distributed in both directions, respectively.

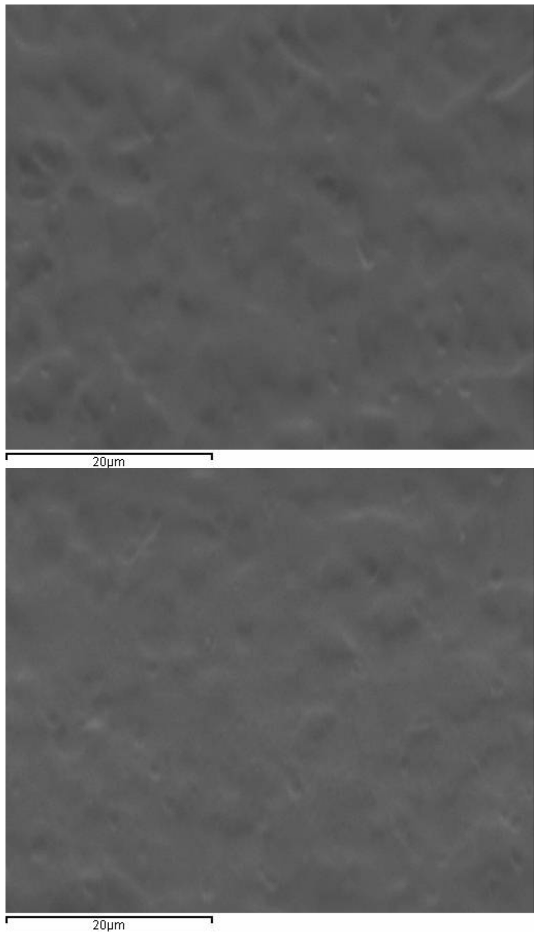

Figure 1. Cross sectional view of 2nd pilgered zirconium alloy tube observed by scanning electron microscopy : (top) center (bottom) inner area

It is interesting why the crystallographic orientation is so different with position of grains. It should be related to deformation behavior of each grain. In case of zirconium, preferred crystallographic orientation exists due to the anisotropy of slip. If tensile and compressive samples are taken from the rolled sheet, the basal poles are preferentially aligned parallel to the direction of the applied force and the prismatic poles are preferentially aligned perpendicular to it.[4] For zirconium tubing formed by pilgering, the texture can be controlled by the ratio of wall thickness-to-diameter reduction. Considering the amount of local deformation force in cross sectional view, the local stress at the grain of inner or outer regions is compressive and tensile in a deformation direction, whereas, the local stress at the grain of the center region is neutral in various direction.

This supports that the (0002) poles of a grain in center region tend to be mainly distributed in radial and transverse directions, whereas, those of a grain in inner surface region are relatively uniformly distributed in both directions, respectively.

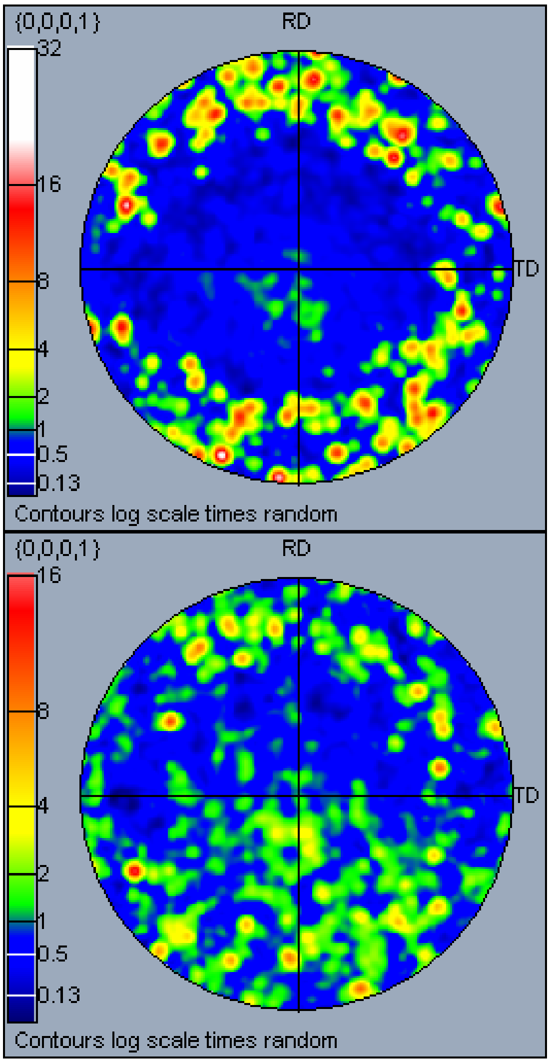

Figure 2. (0002) pole figures of grains in 2nd pilgered zirconium alloy tube : (top) center (bottom) inner area

3. Conclusion

Micro-texture analysis of 2nd pilgered zirconium alloys was carried out by electron backscatter diffraction (EBSD) to study crystallographic orientation of each grain with position of the zirconium tube. For the grains with similar grain size, The basal poles of a grain at center region tend to be mainly distributed in radial and transverse directions, whereas, those of a grain at inner surface region are relatively uniformly distributed in both directions, respectively. This crystallographic orientation is related to local stress distribution during pilgering.

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References

[1] H. Inoue, M. Ishino, T. Takasugi, Texture of TiNi Shape Memory Alloy Sheets Produced by Roll-bonding and Solid Phase Reaction from Elementary Metals, Acta Meterialia, Vol. 51, p. 6373, 2003.
[2] N. Dewobroto, N. Bozzolo, F. Wager, Influence of Deformation Substructures on the Early Mechanisms of Recrystallization in Cold-Rolled Titanium and Zirconium, Materials Science Forum, Vol. 495, p. 711, 2005.
[3] J. K. Lee, S. K. Hwang, M. S. Yang, The effect of Rolling and Heat treatment on the texture of Zircaloy-4 Sheet, J. of the Korean Inst. of Metals, Vol. 26(8), p. 799, 1988.
[4] W. Evans, J. A. L. Robertson, The Physical Metallurgy of Zirconium, CRNL-1208, 1974.