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Grazing Incident X-ray Diffraction Studies on $YMnO_3$ Films

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Multiferroics, which is also called magnetoelectrics, have attracted increasing attention due to coexistence of ferroelectric and ferromagnetic behaviors. More interesting thing is the possibility to control the electric polarization by a magnetic field or conversely the magnetization by an electric field. However, there are very few single phase multiferroic materials due to the chemical incompatibility between magnetism and ferroelectricity. Among them, hexagonal $YMnO_3$ is one of the most well-know geometric frustrated multiferroics and exhibits ferroelectricity below 900 K as well as antiferromagnetic state below 70 K. On the other hand, $YMnO_3$ with orthorhombic perovskite structure does not exhibit ferroelectricity, which tells us that the ferroelectricity in $YMnO_3$ is very sensitive to its crystal structure. Tetragonal or orthorhombic strain may occur for $YMnO_3$ films deposited on different substrates. Detailed structure studies for $YMnO_3$ thin films were presented on this work. $YMnO_3$ thin films with different thickness were deposited on Yttrium-Stabilized-ZrO_2(111) single crystal substrates using Laser Molecular Beam Epitaxy. The roughness of each sample's surface is about 3 nm, which is detected by Atomic Force Microscopy. Only (00l) reflections were observed in X-ray diffraction (XRD) patterns and six-fold symmetry is observed for all films in phi-scanning, which indicates hexagonal $YMnO_3$ with c orientation is formed on YSZ(111) substrate. The out-of-plane lattice parameter decreases with increasing the thickness of the films. It should be noted that there are two sets of crystal structure for hexagonal $YMnO_3$: one is a=0.361 nm and c=1.139 nm with space group P 6_3/mmc, another is a=0.614nm and c=1.14nm with space group P 6_3cm. The in-plane lattice parameters cannot be determined by XRD. Here we used Grazing Incidence XRD (GIXRD) performed in synchrotron radiation facility to determine the in-plane lattice parameters. The depth dependence of in-plane lattice parameters were also measured by GIXRD since that with different incident angle X-ray can penetrate different depth of films. The depth dependence of lattice strain distribution for $YMnO_3$ films indicates that the films include surface layer, strained layer and interface layer.

Keywords: multiferroics, GIXRD, thin film

BR18

Magnetic and Electric Properties of $Mn_{1-x}Fe_xWO_4$ Single Crystal

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In this study, the magnetic and electric properties of $Mn_{1-x}Fe_xWO_4$ (x=0.0, 0.01, 0.02) have been studied by X-ray diffraction (XRD), Superconducting Quantum Interference Device (SQUID), Physical Property Measurement System (PPMS). The crystalline of samples had a monoclinic structure with space group P_{12}/c_1, and the lattice constants and the volumes of unit cell are weakly and linearly increased, respectively, as increasing Fe concentration. It can be explained that Fe is well occupied Mn-site without the other phase or cluster in $Mn_{1-x}Fe_xWO_4$ (x=0.0, 0.01, 0.02) samples. The zero field cooled magnetization curve using SQUID also shows the magnetic phase transition at T_1 and T_2. Magnetic phase transition temperature (T1) which changes from the antiferromagnetic phase to the spiral spin structure is determined to be 7.7 K in $MnWO_4$ sample. The spontaneous electric polarization is revealed with b-axis direction of crystal structure as the value of 25 $\mu C/m^2$ at T_1, and disappeared at 12.5 K(T_2). On the other hands, T_1 and T_2 are measured to be 10.1 K with and 12.1 K in $Mn_{0.98}Fe_{0.02}WO_4$ sample, respectively. It can be explained that the spin-spin exchange interactions are increased by the orbital angular momentum of doping Fe^{2+} ion.