IV AND CV CHARACTERISTICS OF MULTIFUNCTIONAL
ILMENITE-HEMATITE 0.67FeTiO3-0.33Fe2O3

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Abstract – We investigated the IV and CV properties of an [(FeTiO3)0.67 (Fe2O3)0.33] epitaxial thin film. The four point probe (4pp) measurements revealed that the material has a linear IV relation and has a resistivity of approximately 0.56 Ω cm. In contrast, the two point (2pp) measurements are highly non-linear suggesting the existence of Schottky barriers. The CV data suggest that the material under the contacts is depleted. From the corrected CV data, the carrier concentration is found to be of the order of 10^{23}/cm^3.

Keywords: Ilmenite-hematite, multi-functional materials, CV, IV

1. Introduction

In conventional electronics, devices manipulate charge in order to store and transfer data. The emerging technology of spintronics uses the phenomenon of electron spin to encode data. Spintronic devices, such as the spin MOSFET first proposed by Datta and Das,\textsuperscript{1} combine charge transport with spin-dependent effects that arise from the interaction of the charge and properties of the magnetic materials. A major obstacle of spintronics development has been in finding materials with both ferromagnetic and semiconductor properties above room

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temperature. The ideal ferromagnetic semiconductor should have the Curie point well above the device operating temperature, have high mobility, exhibit a spin-split band structure and be controllably doped to produce p-type or n-type material.

The prediction of Curie temperatures much above room temperature in ferromagnetic semiconductors\(^2\) has led to the approach of doping nonmagnetic semiconductor material with magnetic ions. Alternatively, one can investigate materials that are ferro- or ferrimagnetic above room temperature and have semiconductor properties. Individually, ilmenite (FeTiO\(_3\)) and hematite (\(\alpha\)-Fe\(_2\)O\(_3\)) are antiferromagnetic insulators, but compositions of ilmenite-hematite (IH) \([(FeTiO_3)(1-x)-(Fe_2O_3)x]\) are ferrimagnetic over a wide composition range.\(^3,^4\) IH systems with a Curie point above room temperature have been demonstrated.\(^5\) Furthermore, adjusting the composition can produce p- or n-type material.\(^6\)

Although the magnetic properties of IH systems have been well documented, data on its dielectric constant, its mobility, and the type of contact it makes to metals are scarce in literature. IH is a multifunctional material; its unique magnetic and dielectric properties make the interpretation of results obtained with standard semiconductor characterization techniques far from trivial. In this paper we attempt to characterize some of the electric properties of the IH system that will be important for a potential device. The focus is on the characterization of metal semiconductor contacts by IV and CV analysis.

2. Experimental Details

2.1. SAMPLE PREPARATION

The IH film was deposited on a single crystal sapphire substrate (10 × 10 mm) by pulsed laser deposition (PLD). The deposition was carried out in an argon atmosphere of \(10^{-3}\) Torr and at a substrate temperature of 750°C.\(^7\) The epitaxial \([(FeTiO_3)_{0.67}(Fe_2O_3)_{0.33}\) (IH-33) thin film has a thickness of 92 nm as determined by XRR. An Al\(_2\)O\(_3\) layer (142 nm) with a width of approximately 4 mm was deposited at the center of the sample by PLD, leaving on both sides a strip of approximately 3 mm of exposed IH. Six silver contacts were made on the perimeter of the exposed IH thin film using silver epoxy (three on each surface area). A 7th contact was made on top of the oxide in the center of the sample by sputtering Pt through a mask of approximately 2 × 2 mm. Since the oxide contained pinholes or cracks, this center contact should be considered to be a metal-semiconductor contact of which we do not know the effective surface area. The Ag contacts were annealed at 120°C for 20 min to reduce their resistance. The area, the perimeter, and the position of each contact were determined by using a digital top view image of the sample loaded into the Canvas software.