Magnetic Oxide Films for Optical Isolators and Magneto-Electronic Devices

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We have established a thin-film laboratory that includes a pulsed-laser deposition (PLD) system and an ultra-high vacuum sputter/analysis system. In PLD, a high-energy excimer laser is used to ablate a target, releasing a plume of material that deposits on a substrate to form a thin film. The PLD is particularly useful for making complex materials such as oxides because it preserves the stoichiometry of the target material.

We have been using PLD to deposit a variety of oxide films for magneto-optical devices such as isolators. These materials include iron oxide, which can adopt one of four different ferrimagnetic or antiferromagnetic structures depending on deposition conditions, and bismuth iron garnet (BIG, Bi₃Fe₅O₁₂), which is useful for magneto-optical isolators in photonic devices. The ideal material for an isolator combines high Faraday rotation with high optical transparency. Garnets have excellent properties but do not grow well on silicon substrates, making it difficult to integrate these materials. In contrast, iron oxide (maghemite) grows very well on MgO or Si, with high Faraday rotation but its optical absorption is high. Recently we have examined magnetic perovskite thin films such as Fe-doped barium titanate (Figure 1) [1] and Ce-doped orthoferrites (Figure 2). These materials show strong magneto-optical properties with weak optical absorption and the films grow with good quality onto MgO substrates. These films could be useful for waveguide isolators and other magneto-electronic devices in which optical absorption losses are critical. A second project involves the use of electrochemical methods to control the magnetization of iron oxide spinel structure films (magnetite or maghemite) grown on conducting substrates, making a chemically-switchable material. The insertion of Li ions by electrochemical discharge changes the oxidation state of the Fe(III) to Fe(II) and can reduce the magnetization of the film by about 30%, in a reversible process. Recent experiments on nanoparticles of iron oxide show much greater changes in magnetization, up to ~80%, indicating that the process is kinetically limited.

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**Figure 1:** Faraday rotation vs. applied field for 750-nm-thick BaTi₀.₅Fe₀.₅O₃ and BaTi₀.₈Fe₀.₂O₃ films grown in a vacuum on MgO substrates, with the field perpendicular to the film.

**Figure 2:** Faraday rotation vs. applied field for 500-nm-thick CeFeO₃ and YCeCoFeO₆ films grown in a vacuum or under 6-mTorr O₂ pressure on MgO substrates, with the field perpendicular to the film.

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**REFERENCES**