AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

SWISS CONTRIBUTION

Current induced magnetization switching hysteresis loops – micromagnetic modeling and experiment

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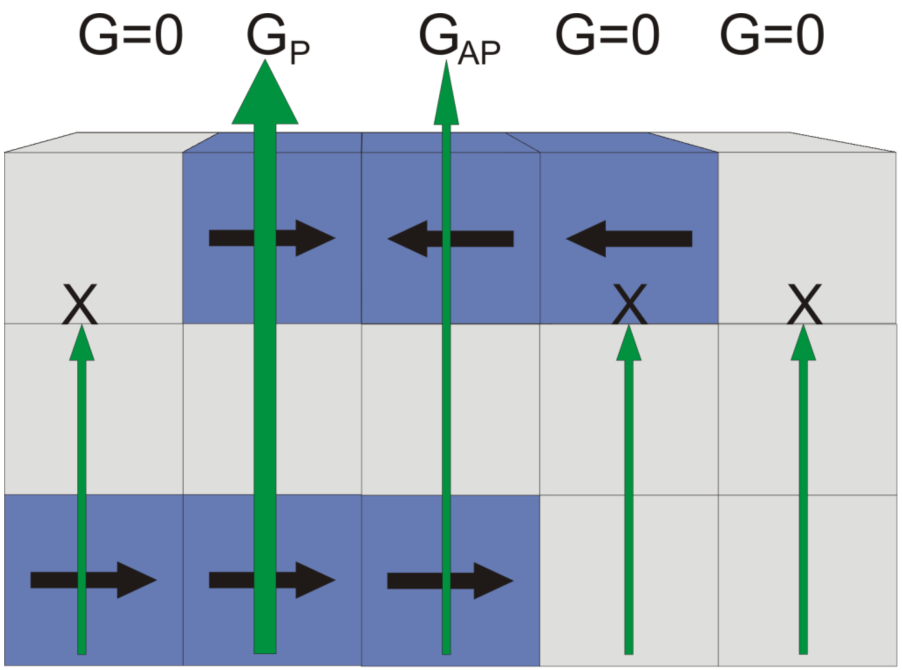
Outline

- Local current model
- Calcuations of Oersted field
- Spin-Transfer-Torque implementation
- Simulation outputs
- Investigated system
- Results and comparison with experiment
- Summary

Current flow model

Channels connected in parallel



resistance given by formula:

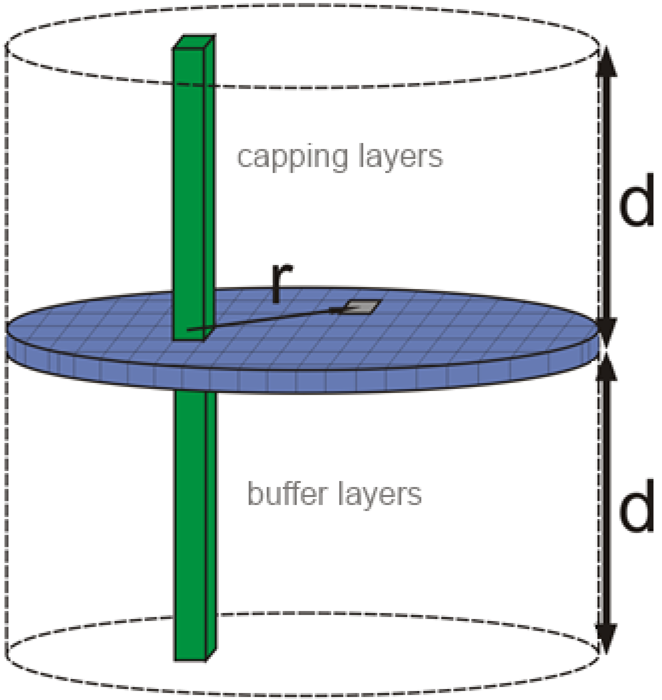
$$R = R_P + \frac{R_{AP} - R_P}{2}(1 - cos\theta)$$

$$\theta = 0 \rightarrow R_P$$
$$\theta = 180° \rightarrow R_{AP}$$

where R_{AP} can be constant or fitted from the experiment

Oersted field

Including contribution form device part outside beyond ferromagnetic layers



contribution from one channel:

$$\Delta H = \frac{I}{2\pi r}\frac{d}{\sqrt{r^2 + d^2}}$$

field in particular cell:

