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Magnetic properties and first-order magnetic phase transition in single crystal FeRh thin film

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Abstract –To understand the mechanism of first-order magnetic phase transition in ordered FeRh thin films, the magnetic properties and first-order phase transition behavior of single crystal FeRh thin film are investigated in detail. The first-order magnetic phase transition is seen at a temperature of around 120°C during heating and cooling process. The M-H loops measured at high temperature of AFM-FM transition show an opening at high magnetic field, which indicate a reversible AFM-FM transition induced by magnetic field. The nucleation and growth kinetics mechanism of the AFM-FM phase transition in FeRh thin films is described by classical Kolmogorov-Johnson-Mehl-Avrami (KJMA) model.

It has been known for a long time that a bulk FeRh exhibits a first order magnetic transition between antiferromagnetic (AFM) state and ferromagnetic (FM) state upon heating or under high pressure. Because of the unique nature of such a magnetic phase transition, this alloy system has been widely studied for various physical properties for thin films and bulks. Among them, magnetic properties and structures are noteworthy mentioning. Further studies found that this transition is accompanied by a unit cell volume expansion of 1%–2%, a reduction in resistivity, and a large change in entropy. This opens up interesting possibilities for technological applications such as heat assisted magnetic recording and microelectromechanical system devices. However, the physical mechanism of this first-order AFM/FM phase transition in ordered FeRh-based thin films is still not very clear. To further understand the mechanism of first-order AFM/FM phase transition in ordered FeRh thin films, the magnetic properties and first-order phase transition behavior of single crystal FeRh thin film are investigated in detail in this presentation.

Single crystal FeRh thin film with a thickness of 100nm was fabricated onto MgO(100) substrates by using sputtering from $Fe_{50}Rh_{50}$ alloy target. The substrate temperature during deposition was kept at around 450°C. The structural analysis of the films was performed by X-ray Diffractometer (XRD) and magnetic properties were carried out using a vibrating sample magnetometer (VSM) in fields up to 15kOe.

XRD patterns show that (001) oriented FeRh thin film with ordered CsCl structure were obtained on MgO(100) substrate, and φ-scan confirms that the films exhibit four-fold symmetry in the film plane, indicating that the films are single crystalline films. The first-order magnetic phase transition in FeRh single crystal thin film is seen at a temperature of around 120°C during heating and cooling process. It is seen that the transition temperatures in perpendicular direction is higher than that of parallel parallel. This is most likely due to the arises from the self demagnetization field encountered when the magnetization is perpendicular to the field which tends to retain the formation of the ferromagnetic phase. The M-H loops measured at high temperature of AFM-FM transition show an opening at high magnetic field, which indicate a reversible AFM-FM transition induced by magnetic field. In addition, the phase transition kinetics is also studied by using the time and temperature dependent magnetization measurement. The nucleation and growth kinetics mechanism of the AFM-FM phase transition in FeRh thin films is described by classical Kolmogorov-Johnson-Mehl-Avrami (KJMA) model.