CALIFORNIA STATE SCIENCE FAIR
2015 PROJECT SUMMARY

Name(s)

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Project Number

S1710

Project Title

Characterization of Magnetic Tunnel Junctions for Next-Generation Energy-Efficient Memory Technologies

Abstract

Objectives/Goals

Magnetoresistive random-access memory (MRAM) combines fast read/write time, high endurance, and nonvolatile storage. Magnetoelectric RAM (MeRAM), a new class of MRAM, uses voltage-controlled magnetic anisotropy (VCMA) and high resistance-area product (RA) to lower coercivity and limit the writing current when changing the polarity of the ferromagnetic layers in a magnetic tunnel junction (MTJ). High tunnel magnetoresistance (TMR) enables the resistance-state of an MTJ to be read accurately with greater tolerance and thus less sensitive, less expensive reading devices. The objective of this project is to characterize the relationship between TMR and RA to improve energy-efficiency and lower cost.

Methods/Materials

Using sputtering deposition and photolithography, MTJs were fabricated with an MgO insulator layer of graduated thickness between conductive Co(40)Fe(40)B(20) ferromagnetic layers. Ta buffer layers develop perpendicular magnetic anisotropy and a Pt cap prevents unwanted oxidation. To determine TMR and RA, the voltage across each MTJ was measured with a four-point DC probe station using a 0.01 mA current and a magnetic field sweeping between ±600 Oe.

Results

TMR has a maximum for MgO thickness, indicating optimal oxidation: peak TMR occurs when the MgO layer is oxidized and insulating and the CoFeB layers are un-oxidized and conducting. RA values increase exponentially with MgO thickness and are nearly identical across MTJ sizes, reflecting both the exponentially decreasing electron wave amplitude in the insulator and the resistance-resistivity relationship. RA, found to be above 1000 ohm micron sq, is sufficiently high at TMR peak to limit the current during VCMA switching.

Conclusions/Discussion

Sputtering deposition on buffer layers is sound and allows highly spin-dependent tunneling to occur. However, peak TMR is too low for application purposes, due to the possibility of reading error caused by antiparallel and parallel resistance overlap. A trade-off between TMR and RA is required, indicating TMR improvement is key. Sidewall redeposition, due to etching, and magnetic material damage, due to reactive etching chemicals, may be affecting resistance and suppressing TMR, and are the subject of further investigation and remediation.

Summary Statement

Magnetic tunnel junctions were tested for tunnel magnetoresistance and resistance-area product and fundamental relationships established, indicating the need to control the adverse effects of fabrication on resistance.

Help Received

Mentored and supervised by the UCLA lab of Dr. Kang Wang.