Magneto-optical Studies of GaMnN Thin Films

Patricia Nichols, University of Pittsburgh, Pittsburgh, Pennsylvania, SURF 2007 Fellow
Faculty Advisor: Dr. Ian Ferguson   Mentors: Zaili Fang, Shalini Gupta, Matthew Kane

Introduction

Spin Transport Electronic Devices manipulate both fundamental properties of electrons; the electron spin stores the information while the electron charge carries it. In comparison to traditional electronic systems currently available, spintronic devices can produce higher information storage densities, faster data manipulation, and lower power consumption. The material properties required include a semiconductor that supports a magnetic moment at room temperature. Dilute magnetic semiconductors are traditional semiconducting materials doped with transition metal ions. This study investigates gallium nitride films doped with manganese ions. GaN is a wide-band gap semiconductor with theoretical predictions for high Curie temperature after doping, which allows for magnetic functionality at room temperature. Mn has 5 unpaired electrons in the d-shell so it demonstrates a large observed spontaneous magnetic moment. Magnetic Circular Dichroism, a magneto-optical experimental method, is utilized to gain information about the magnetic properties of the GaMnN thin films. The goal of this research project was to optimize and calibrate the MCD setup in order to test GaMnN thin films.

Procedure

MCD consists of circularly polarized light passing through a sample in a magnetic field. A detector at the end of the optical path is connected to electronic amplifiers and a computer system to collect the resulting AC and DC signals. In the presence of a magnetic field, ferromagnetic ions show an MCD signal. Potassium ferricyanide diluted in water was established as a calibration standard based on literature reference. The GaMnN thin films were grown by metal organic chemical vapor deposition (MOCVD) on sapphire substrates with a film thickness of 1 micron and a composition of 1% Mn.

Results and Discussion

Several factors contributed to optimization of the MCD setup including installation of a high wattage lamp with smooth light spectrum, isolation of electronic equipment, and alignment of optical components. The high wattage lamp provided higher intensity light which passed through the sample substrate more effectively. Isolation of electronic equipment reduced the noise found in the MCD signal. Alignment of all optical components was essential to minimize the reduction of light intensity.

After optimization, potassium ferricyanide was measured and found to correlate to the literature reference with MCD signal shape and peak around 425nm as presented in Figure 1.

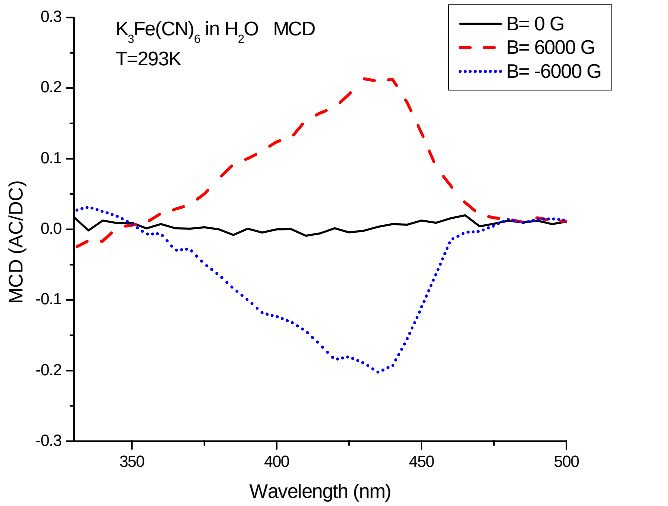

Figure 1: Potassium Ferricyanide MCD
For literature comparison see Castiglioni, CD Spectropolarimetry (2001) 11.

Based on previous studies, GaMnN has potential to demonstrate a weak MCD signal at room temperature and a stronger signal at cryogenic temperatures. Figure 2 illustrates the MCD signal of GaMnN film with polished substrate at 0G and 5000G magnetic fields. If present, the signal at 5000G is so small that it is within the noise floor of 0G. Future studies should investigate the signal at cryogenic temperatures because it reduces the thermal vibration interference. Increased thinning of the sapphire substrate would allow a stronger MCD signal because the overall light intensity would be higher.

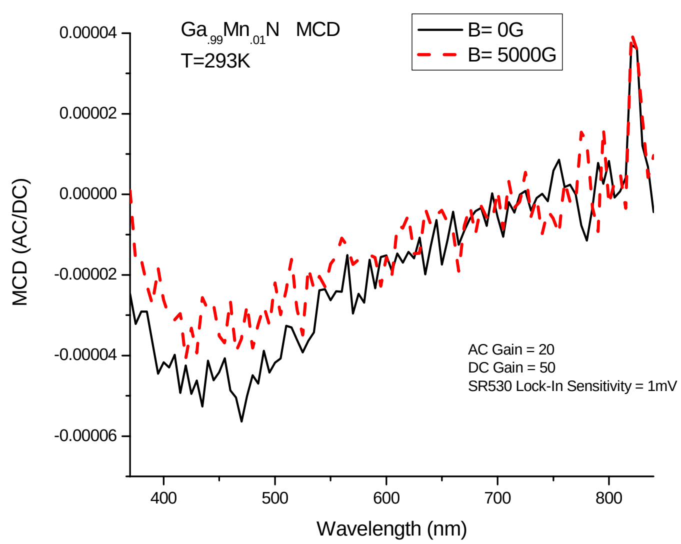

Figure 2: GaMnN MCD

Conclusion

Magnetic Circular Dichroism, when appropriately optimized and calibrated, is an important experimental technique to gain magnetic information about GaMnN thin films in addition to any dilute magnetic semiconductor material.