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EXAFS study on clustering of Fe atoms implanted in silica glass

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1 Introduction

In our previous report[1], we have shown through the XANES measurements that during the energetic Fe ion implantation in silica glass, the valence of Fe ions tends to decrease, and becomes close to zero (pure Fe) when Fe ion fulence is large. In other words, when focused on one Fe nanoparticle implanted in silica glass, more Fe atoms exist around the Fe nanoparticle with increasing ion fluence. In the present report, we will show the change in EXAFS spectra for various Fe ion fluences and will discuss the structure of Fe nano-particles in silica glass.

2 Experiment

Target samples were SiO_2 sheets with the dimension of 5mmx5mmx1mm. They were implanted with 380keV Fe ions at the fluences of $3x10^{16}$, $1.4x10^{17}$ and $2.1x10^{17}/cm^2$ at room temperature by using an ion-implanter at Takasaki Advanced Radiation Research Institute, QST. The effect of the implantation on magnetic properties was studied by using a SQUID magnetometer. In order to investigate the atomic arrangement of the implanted Fe ions, the extended x-ray absorption fine structure (EXAFS) measurements around the Fe-K edge (7.11 keV) were performed at a synchrotron radiation facility of High Energy Accelerator Research Organization (KEK-PF). For comparison, the EXAFS spectra for iron oxide(Fe_2O_3) and pure iron (α-Fe) were also measured.

3 Results and Discussion

Fig. 1 shows the EXAFS-FT spectra for silica glass implanted with Fe ions. For comparison, the spectra for Fe_2O_3 and pure iron are also plotted in the figure. The spectrum for Fe_2O_3 shows a clear peak at 1.4 A corresponding to oxygen atoms as nearest neighbors of Fe atoms. Other peaks for the regular atomic arrangements of iron and oxygen atoms around iron atoms are also observed in the spectrum for Fe_2O_3. The spectrum for silica glass implanted with $3x10^{16}/cm^2$ Fe ions has also a peak at 1.4A. This peak can be identified as due to oxygen atoms which are nearest neighbors of iron atoms. However, we can not see any other clear peaks in the spectrum. The result implies that in silica glass implanted with $3x10^{16}/cm^2$ Fe ions, amorphous iron oxide clusters are produced. With increasing the Fe implantation fluence,

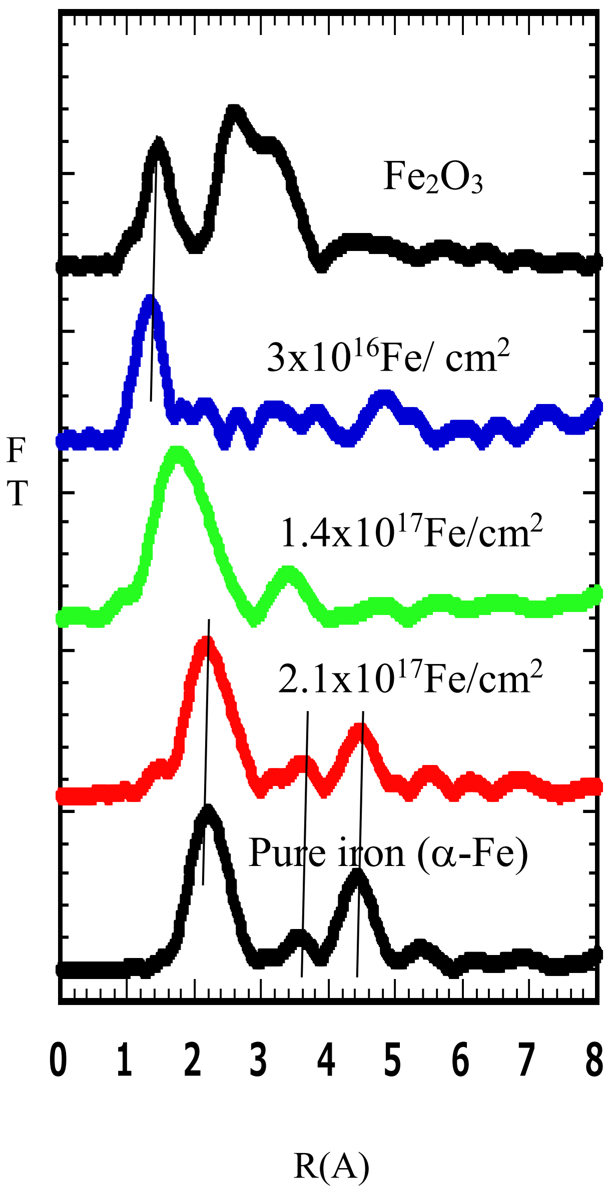

Fig. 1 EXAFS-FT spectra for silica glass implanted with Fe ions. Spectra for Fe_2O_3 and pure iron are also shown.

