2313
doi:10.1017/S1431927615012349 Paper No. 1155 Microsc. Microanal. 21 (Suppl 3), 2015
© Microscopy Society of America 2015

Interface Magnetism Studied by Electron Holography with Multiple-biprisms

Yasukazu Murakami[1]

[1.] Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai, Japan.

Revealing spin order in interface regions is important for both materials science and technologies. An intriguing phenomenon is the magnetic anomaly observed in an antiphase boundary (APB), which is a planar defect produced in ordered alloys. Atomic disordering within an APB has been believed to deteriorate ferromagnetism. Although this relationship induces useful functionalities such as pinning of magnetic domain walls, the magnetic degradation in APBs is deleterious for spintronic applications. Thus, a big challenge in materials science is to explore a distinct type of APB, in which the ferromagnetic spin order is not appreciably depressed; instead, the magnetization can be increased in APBs. Using electron holography with multiple biprisms, we have demonstrated that the magnetization can be amplified in APBs produced in $Fe_{70}Al_{30}$ [1]. In particular, we employed a technique of split-illumination [2] in order to acquire electron holograms from a portion away from the specimen edge.

As illustrated in Fig. 1, an APB changes the geometrical phase of the B2-type superstructure in $Fe_{70}Al_{30}$. A thermally induced APB shows a finite thickness, in order to avoid energy penalty due to unfavorable atomic pairing [3]. We accordingly observe local atomic disorder in the APB region. For transmission electron microscopy studies, we focused on particular APB planes that were almost parallel to the incident electrons. A high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) image revealed a well-defined B2-type superstructure made of Fe columns and Fe/Al columns in the matrix regions: see Fig. 2. As shown in Fig. 2(b), difference in the peak intensity was obscured in the APB region, because of the atomic disordering (A2-type disordering) that occurred over this area. The width of the thermally produced APB appears to be 2–3 nm, although the result contains an uncertainty (approximately 1 nm) due to the ambiguity in determining the terminal positions.

Figure 3 provides magnetic flux density maps (mapping of the phase gradient revealed by electron holography), observed as a function of temperature. For convenience, Fig. 3(a) shows locations of APBs in this view field. As shown in Fig. 3(b), the specimen appears to be magnetized approximately in one direction at 293 K; *i.e.,* anomaly in APBs is not yet clear because of the significant magnetization in both matrix and APB regions. The magnetization in the matrix is significantly reduced by heating the specimen to 573 K. However, the magnetization in APBs remains pronounced at elevated temperatures, as shown in Figs. 3(c) and 3(d). Further heating makes the whole area of the specimen paramagnetic, as shown in Fig. 3(e). The results explicitly indicate that the ferromagnetic phase can be stabilized in the APB region. Our observations are unusual compared with those reported for other alloys in which APBs deteriorate ferromagnetic spin order.

This study was supported by a grant from JSPS through the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Tonomura Project).

References:
[1] Y Murakami *et al*, Nature Communications **5** (2014), p. 4133.
[2] T Tanigaki *et al*, Appl. Phys. Lett. **101** (2012), p. 043101.
[3] S M Allen and J W Cahn, Acta Metall. **27** (1979), p. 1085.

https://doi.org/10.1017/S1431927615012349 Published online by Cambridge University Press

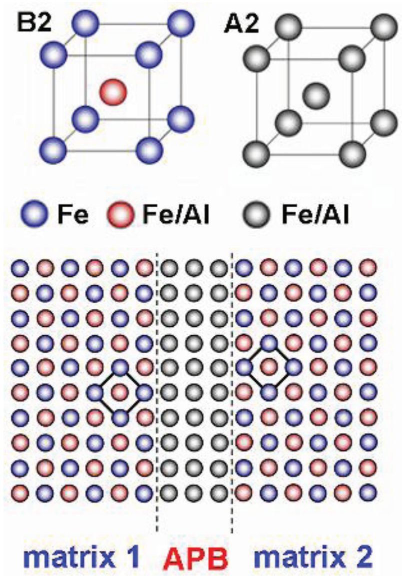

Figure 1. Structure of APB produced in $Fe_{70}Al_{30}$ alloy showing B2-type structure. Reprinted from Ref. 1.

