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Temperature dependence of soft x-ray MCD of Cr-doped GaN

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Transition-metal doped GaN have been of much interest since high Curie temperature ferromagnetism was theoretically predicted. Although ferromagnetic behavior at room temperature was reported on Cr-doped GaN, the origin of the magnetism is still unclear. Here, we performed soft X-ray Magnetic Circular Dichroism (XMCD) measurements to reveal microscopic magnetic characteristic.

Cr-doped GaN films were grown on sapphire substrates by NH_3-assisted MBE. The samples showed ferromagnetic behavior at room temperature. However, with the increase of Cr concentration, paramagnetic component appeared. The both components coexist for the samples with moderate Cr concentrations. X-ray absorption spectra (XAS) were measured in a total electron yield mode around Cr $L_{2,3}$-edge, and XMCD spectra were measured by switching polarity of circular polarized light at the each photon energy. A magnetic field of ± 1.4 T was applied to the sample perpendicular to the sample surface.

XMCD peak intensity of the $Ga_{0.97}Cr_{0.03}N$ film was plotted as a function of temperature in Fig.1. The temperature dependence was well described by the Curie-Weiss law, which suggests paramagnetic behavior. In order to compare magnetic characteristic between total magnetization of the sample and microscopic magnetization on Cr ions, magnetization versus temperature relation measured by SQUID magnetometer is also displayed in Fig.1. Note that finite offset is necessary to fit each other. Namely, the ferromagnetic contribution observed in SQUID measurement as nearly temperature independent component cannot be observed in XMCD measurement.

The XMCD behavior is basically same whether the sample surface was capped with a In layer or not. No effect from sample surface is expected. Contribution from other magnetic impurity is unlikely because we used high purity source for MBE growth. Since the XMCD measurement is limited by the penetration depth of light, ferromagnetic component may come from some limited part like interface in the film. The inconsistency is still not clear at the present.

We also examined Cr composition dependence of XAS spectra. Fig. 2 shows Cr $L_{2,3}$-edge XAS measured at 40 K. It can be seen that the peak position and spectral shape change depending on the Cr concentration. The oxidation state of Cr ions may change with the Cr concentration.

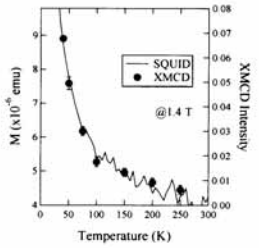

Fig. 1. Temperature dependence of Cr $L_{2,3}$-edge XMCD peak intensity compared with magnetization measured by SQUID magnetometer.

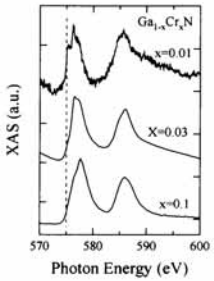

Fig. 2. Composition dependence of Cr $L_{2,3}$-edge x-ray absorption spectra measured at 40 K.

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Magnetic structures of nanostructured transition metals on vicinal Au(788) surfaces

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The fabrication of low-dimensional metal nanostructures has received a great deal of attention in recent years. Theoretical works have predicted the appearance of strongly enhanced magnetic moment for 1 ML films of 3d transition metals on noble metal substrates. Recently, we have observed the growth of transition metals on vicinal Au(111) surfaces by scanning tunneling microscopy and found that dosed atoms are adsorbed at step edges to form one-dimensional (1D) nanostructures via step decoration mechanism. In this study, we examine the magnetic structures of 1D Fe nanostructures formed on a Au(788) surface using magnetic circular dichroism (MCD) in the core-level x-ray absorption spectroscopy.

At the coverage of 0.25 ML, the step edges are fully decorated with dosed Fe atoms, and 1D Fe wires corresponding two or three rows per terrace are formed along the steps. At T=40 K, absorption spectra at the Fe $L_{2,3}$ edges show a significant XMCD signal, suggesting that the existence of the ferromagnetic order for 1D Fe wires in an external magnetic field of 1.4 T. As the temperature is increased, the MCD signal is decreased and almost disappears above 150 K.

As the coverage is increased, 1D Fe adlayers approach the adjacent adlayers in a step-flow growth mode, leading to a 2D-network structure. At the coverage of 1.2 ML, a larger XMCD signal is clearly observed at T=40 K compared to 0.25 ML. With increasing temperature, the MCD intensity is gradually decreased, and paramagnetic nature is found at RT. The temperature dependence of the MCD revealed that magnetic phase transition temperature is decreased with reducing dimensionality, but the MCD intensities per atom are almost same at T=40 K. This result is contrast to larger orbital and spin magnetic moments observed for 1D Co chains on Pt substrates compared to bulk.

Furthermore, we observed a characteristic temperature dependence of the MCD for 0.25 ML Co on Au(788). This is probably due to the difference in growth mode, showing a mixture of 1D Co wires and 2D Co dots.