Buffer influence on magnetic dead layer, critical current and thermal stability in magnetic tunnel junctions with perpendicular magnetic anisotropy

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SWISS CONTRIBUTION

Motivation

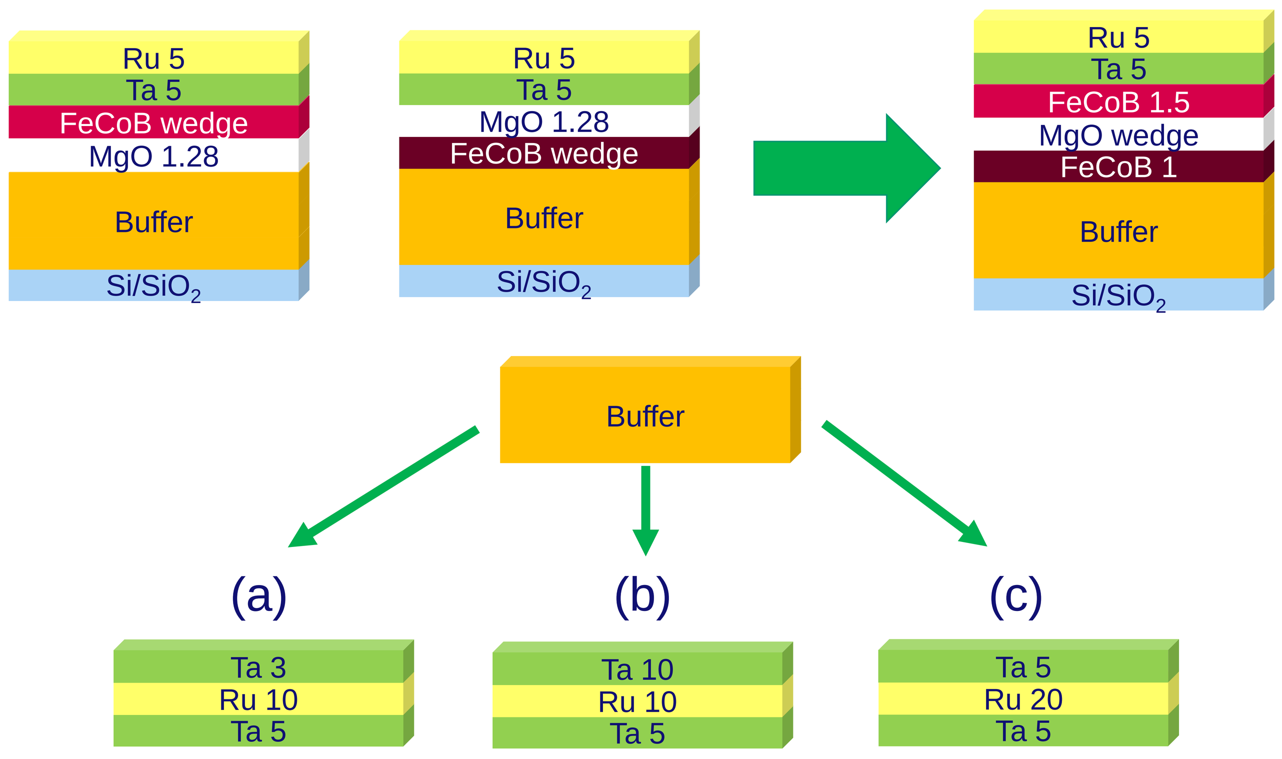
Magnetic Tunnel Junctions (MTJs) with Perpendicular Magnetic Anisotropy (PMA) have recently brought a significant attention in view of application as high-density non-volatile magnetic random access memory due to their possible low critical current density, good thermal stability and downscalable junction size.

Aims

In order to optimize critical current and thermal stability of MTJs we investigate Ta/Ru-based buffer influence on the microstructure and magnetic properties. We examine current-induced switching in nanopillars and perform additional measurements of damping in order to explain obtained results.