the shape of the spectrum changes, and for the Fe implantation with the fluence of 2.1x10^{17}/cm^2, the shape of the spectrum is almost the same as that for pure iron. Therefore, we can conclude that Fe iron implantation with the fluence of 2.1x10^{17}/cm^2 produces pure iron (α-Fe) clusters in silica glass. The existence of α-Fe clusters can be confirmed by means of SQUID measurement. Figs. 2 and 3 show the magnetization, M, as a function of external magnetic field, H, (M-H curves) for silica glass implanted with various fluences.

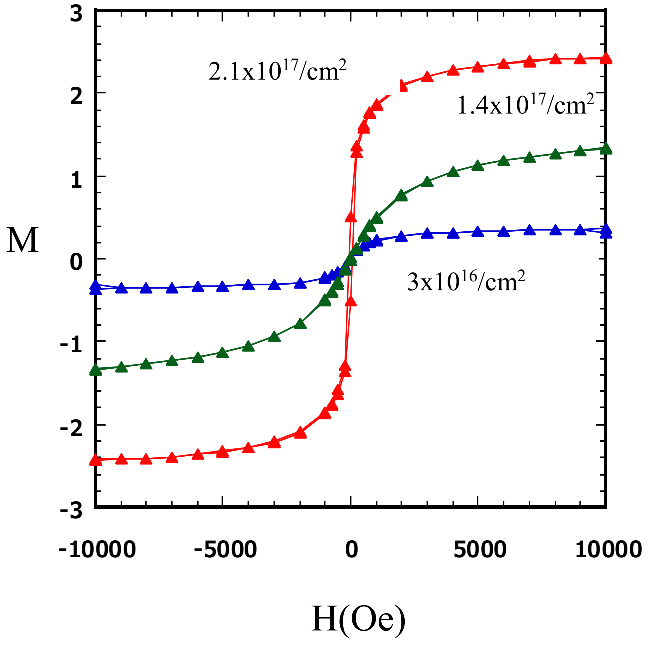

Fig. 2 Magnetization-external magnetic filed (M-H) curves for silica glass samples Fe-implanted with fuences of 3x10^{16}, 1.4x10^{17} and 2.1x10^{17}/cm^2.

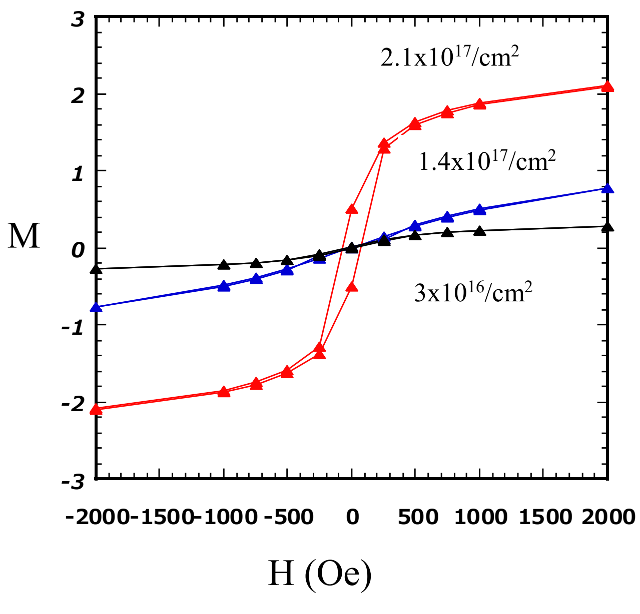

Fig. 3 Magnification of Fig.2 near the origin.

As can be seen in the figures, the magnetization increases with increasing the Fe ion fluence. In the M-H curves for 3x10^{16} and 1.4x10^{17}/cm^2 Fe ion implantation, the hysteresis can hardly be found, meaning that the Fe clusters in such silica glass samples show the (super)paramagnetic character. On the other hand, for the Fe implantation with the fluence of 2.1x10^{17}/cm^2, a clear hysteresis can be observed in the M-H curve. This result is consistent with the result of EXAFS measurement; the Fe ion implantation with the fluence of 2.1x10^{17}/cm^2 produces ferromagnetic α-Fe clusters in silica glass.

References

[1] K. Fukuda *et al.*, Photon Factory Activity Report 2016 #34(2017)B.

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