DC and AC Characterization of Magnetic Field Sensors with Ultrathin Magnesium Oxide Tunnel Barriers

M. Arikan[a], S. Ingvarsson[a], M. Carter[b] and G. Xiao[c]

[a] Science Institute, University of Iceland, Dunhagi 3, Reykjavik IS107, Iceland

[b] Micro Magnetics Inc., 617 Airport Road, Fall River, Massachusetts, 02720, USA

[c] Physics Department, Brown University, Providence, Rhode Island, 02912, USA

We have studied the magnetoimpedance of micron sized magnetic tunnel junction (MTJ) sensors with 1.7 nm magnesium oxide (MgO) tunnel barrier [1]. Both DC and AC properties of the sensors were measured by means of tunneling magnetoresistance (TMR) and AC impedance spectroscopy between 100 Hz and 40 MHz as a function of applied external magnetic in the sensing direction. The results have basic scientific importance and should affect the design of novel sensing devices. Two different kinds of sensor were investigated in this work: Single and multiple-MTJ sensors. In the first case, the sensors included only one tunnel junction. The structure of the magnetic tunnel junctions is as follows [2] (thicknesses in nanometers): Ta(5)/Ru(30)/Ta(5)/$Co_{50}Fe_{50}$(2)/IrMn(15)/ $Co_{50}Fe_{50}$(2)/Ru(0.8)/$Co_{40}Fe_{40}B_{20}$(3)/MgO(1.7)/$Co_{40}Fe_{40}B_{20}$(3)/Ta(5)/Ru(10). They were sputter deposited on thermally oxidized Si wafer substrates. Measured DC resistances of the sensors are on the order of 1 k with very high TMR values between 118 % and 137 %. The samples were also measured by frequency dependent AC impedance spectroscopy. A simple RLC circuit model used to fit the data. The results are in agreement with DC measurements. Contrary to the previous reports in the literature [3, 4], we didnt observe field dependent spin-capacitance despite excellent agreement in other parameters such as interface capacitance. We attribute this discrepancy to the size of our samples and reach a conclusion that limits the applicability of the spin-capacitance concept to large area devices. In the second part of this work, we have measured multiple-MTJ sensors based on the same structure given above [5]. Each sensor had 24 MTJs, connected in series in a serpentine shape. The DC resistances were on the order of 1 to 10 k with TMR values between 89.5 % and 140.9 %. AC measurements agreed very well with DC results and the data was modeled by using a simple RLC circuit. Unlike the single junction devices, we observed non-zero magnetocapacitance and magnetoinductance besides magnetoresistance. We explain this as a result of the sensor geometry. We show that magnetocapacitance can be used to detect the DC magnetic fields and give the sensitivity of our devices.

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