Large Faraday effect of amorphous iron silicate thin films by metallic iron

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Amorphous oxides containing transition metal have attracted much attention because some of them are transparent to the visible light and exhibit Faraday effect. The Faraday effect plays an important role in telecommunication or laser technology, where it is a key component of many optical devices such as optical isolators, modulators, and switches. Glasses containing rare-earth element have been studied for optical isolators. However, conventional glassy materials have smaller Verdet constant compared to crystalline materials, meaning that it is necessary to prepare large devices so as to achieve sufficient rotation angle. This prevents integrated systems of small size. To overcome this limitation of glassy materials, composites of nanoparticles with glassy matrix have been proposed.

For the present study, we have prepared amorphous thin films with nominal compositions of xFeO·(100–x)SiO_2 (x = 10, 33, 50, 67 in mol%) on silica glass substrates by using a pulsed laser deposition method. The thickness of the resultant films was estimated to be 260, 360, 280, and 240 nm for x = 10, 33, 50 and 67, respectively. The amorphous FeO-SiO_2 thin films show large Faraday effect especially in the short wavelength range of visible light. The rotation angle for 67FeO·33SiO_2 is 4110 rad/m at 633 nm under 15 kOe, which is larger by one order of magnitude than that of Eu^{2+}-containing glasses; the Verdet constant of 58.0EuO·12.0Al_2O_3·20.0B_2O_3·10.0SiO_2 is –300 rad/(Tm) at 633 nm. The rotation angle is extraordinary large for glassy materials, and cannot be explained only by the magnetic moment of Fe^{2+} ions. X-ray photoelectron and X-ray absorption near edge structure spectroscopies point to the predominance of Fe^{2+}, but the Fe^0 state was also detected. Tiny metallic iron crystals were directly observed by transmission electron microscope. Selected area electron diffraction reveals that a ring with few single sharp spots is present at 2.0 Å consistent with the (110) lattice spacing of metallic iron together with broad rings typical for glass. Dark field images using small portions of the 2 Å ring exhibit numerous iron nanoparticles of 2 to 3 nm diameter throughout the iron-rich glass.

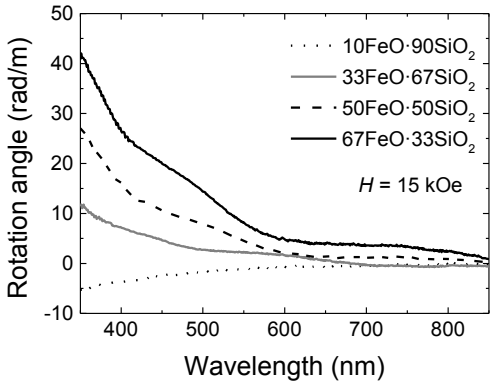

Figure 1 Wavelength dependence of Faraday rotation angle of FeO-SiO_2 thin films under the magnetic field of 15 kOe.

Thus, it is shown that the large Faraday effect of amorphous FeO-SiO_2 thin film is due to the presence of metallic iron clusters.