# STRUCTURAL PROPERTIES OF MAGNETITE FILMS GROWN BY PULSED LASER DEPOSITION

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## Introduction

Magnetite has attracted enormous attention due to its half metallic ferromagnetic nature and high Curie temperature [1]. These properties make magnetite a promising material for applications in spin electronic devices such as magnetic tunnel junctions for magnetic random access memory. Various growth techniques, such as electron beam deposition, molecular beam epitaxy, radio-frequency sputtering, and pulsed laser deposition, have been explored in order to obtain magnetite films. Among them, pulsed laser deposition is a promising growth technique for a range of thin films from nanocomposite to epitaxial growth. Its advantages include stoichiometric transfer, growth from an energetic beam, reactive deposition, and inherent simplicity for the growth of multilayered structures.

The magnetite grown on sapphire system is an important candidate for heteroepitaxial magnetic tunneling junction structures involving half metallic magnetite electrodes and an alumina tunneling barrier, which are predicted to exhibit giant tunnel magnetroresistance [2]. In this work, we present the structural properties of the magnetite films grown on sapphire substrates by pulsed laser deposition.

## Experimental

Magnetite thin films were grown on sapphire substrates by pulsed laser deposition. A KrF excimer laser source ($\lambda$=248 nm) with a repetition rate of 2 Hz and a energy density of 2 J/cm$^2$ at the target surface was used to ablate the target. Before each deposition, the chamber was evacuated to a pressure of $2.4\times10^{-7}$ Torr using a turbomolecular pump. The substrate temperature was monitored using a thermocouple and controlled at 600℃. X-ray diffraction and Raman spectroscopy were used to study the structural properties of the magnetite thin films. The magnetic properties of the magnetite thin films were investigated by the vibrational sample magnetometer at room temperature.

## Results and Discussion

The X-ray diffraction pattern of the magnetite film on sapphire substrate grown at a substrate temperature of 600℃ is shown in Fig. 1. Two diffraction peaks related to the (222) and (333) reflections from magnetite are clearly observed together with the peak of (0006) reflection peak from sapphire substrate, suggesting that the magnetite is epitaxially grown on sapphire substrate and the preferred orientation of the obtained magnetite film is along the <111> direction. The lattice constant which was determined from the (222) peak in Fig. 1 for the magnetite is 8.4Å, which is in good agreement with that reported for the stoichiometric value of magnetite.

It is known that hematite, maghemite, and wüstite may also be formed in the case of the growth of magnetite thin films. Since the crystal structures and lattice constants for magnetite and maghemite are quite similar, it is difficult to rule out the presence of maghemite in magnetite thin films only by X-ray diffraction pattern. Raman spectroscopy is highly sensitive to the chemical composition of crystalline materials [3]. Therefore, we performed Raman spectroscopy measurements in order to further confirm the structure of the magnetite film. The Raman scattering was recorded in the backscattering geometry using an Ar ion laser at 488 nm. Figure 2 shows the Raman spectrum obtained at room temperature for the magnetite film. Raman peaks related with only magnetite are observed for the thin films grown at a substrate temperature of 600℃. We note that the peak appeared at 418 cm$^{-1}$ is ascribed to the $A_{1g}$ mode of sapphire substrate and no Raman peaks related with maghemite and wüstite are observed for the magnetite film obtained in this work. The results indicate that the single phase magnetite films can be obtained by pulsed laser deposition.