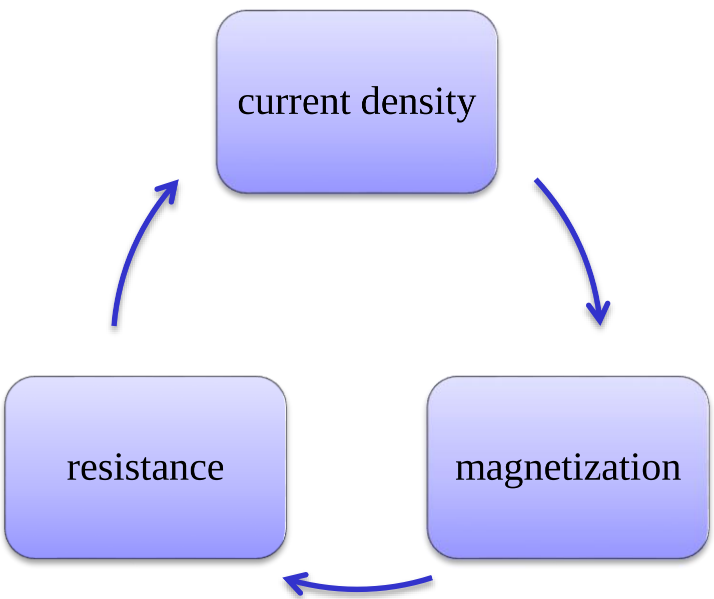
$$H = \sum \Delta H$$

Spin-Transfer-Torque

LLG equation with Slonczewski's component

$$\frac{d\vec{m}}{dt} = -\gamma_0 \vec{m} \times \vec{H}_{eff} + \alpha \vec{m} \times \frac{\partial \vec{m}}{\partial t} + \gamma_0 a_J \vec{m} \times (\vec{m} \times \vec{p}) + \gamma_0 b_J \vec{m} \times \vec{p}$$

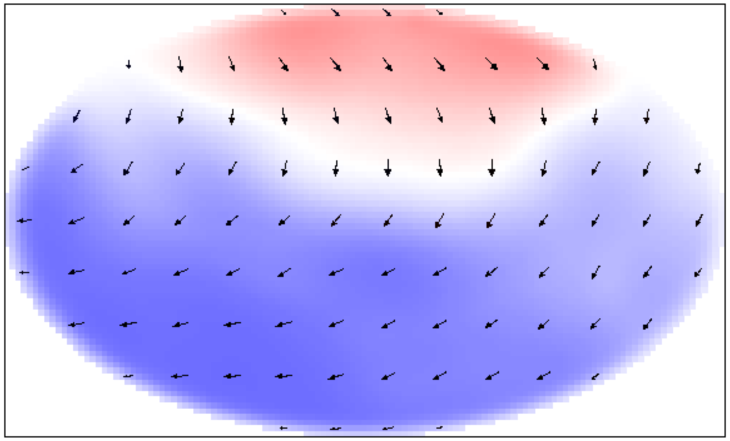
↑ precession ↑ damping ↑ in-plane torque ↑ prependicular torque