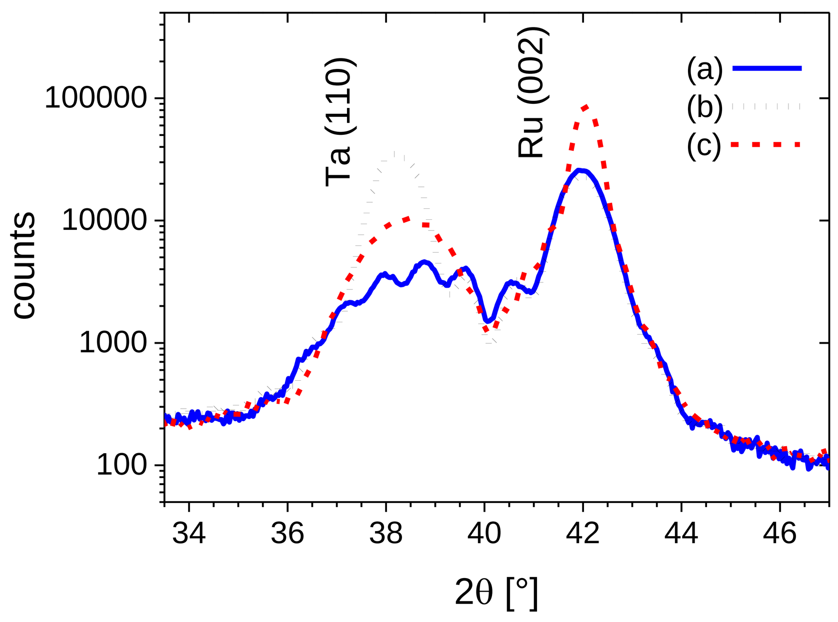
Step 1: Samples preparation

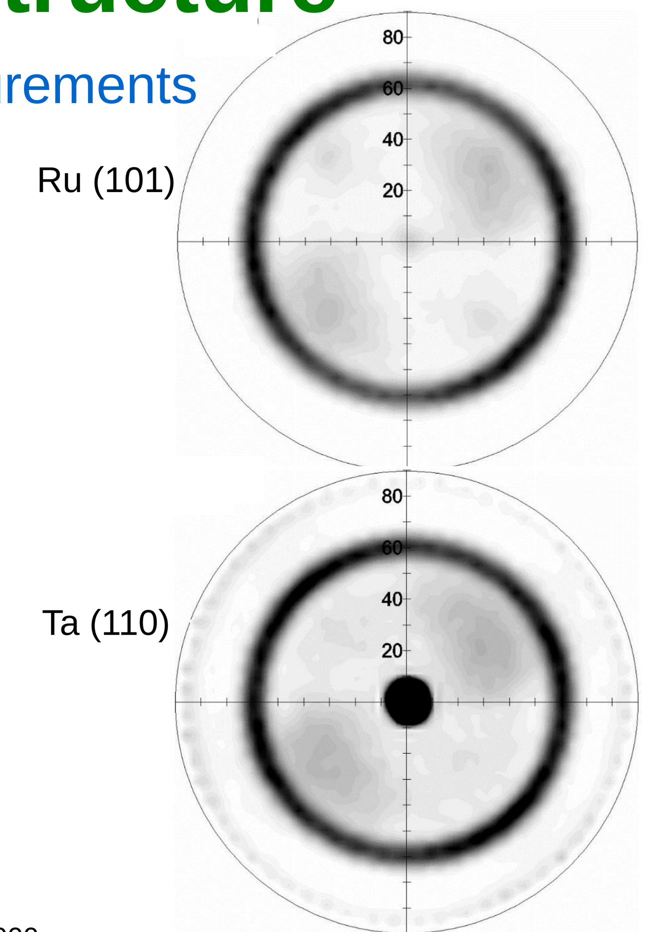
$Fe_{60}Co_{20}B_{20}$-based structures using a Singulus Timaris cluster tool system