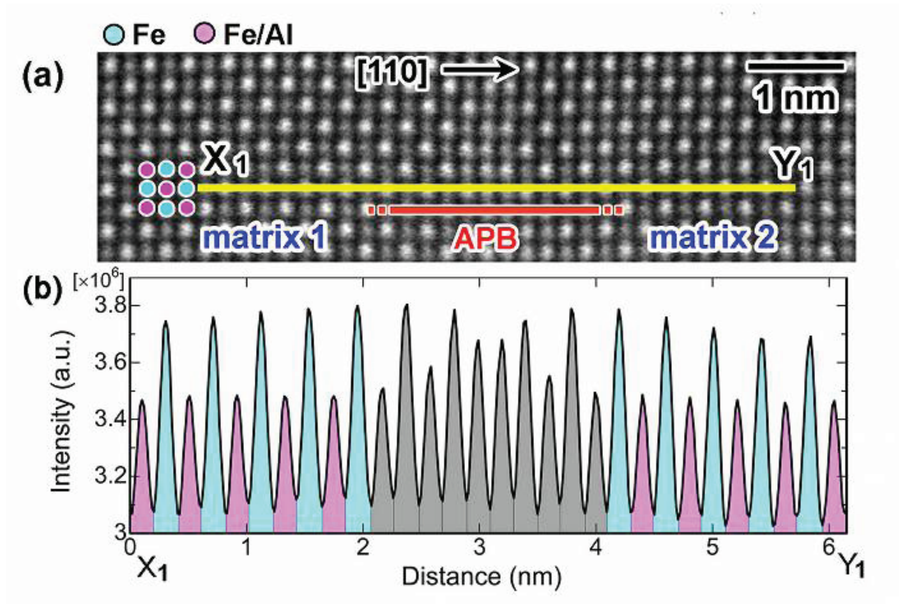

Figure 2. Atomic disorder observed in the APB region in $Fe_{70}Al_{30}$. (a) HAADF-STEM image, acquired from an area with approximately edge-on APB. (b) Intensity profile measured in X_1-Y_1 line. Reprinted from Ref. 1.

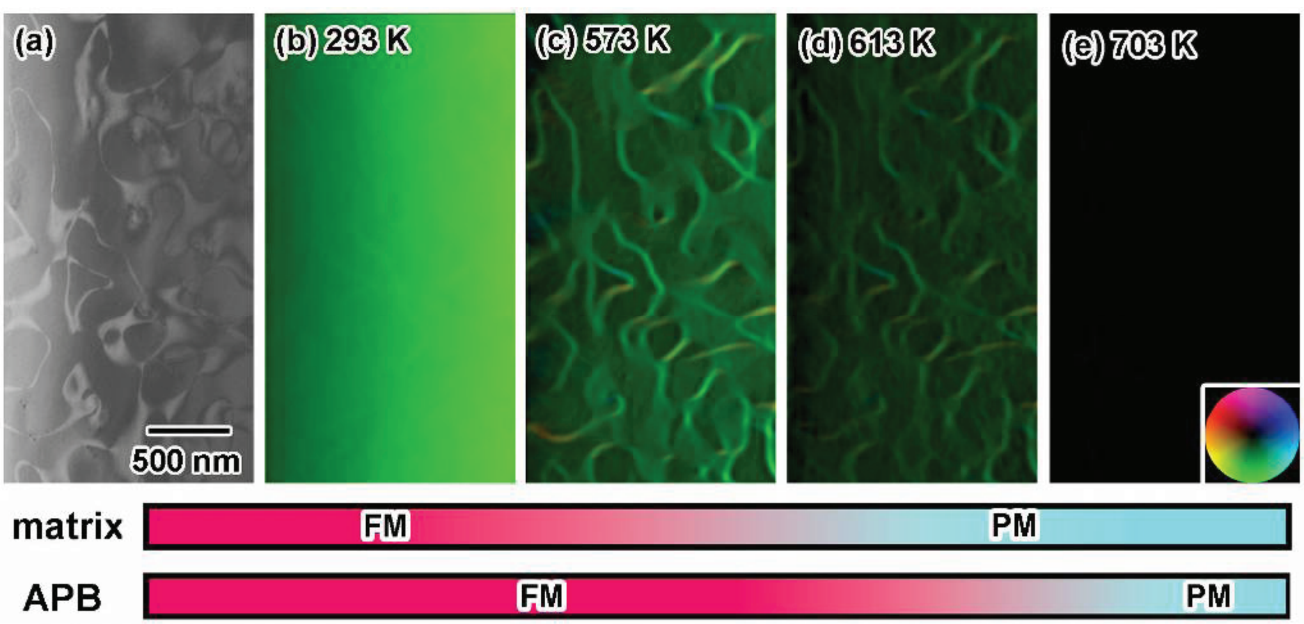

Figure 3. Magnetic anomaly in APBs observed in $Fe_{70}Al_{30}$. (a) TEM image showing the locations of APBs. (b)-(e) Mapping of the phase gradient, representing the in-plane magnetic flux density. Refer to the color wheel for the direction and magnitude of the magnetic flux. FM and PM represent ferromagnetic and paramagnetic, respectively. Reprinted from Ref. 1.

https://doi.org/10.1017/S1431927615012349 Published online by Cambridge University Press