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Controlled pulse shape cooling in planar TAS-STT-MRAM for improved writeability.

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I. INTRODUCTION

In field written thermally assisted (TAS) MRAM, the storage layer is pinned with an antiferromagnetic layer. The writing of TAS-MRAM consists of heating the storage layer above the blocking temperature of the antiferromagnet using an injected current pulse through the tunnel barrier. This pulse can be used to assist the writing either combined to an external magnetic field or to a spin transfer torque (STT) [1] effect coming from the spin polarized current flow. After setting the storage layer direction during the write step, the current pulse is removed, pinning the storage layer in the set direction. The actual temperature decay occurs in a timescale of few tens of nanoseconds [2]. STT is efficient while the current is flowing through the junction but disappears during cooling, once the heating pulse is removed. This assumption is valid if the temperature gradients across the barrier, giving rise to spin accumulation of thermal origin are negligible. In these conditions, when the temperature is above or close to the blocking temperature of the antiferromagnetic layer pinning the storage layer, the written state might be thermally unstable. In this paper, we have investigated the possibility of controlling the temperature decay, so that the spin polarized current and temperature decay at the same rate. We show that there is an improvement in writing reproducibility using a linear transition at the end of the current pulse during the cooling phase. This is especially evident in cases where STT influence on the field writing is more significant. The write error rate dependence with the voltage transition duration was measured, and we find an optimum value for a 70ns transition, corresponding to a linear pulse amplitude decay of 18mV/ns.

II. STT EFFECT, SUSTAINED WITH INCREASING VOLTAGE THANKS TO LINEAR PULSE TRANSITION FOR COOLING

We measured writing state diagrams of TAS-MRAM magnetic tunnel junctions as function of magnetic field and pulse voltage. Current flow direction was reversed, using positive and negative polarities for the heating pulse voltage sent through the junction to evaluate the effect of STT on the writing. We observe that STT results in a reduction of the writing field to obtain the Rmin (Rmax) parallel (antiparallel) state with positive (negative) polarity of the heating pulse (Fig 1). The electron flow direction is from the reference to storage layer for positive polarity favoring the Rmin state.

In the case where a sharp pulse transition of 2.5ns is used (Fig. 1a), the reproducibility of the written state is reduced as the pulse voltage increases. It can also be seen that, even if the correct pulse polarity for STT assisted field switching is used, there is a decrease in switching probability as the pulse amplitude is increased. This is contrary to the expected behavior, where higher pulse current density should result is a larger STT effect.

It is possible to obtain reproducible STT assisted switching when writing a state with the correct current polarity, by introducing a linear pulse transition of 70ns during cooling, at the end of the heating pulse (fig. 1b). In this case the writing probability dependence with field is constant, even as the pulse voltage is increased from 1.1V to 1.3V.

III. WRITEABILITY DEPENDANCE WITH TRANSITION DURATION

We measured the writing probability by cycling 800 times using different pulse trailing transitions for 1.3V amplitude, having the correct polarity for STT assisted switching. The pulse width was kept constant at 50ns and the width of the trailing linear transition was varied from 2ns to 150ns. We measured that the error rate decreases quickly for trailing transitions from 2ns up to 50ns. This is attributed to the assistance of the STT effect, which may reach an optimum value at 70ns. The physical mechanism for this optimum value is still under investigation, but one possibility is that the written state might be unstable just after writing if the STT current is decreased to zero while the temperature is still above or close to the blocking temperature. Another possibility is for the effect to be related to some micromagnetic configuration after writing. In conclusion, we have demonstrated that using a trailing pulse linear transition of 70ns during the cooling period of the thermally assisted writing, the writing error rate can be decreased by on order of magnitude, using spin transfer torque assistance to stabilize the written state.

1) I L Prejbeanu, R Sousa "MRAM Cell and Method for Writing to the MRAM Cell using a Thermally Assisted Write Operation with a Reduced Field Current" - US Patent No US20130182499 A1 (2013)

2) C. Papusoi, R. Sousa, J. Herault, I.L. Prejbeanu and B. Dieny "Probing fast heating in magnetic tunnel junction structures with exchange bias", *New Journal of Physics* 10 (2008) 103006

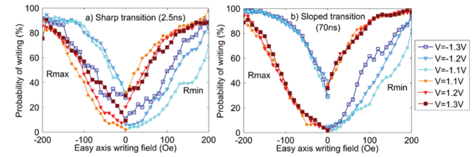

Fig. 1: Writing probability is higher (writing field lower) using the advantageous polarity from STT point of view. Using a pulse with a sharp voltage trailing transition (a) the difference between advantageous and disadvantageous voltage polarity (efficiency of STT) decreases when voltage increases from 1.1V to 1.3V. Using a pulse with a trailing transition (b), the efficiency of STT is sustained with increasing voltage.