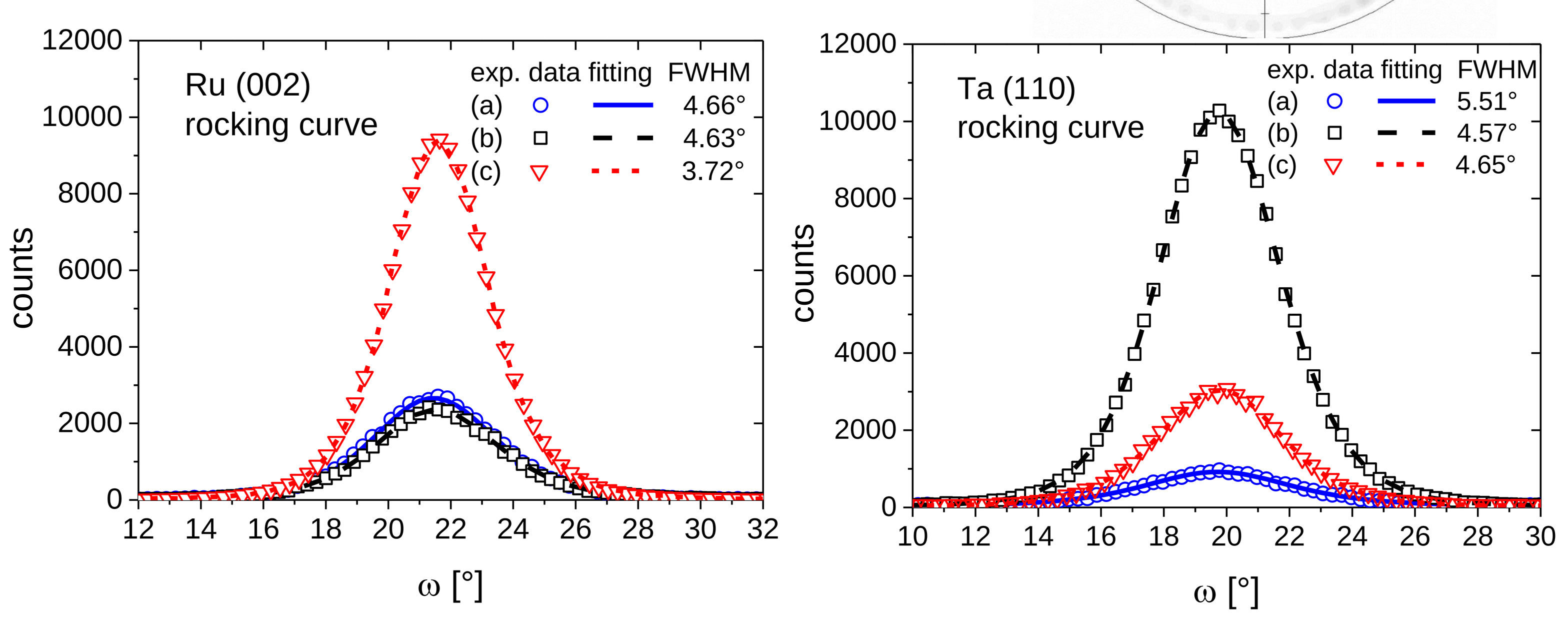


Step 2: Microstructure

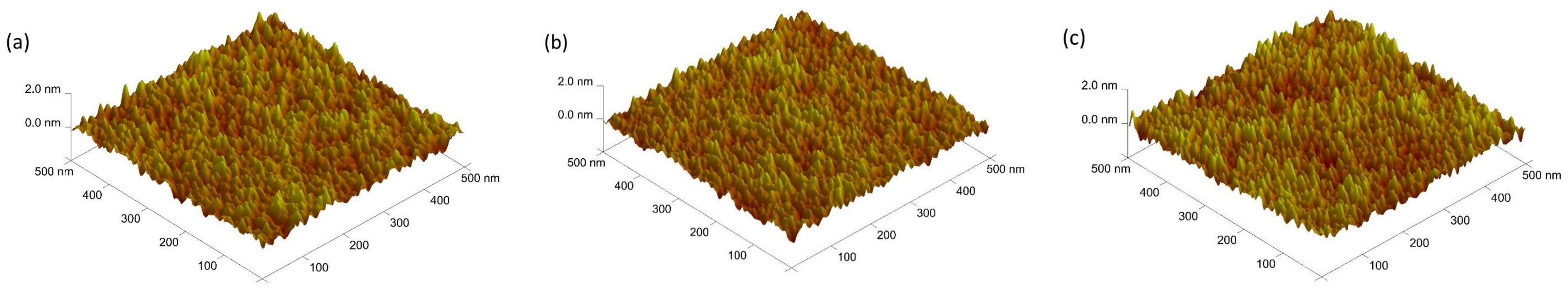
XRD texture measurements





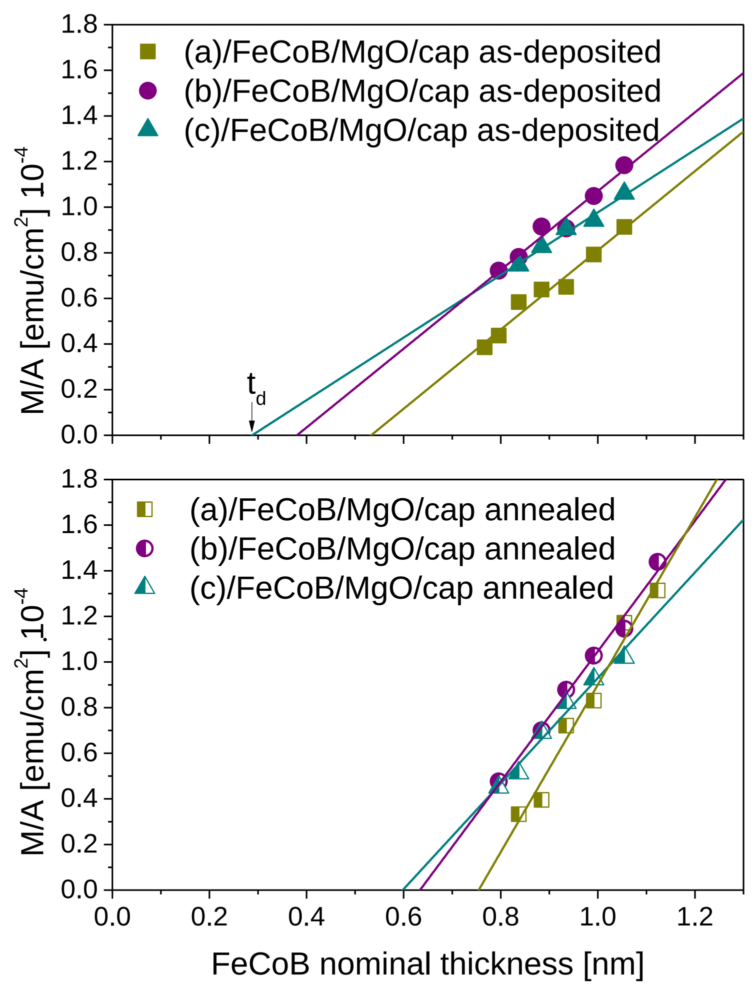


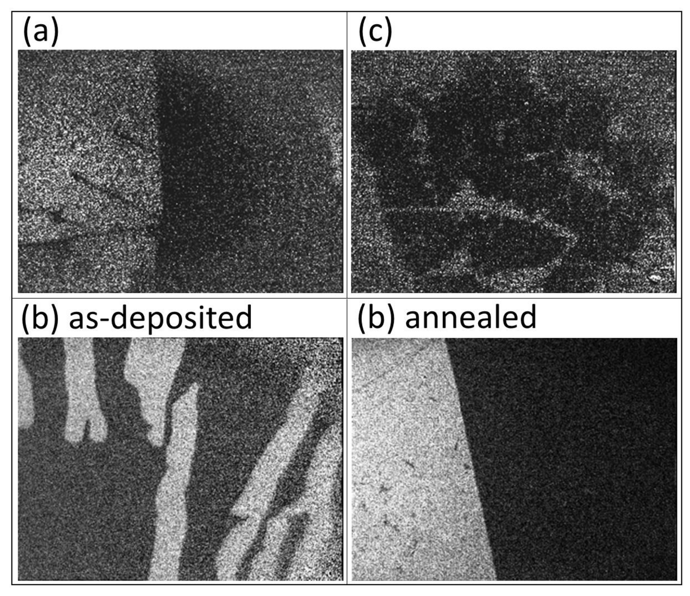
AFM topography measurements

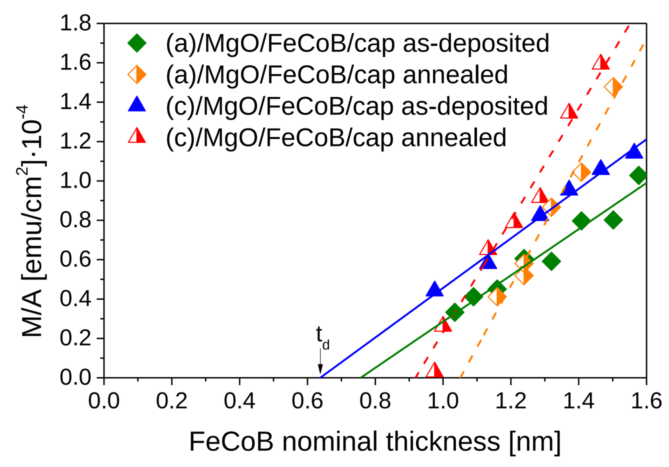


Step 3: Magnetic properties

VSM and p-MOKE measurements





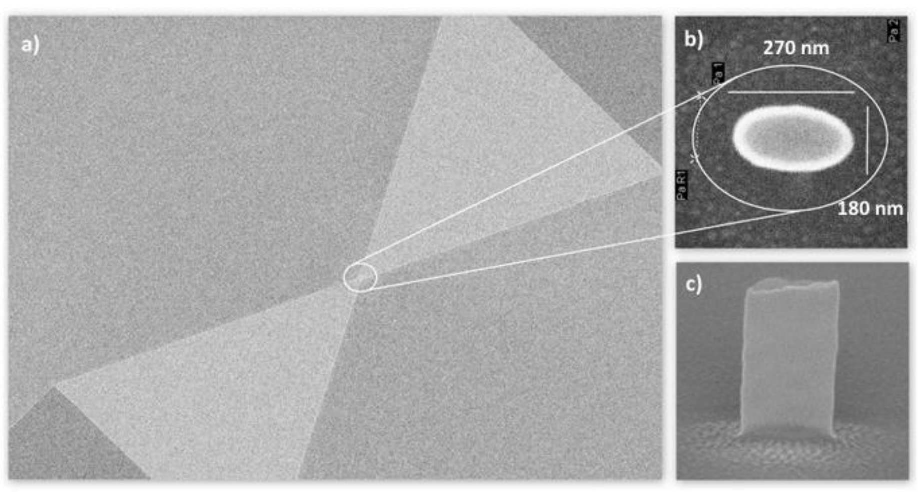


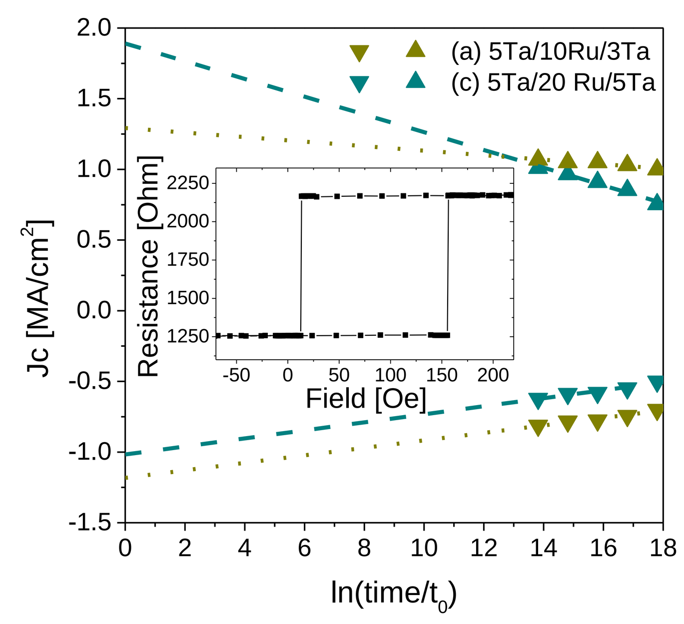
VSM measurements of anisotropy fields

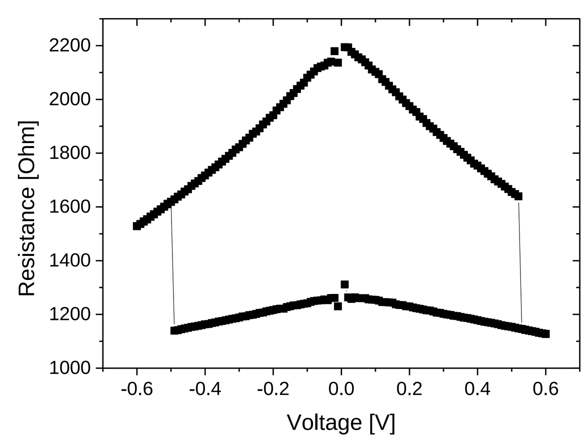
