STT-RAM with a Composite Free Layer: High Thermal Stability, Low Switching Barrier, and Sharp Switching Time Distribution

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Perpendicular MTJs (p-MTJ) with interface-induced anisotropy show great potential for future memory applications, but still require damping reduction and thermal stability increase [1]. A penta-layer MTJ with a composite free layer proposed in [2] has demonstrated a substantial decrease of the switching time and current. The free magnetic layer of such a structure consists of two half-ellipses separated by a non-magnetic spacer (Fig.1). In contrast to [1], the magnetization of the magnetic layers lies in-plane. This allows to broaden substantially the scope of the magnetic materials suited for constructing MTJs and to boost the thermal stability factor while keeping the switching fast. As the physical reason of the fast switching we found that the switching processes of the left and right part of the composite free layer occur in opposite senses to each other. Each half of the free layer generates a stray magnetic field which influences the other half and helps accelerating switching (Fig.1). It is important that under the influence of the magnetic fields generated by either half of the composite free layer the switching mostly occurs in the *x-y* plane. This fact means that, as in p-MTJs, the switching barrier in an MTJ with composite free layer becomes practically equal to the thermal stability barrier defined here by shape anisotropy. Fig.2 shows the thermal stability factors for MTJs with a composite free layer as function of the short axis. An MTJ with 52.5×10nm^2 cross section and 5nm thickness of the free layer has a thermal stability factor ~60kT, which exceeds that for the p-MTJ demonstrated so far [3]. Another important advantage of using a composite free layer is that the width of the switching time distribution for the MTJ with a composite free layer is ~10^2 times sharper than that for the MTJ with a monolithic free layer (Fig.3).

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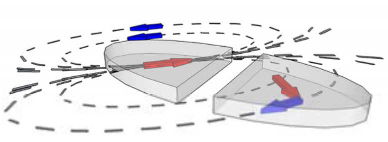

Fig.1. Schematic illustration of the switching principle in MTJ with composite free layer.

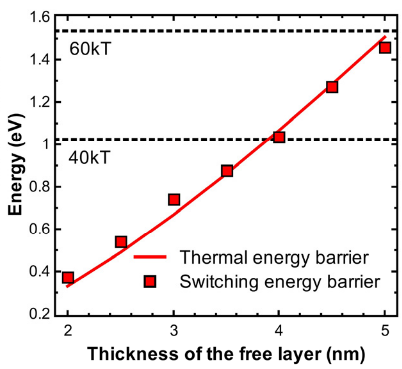

Fig. 2. Thermal energy versus switching energy barriers for MTJs with composite free layer and 52.5×10nm^2 cross-section as function of thickness of the free layer.

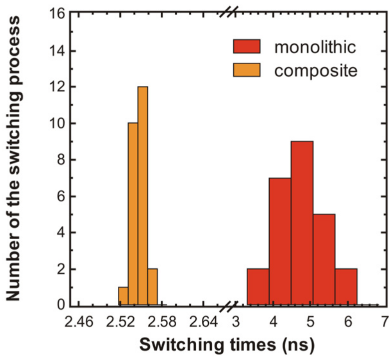

Fig. 3. Distribution of the switching times for an MTJ of 155×60nm^2 cross-section with monolithic and composite free layer.

References

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