Spin-Torque Switching in MgO-based Magnetic Tunnel Junctions for Next Generation Non-Volatile Memory Applications

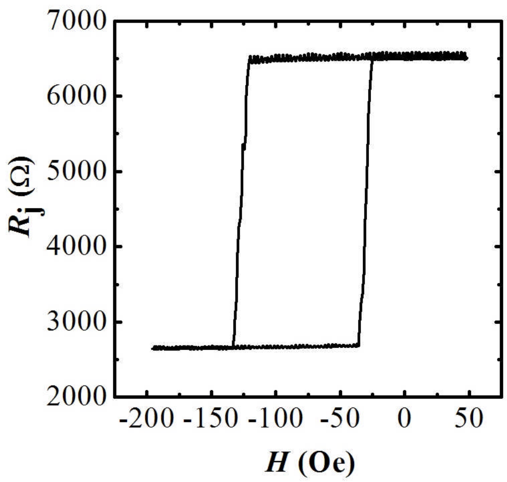
Solomon Assefa, J. Nowak, J. Z. Sun, E. O'Sullivan, S. Kanakasabapathy, and W. J. Gallagher
IBM TJ Watson Research Center, Yorktown Heights, NY 10598, USA
Y. Nagamine, K. Tsunekawa, D. D. Djayaprawira, and N. Watanabe
Electron Device Equipment Division, Canon ANELVA Corporation,
5-8-1, Yotsuya, Fuchu-shi, Tokyo 183-8508, Japan

When injected spin polarized electrons interact with the magnetic moment of a free layer, their angular momentum becomes transferred to the free layer [1, 2]. If sufficient current is applied, the exerted torque switches the free layer either parallel or anti-parallel to the pinned layer depending on the direction of flow of the current. This type of localized current switching is attractive for an MRAM application because it does not have the half-select problems of conventional MRAM. Moreover, current requirements for spin transfer switching go down as devices scale to smaller sizes, which makes current-induced spin transfer a good potential scaling path for the MRAM write operation.

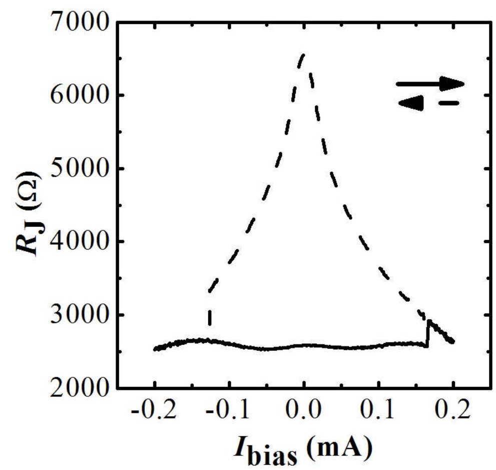
The work presented here explores the fabrication and characterization of MgO-based sub-100nm magnetic tunnel junction (MTJ) devices for current-induced spin-transfer switching. The devices were fabricated on one inch substrates utilizing a self-aligned lift-off process. Resist shapes defined by electron-beam lithography were used as a mask to ion-beam etch (IBE) the MTJ structures into the magnetic films. The etch depth was determined by utilizing secondary ion mass spectroscopy (SIMS) signal in order to stop on the tunnel barrier. The resist remaining after ion milling was subsequently used as a self-aligned mask to lift-off a deposited insulator film layer. The process was completed by the patterning of the bottom and top electrodes.

The fabricated tunnel junctions were characterized at room temperature with a quasi-static electrical measurement setup. Based on current-in-plane tunneling (CIPT) characterization, the blanket films had resistance-area (RA) product of ~10 $\Omega\text{–}\mu m^2$ and tunneling magnetoresistance (TMR) of ~160%. The properly patterned devices demonstrated RA of ~15 $\Omega\text{–}\mu m^2$ and TMR of ~150%, comparable to the values obtained on the un-patterned blanket wafers. Furthermore, TMR obtained by field-sweep and current-sweep was equal in magnitude, indicating complete current-induced magnetic switching between parallel (P) and anti-parallel (AP) states. While applying an external field of -68Oe, the MTJ devices switch from P→AP at 0.15mA and switch back from AP→P at -0.13mA. Based on these results from one inch substrates, processes were developed in order to build spin-torque memory devices on 200mm wafer utilizing the 0.18μm fabrication facility at IBM. Preliminary results obtained from characterization of the devices will be discussed.

1. 1. J.C. Slonczewski, *J. Magn. Magn. Mater.* **159**, L1-L7 (1996).
2. L. Berger, *Phys. Rev. B* **54**, 9353-9358 (1996).



1 (a)



1 (b)

Figure 1: On one inch substrates (a) R (H) measurement on a 50nm by 150nm elliptical device shows RA~15 Ω-μm^2 and TMR~150%. (b) R (I) measurement at an external offset field of -68Oe shows P→AP and AP→P switching at +0.15mA and -0.13mA respectively. The TMR values in (a) and (b) are equal, indicating current-induced complete magnetic switching.