doi:10.1017/S1431927611010075
Microsc. Microanal. 17 (Suppl 2), 2011

AEM Study of Oxygen Effect on a Soft Magnetic Alloy

S. Elhalawaty*, R. W. Carpenter **, J. George ***, S. R. Brankovic ****

* Materials Science and Engineering Graduate Program, School for Engineering of Matter, transport and Energy, Arizona State University, 85287-6106
** LeRoy Eyring Center for Solid State Science, Arizona State University, AZ 85287- 9506
*** Center for Nanomagnetic Systems, University of Houston, TX 77204-4005
**** Electrical and Computer Engineering Department, University of Houston, TX 77204-4005

FeCo soft high magnetic moment alloys, near equiatomic composition, have received noticeable interest because they display soft ferromagnetic behavior, with high Curie temperature, large saturation magnetic flux density, high permeability associated with the very low magnetocrystalline anisotropy K_1 and low coercivity [1]. Therefore, they have been widely utilized in magnetic recording write heads [2] and high temperature applications such as gas turbine engines and magnetic bearing for high speed motors [3]. In this study $Co_{40-37}Fe_{60-63}$ alloys have been electro-deposited on Si substrates with variable synthesis conditions to incorporate an oxygen rich phase in the deposited films. A good understanding of magnetic properties often requires knowledge of structural properties of grown films. Transmission electron microscopy (TEM) was a powerful tool in this study to correlate the structure to the magnetic properties of deposited films. Oxygen in the deposited films has been identified using energy dispersive spectroscopy (EDS) and electron energy loss spectroscopy (EELS) during Z-contrast scanning transmission electron microscopy (STEM). Oxygen rich phase at matrix grain boundaries increased coercivity and reduced saturation magnetization of the FeCo films.

Figure 1(a) shows a Z contrast image for S1 and it is clearly seen that there are some dark particles/regions within the gains, which could be regions of higher oxygen concentration. This was confirmed by nanoEELS as displayed in the inset. The O K-edge fine structure from dark region corresponds to FeO type oxide according to the fingerprinting in Colliex et al [4]. However the oxygen distribution in S2 is mainly segregated at grain boundaries as confirmed by EELS line scan shown in fig. 1(b). Note that S2 has somewhat different electrodeposition synthesis to introduce higher oxygen content than S1. Figure 1(c) shows the Fe/Co ratio of the dark area is 2.6 and the oxygen peak is much larger. In these regions, the oxide phase is Fe-rich. However, the matrix Fe/Co ratio is 1.7 which is consistent with the alloy composition $Co_{40-37}Fe_{60-63}$ and the oxygen peak is very small. Figure 2 shows DF image for S2. It revealed that the grain size was 10-20 nm. Diffraction contrast images of S1 were essentially the same as S2. The oxide Fe-rich phase in S1 is mainly FeO type, whereas in S2 is Fe_2O_3 as shown from onset K-edge EELS spectra in fig. 3.

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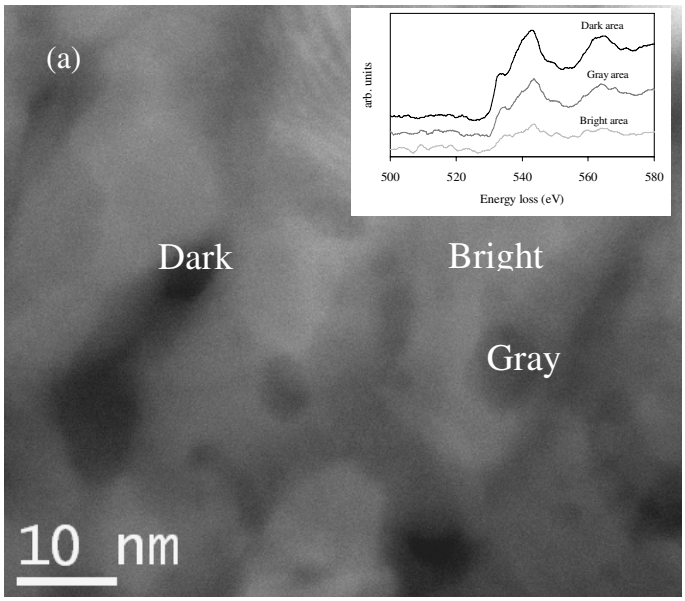
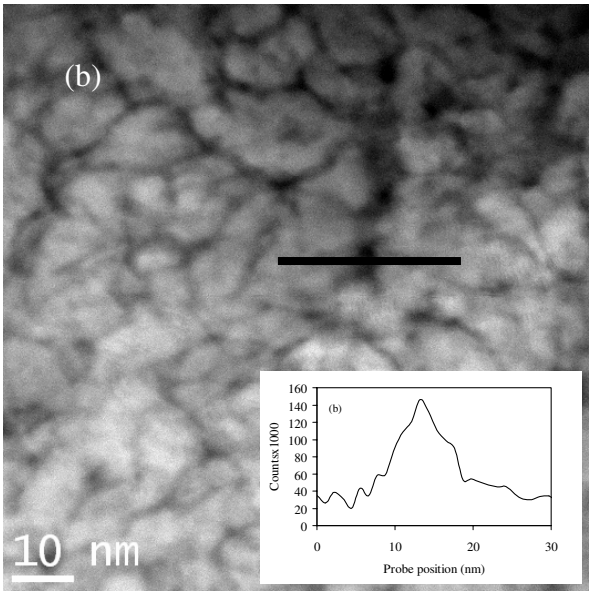