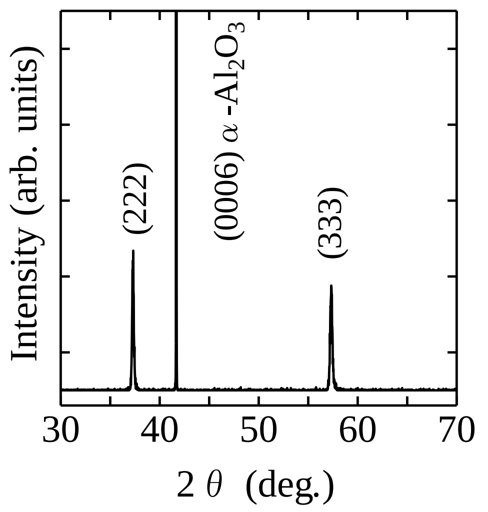


**Figure 1** X-ray diffraction pattern of the magnetite film on sapphire substrate grown at a substrate of 600℃.

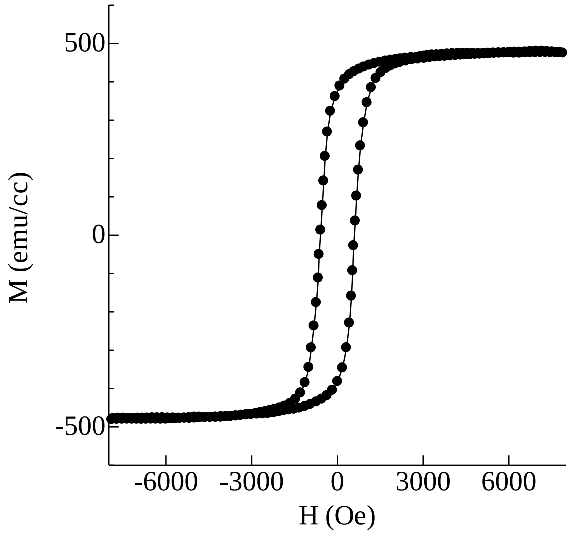


**Figure 3** Magnetic hysteresis loop of the magnetite film on sapphire substrate grown at a substrate of 600℃.

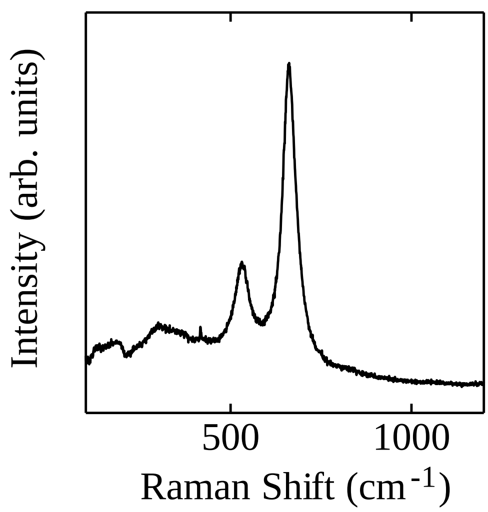


**Figure 2** Raman spectrum obtained at room temperature for the magnetite film on sapphire substrate grown at a substrate of 600℃.

Magnetic hysteresis loop of the magnetite film grown at a substrate temperature of 600℃ is shown in Fig. 3. The external magnetic field was applied parallel to the plane of the sapphire substrate. From Fig. 3, we find that the saturation magnetic moment of the single phase magnetite thin film is 483 emu/cc, which is in good agreement with the value reported for bulk magnetite. We note that the best saturation magnetic moment of the magnetite film on sapphire substrate reported by Parames et al. [4] is 315 emu/cc. It is well known that the physical properties such as magnetic behavior of magnetite is strongly affected by the presence of antiphase boundaries, which are growth defects resulting from the nucleation of islands corresponding to a stacking fault in the iron cation sublattice. The observed bulk-like magnetic properties from our sample suggests that the magnetite film is of high crystal quality without antiphase boundaries.

**Conclusion**

We have grown magnetite thin films on sapphire substrates by pulsed laser deposition at a substrate temperature of 600℃. X-ray diffraction and Raman spectroscopy revealed that the obtained magnetite film is of high crystal quality without antiphase boundaries, suggesting that the pulsed laser deposition is a promising technique to grow high quality of magnetite for applications in spin electronic devices.

**References**


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