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Ferromagnetism of $V_{1-x}Cr_xO_2$ studied soft x-ray magnetic circular dichroism

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INTRODUCTION

The field of spintronics is rapidly evolving with exploration of materials being at the forefront of discovery and the catalyst for technology. Spin polarized transport in these materials has become an important effect in exploiting the spin degree of freedom of the electron. Chromium dioxide (CrO_2) is a ferromagnetic half-metal with a high degree of spin polarization and a Curie temperature of 395 K ideal for practical applications. Recent theoretical and experimental analysis indicates CrO_2 is nearly 100% spin polarized. Unfortunately, preparation of single phase CrO_2 thin films is difficult, and present growth methods such as chemical vapor deposition (CVD) are not well suited for multilayer device fabrication. Furthermore, chromium has many oxidation states, including, CrO_3, Cr_2O_5, CrO_2, and Cr_2O_3, and the CrO_2 phase is metastable, and is known to readily irreversibly decompose to the Cr_2O_3 phase at temperatures between 250°C and 460°C. CrO_2 crystallizes in a tetragonal structure, similar to that of the high temperature tetragonal structure of vanadium dioxide (VO_2). Vanadium Dioxide (VO_2) undergoes a first order metal-insulator transition (MIT) at 341 K. The first order phase change is dominated by a structural transformation from a high temperature tetragonal structure to a low temperature monoclinic structure.

EXPERIMENT

The sample studied here are $V_{1-x}Cr_xO_2$ (x=0-0.30) (VCO) thin films. The VCO thin films were grown by a magnetron sputtering on R-sapphire substrate. The sample is annealed in controlled oxygen to obtain a clean surface. The XAS and XMCD measurements were done at BL-16 of KEK-Photon Factory (PF), Japan. The XAS spectra were taken in the total electron yield (TEY) mode.

RESULTS AND DISCUSSIONS

The XAS spectra were taken in a magnetic field of 2T at temperature of 300K and are denoted by μ^+ and μ^- for left and right circularly polarized light, respectively. The XMCD spectrum was obtained by taking a difference between the XAS spectra with negative and positive helicity of the circular polarized light. Figures 1 show the V and Cr 2*p*-3*d* XAS and the XMCD spectra, respectively. The main two groups of the peaks shown in the XAS spectra are due to the $2p_{3/2}$ (L_3 edge) and $2p_{1/2}$ (L_2 edge) spin-orbit components. The V and Cr ions were in the 4+ and 4+ states, respectively, and both sublattices were found to be antiferromagnetically coupled to each other, finding from the opposite signs of the XMCD signals. From the sum rule analysis, the orbital and spin magnetic moments of Cr ions are found to be 0.01 and 0.10 μB/ion, respectively. The magnetization increases significantly with Cr concentration (not shown here), which is promising for future device applications, where one can tune the magnetic properties by varying the dopant concentration.

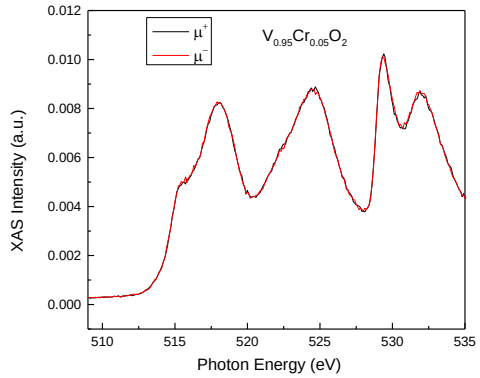

Figure 1: V and Cr $L_{2,3}$-edge XAS and of $V_{0.95}Cr_{0.05}O_2$ thin films.

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