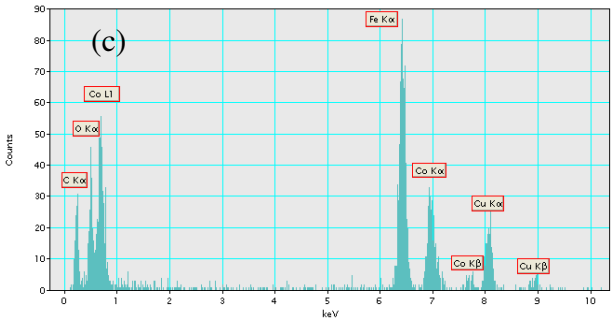
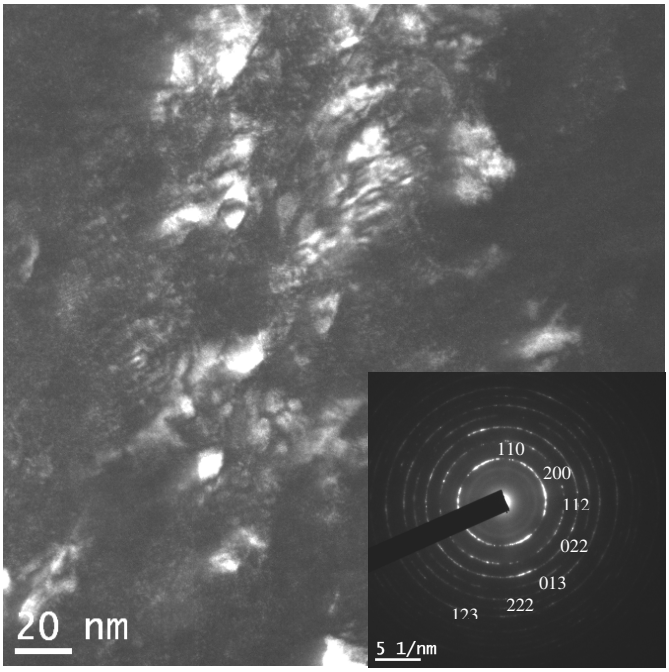


Fig. 1 (a) Z contast image for S1. The inset shows EELS spectra from indicated regions, after background subtraction, showing presence of oxygen-rich phase. (b) Z contast image for S2. The inset shows O-K EELS line scan collected from line shown in the image. (c) EDS spectrum collected from dark area in S1.



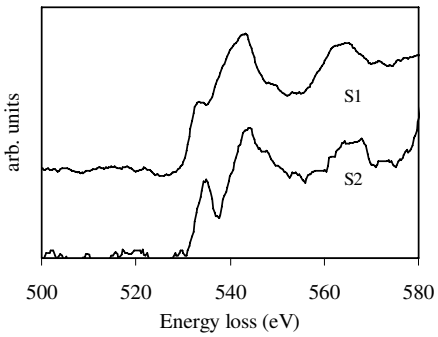


Fig. 3 O-K edge nanoEELS spectra from dark regions in both samples. Note: the edge onset structure is different.

Fig. 2 200 keV cross-sectional DF image for FeCo film S2. The matrix grain size is 10-20 nm. Inset: SAD showing a bcc poly-crystal structure with <111> texture.

https://doi.org/10.1017/S1431927611010075 Published online by Cambridge University Press