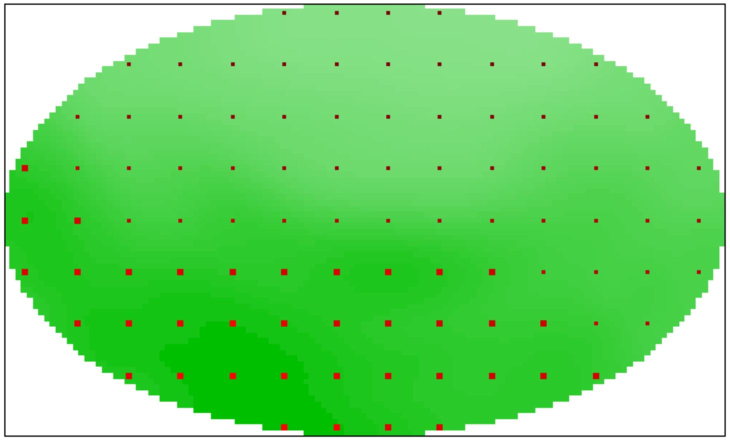
current-resistance feedback
due to STT and magnetoresitance

Simulation outputs

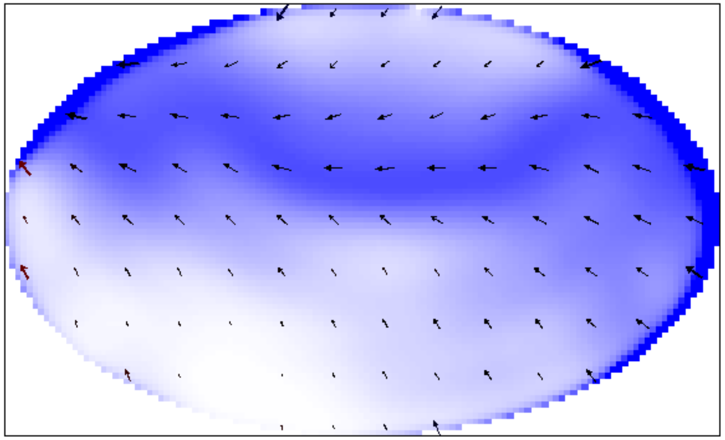
free layer magnetization distribution



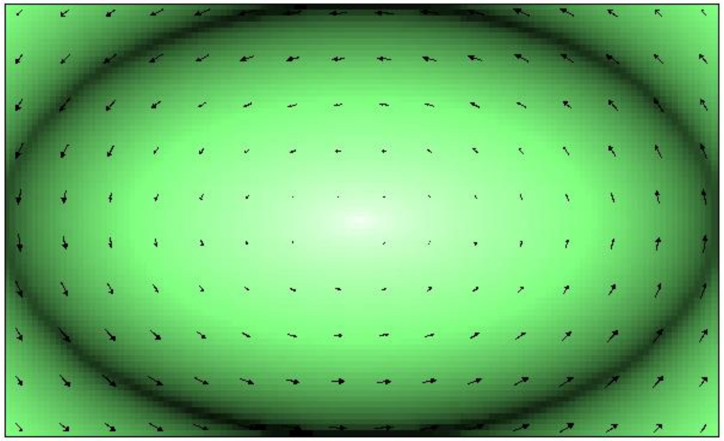
current density distribution



in-plane torque in free layer distribution

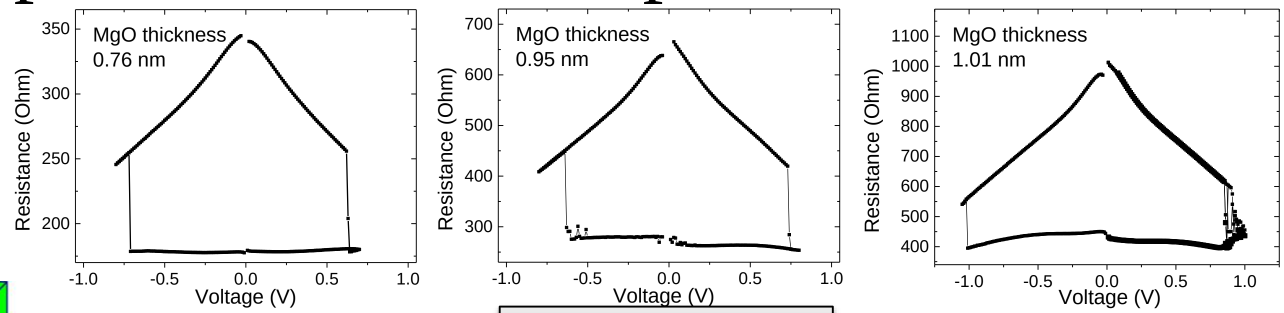


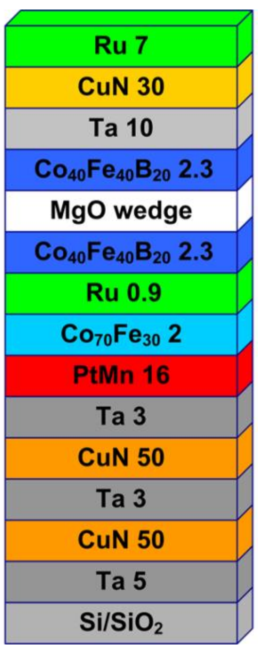
Oersted field distribution

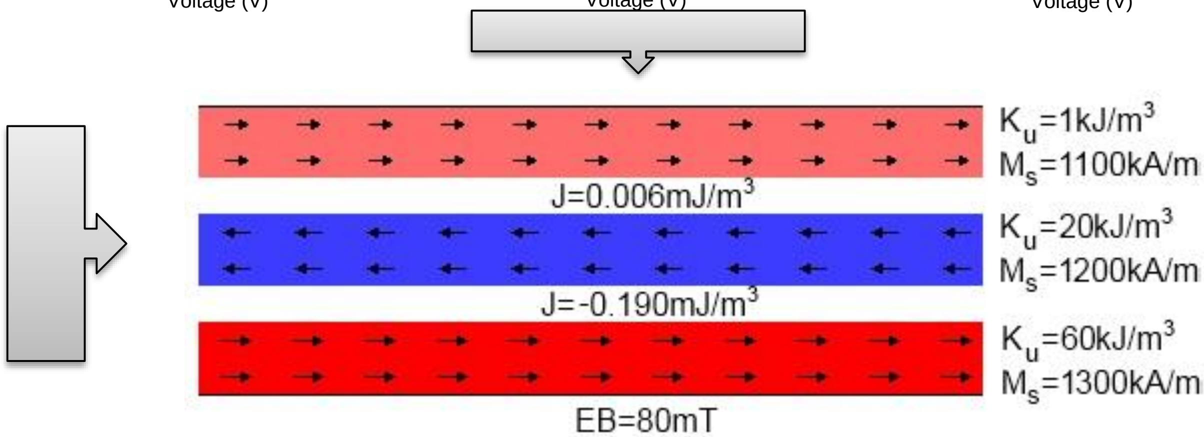


Investigated system

