Serial MTJ sensors based on MgO in bridge configuration for in-chip current field detection

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Nowadays and more than ever, control and precision regarding electronic circuits became very important, especially concerning microelectronic devices where electrical current, power and energy measurements have been a matter of concern. New precise, integrable, low power consumption and low cost devices are demanded and they are mainly needed in integrated circuits (IC), systems-on-chip (SOC), micro-electromechanical systems (MEMS), among others.

Magnetic tunnel junctions (MTJ) have been currently used as sensors for electrical currents measurements in IC. In addition, these sensors have also been used in Wheatstone bridge configuration for low current measurements [1]. Current lines are integrated on top of the sensor.

In this work a new configuration is being used: instead of a Wheatstone bridge of 4 singular sensors, we are using a bridge of 4 series of MTJ's. Each bridge's branch has 380 sensors connected in series. The design was projected using CAD and besides bridges, isolated sensors and isolated series were also designed as reference (Fig.1). MTJ's structure was deposited by magnetron sputtering in Nordiko 2000 sputtering system [2] and microfabricated using photolithography by direct write laser. Each active sensing element has an area of 2x30 μm^2.

Devices were characterized using an external magnetic field in the range [-140,140]Oe. An isolated individual MTJ sensor presented a TMR of 101.7% for a 5.0mV of bias voltage, with a linear range between 0 Oe and 50 Oe and RxA = 90.9 $k\Omega\mu m^2$. A sensibility of 13.05Ω/Oe was achieved for this sensor (Fig. 2).

Concerning a bridge (4 MTJ series of 380 sensors) it was obtained a TMR of 56.54% using a bias current of 5.0μA. Output had a linear response between 0Oe to 55Oe, presenting a sensibility in this range of 2.29 kΩ/Oe (Fig. 3).

Using MTJ elements connected in series increases the total magnetic volume of the sense layer (~N x V_{free}) and thus allows using bias currents as large as needed, up to several amperes, which means a higher output of the sensor for the same input when comparing to single sensors. It also has the advantage of getting a lower noise level in measurements.

References

[1] "Magnetic Field Sensors Based on Giant Magnetoresistance (GMR) Technology: Applications in Electrical Current Sensing", Càndid Reig, María-Dolores Cubells-Beltrán, Diego Ramírez, Sensors 2009, vol9, pp. 7919-7942, October 2009.

[2] "Effect of CoFeB thickness and shape anisotropy on the transfer curves of MgO Magnetic Tunnel Junctions", P.Wisniowski, S.Cardoso, P.P.Freitas, J.Appl.Phys., vol.103, pp.07A910-07A912, April 2008.

Figures

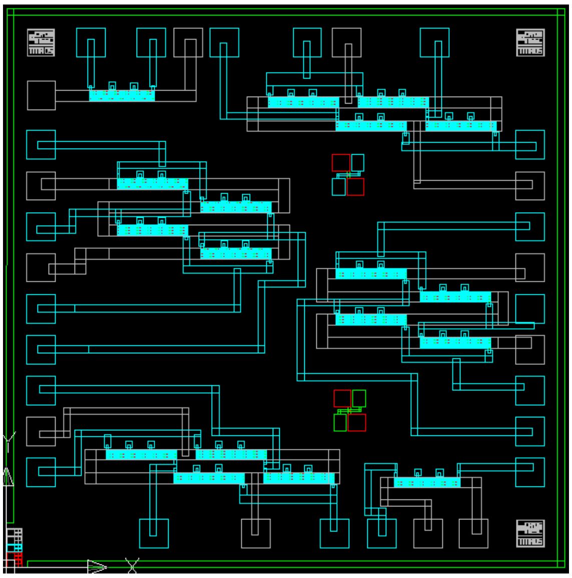

Figure 1: Mask design

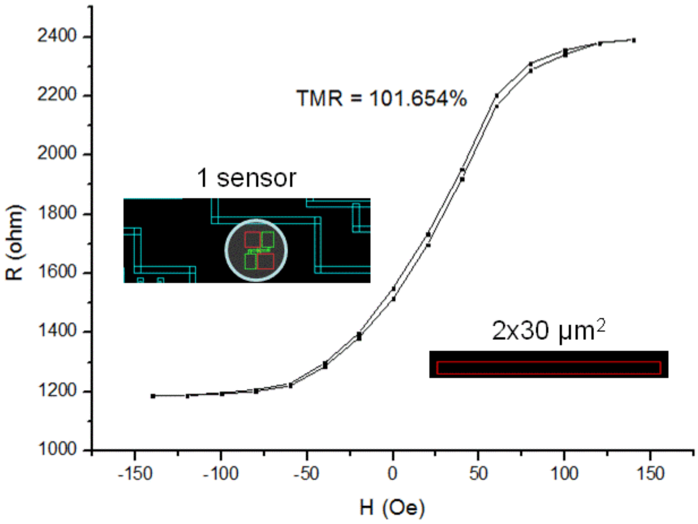

Figure 2: Isolated sensor output

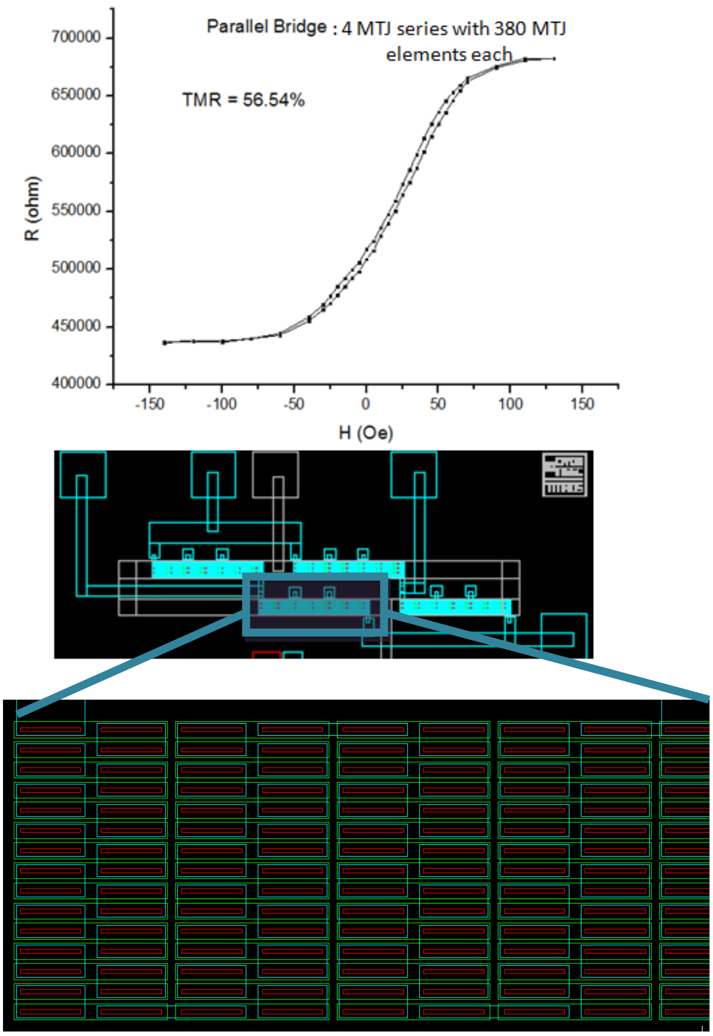

Figure 3: Bridge (4 MTJ series) output

Figure 4: Sample structure