Buffer (a) free layer H_k=1010 Oe, reference layer H_k=5620 Oe

Buffer (c) free layer H_k=920 Oe, reference layer H_k=5330 Oe

Step 4: Nanostructurization and CIMS







Buffer (a) J = 1.25 MA/cm²

Buffer (c) J = 1.5 MA/cm²

Calculation of thermal stability factor:

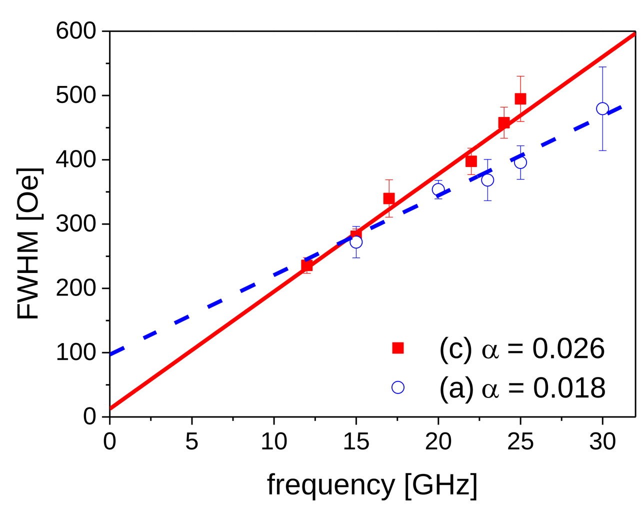
$$J_c = J_{crit}\left(1 - \frac{1}{\Delta} ln\left(\frac{t_p}{t_0}\right)\right)$$

Buffer (a) Δ = 63

Buffer (c) Δ = 32.5

Step 5: Damping measurements

Damping calculated from VNA-FMR



Summary and conclusions

- Buffer (a) Ta 5 / Ru 10 / Ta 3 : the thickest dead layer, the weakest texture, the smallest roughness and MOKE images with one large domain
- Buffer (c) Ta 5 / Ru 20 / Ta 5 : the thinnest magnetically dead layer, the strongest texture, the biggest roughness and irregular domain images
- Buffer (b) Ta 5 / Ru 10 / Ta 10 : intermediate properties between the other two
- Buffer (a) has larger anistropy fields than buffer (c)
- Critical current - buffer (a) slightly better than buffer (c)
- Thermal stability - two-fold difference in favour of buffer (a)
- Difference in damping: 44% greater for buffer (c)
- We conclude that the difference in damping factors compensates for the difference in the switching barrier heights. As a result, by adjusting buffer characteristics one can obtain a significant increase in thermal stability factors while keeping the critical current values at a similar level.

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