System specification and experimental CIMS loops



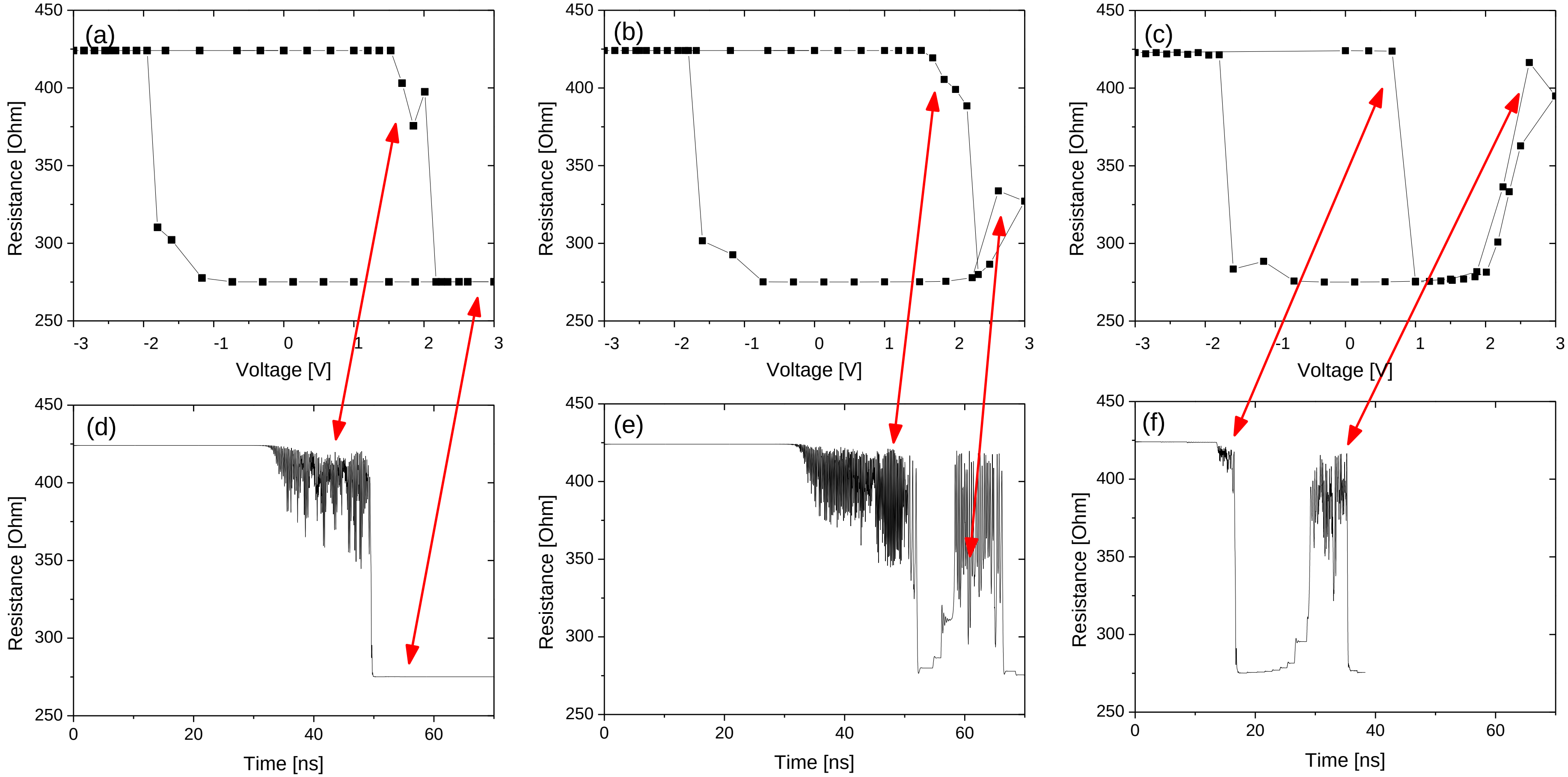




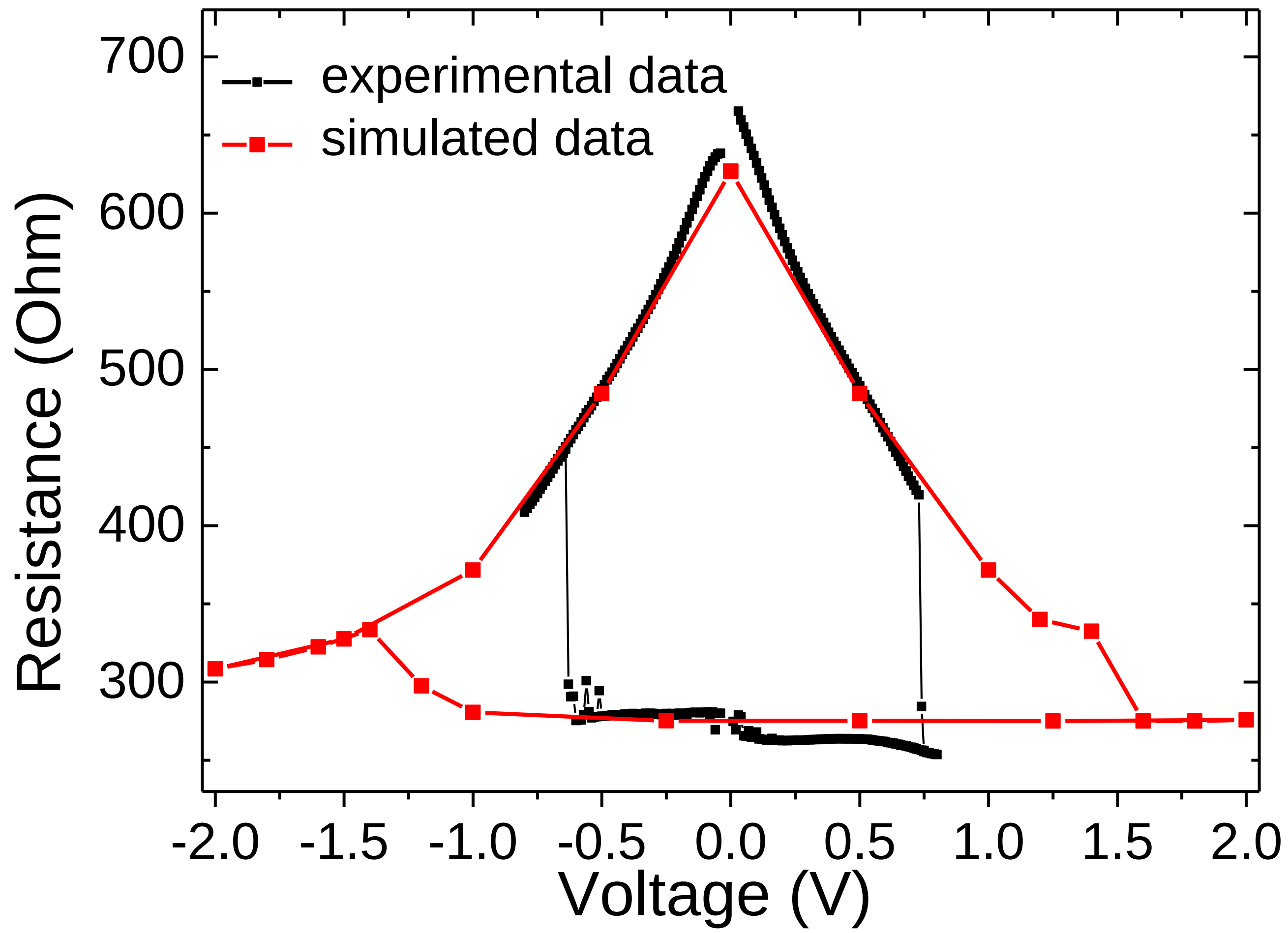
Junction size $250\times150\times8nm$, cell size $2\times2\times1nm$ (75000 cells),
α=0.017, $A = 13 \cdot 10^{-12}$, $\gamma_0 = 2,21 \cdot 10^5 \frac{m \cdot s}{A}$

Simulation results

in-plane torque	in-plane torque and perpendicular torque	both torques and Oersted field



Comparison with experiment



Summary

- We have developed an open source extension of OOMMF, that allows for simulation of STT due to current flow in function of applied time-changing voltage.
- Contributions of in-plane and out-of-plane STT components, as well as Oersted field has been investigated.
- We have implemented current-resistance feedback which affects dynamics of switching process.
- By including in simulation voltage dependent resistance of AP state, we get realistic hysteresis loops that are comparable with experimental data.

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Reference publications:

W. Skowroński, M. Frankowski et al. *Influence of MgO tunnel barrier thickness on spin-transfer ferromagnetic resonance and torque in magnetic tunnel junctions*, Phys. Rev. B, 87 (2013), p. 094419

M. Frankowski et al. *Micromagnetic model for studies on Magnetic Tunnel Junction switching dynamics, including local current density*, Phys. B. In Press, avaliable on-line

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