Influence of disorder on vortex domain wall mobility in magnetic nanowires

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A large amount of future spintronic devices is based on the control of the static and dynamic properties of magnetic domain walls in magnetic nanowires. For these applications, understanding the domain wall mobility under the action of spin polarized currents is of paramount importance. Numerous studies describe the spin-current driven domain wall motion in nanowires with ideal material properties, while only some authors take into account the influence of the nanowire edge roughness [1]. In this contribution we numerically investigate the influence of distributed disorder on the vortex domain wall mobility in Permalloy nanowires.

To this aim, we use the GPU based micromagnetic software package MuMax[2] to simulate the propagation of vortex domain walls in nanowires with cross sectional dimensions of 400x10 nm². We apply spin polarized currents acting on the domain wall by means of the Spin Transfer Torque (STT) mechanism, considering a system with perfect adiabaticity ($\beta=0$) and with non-adiabatic STT contributions ($\beta=\alpha$ and $\beta=2\alpha$, α is the Gilbert damping). As in [3], the disorder is simulated as a random distribution of 3.125x3.125nm² sized voids. For each current value, average domain wall velocities are computed considering 25 different realisations of the disorder.

We find that even very small disorder concentrations have a huge impact on the domain wall mobility. In the non-adiabatic case ($\beta=2\alpha$), the domain wall velocity is largely suppressed below the Walker breakdown since the disorder is able to pin the vortex structure hindering the formation of the transverse domain wall, characteristic to the movement in this current region. In the adiabatic case ($\beta=0$), the intrinsic depinning threshold is largely reduced. Even very small disorder densities disable the domain wall to internally balance the Landau-Lifshitz-Gilbert torques with the STT torques, resulting in a non-zero domain wall speed. At low currents, the disorder pins the domain wall structure.

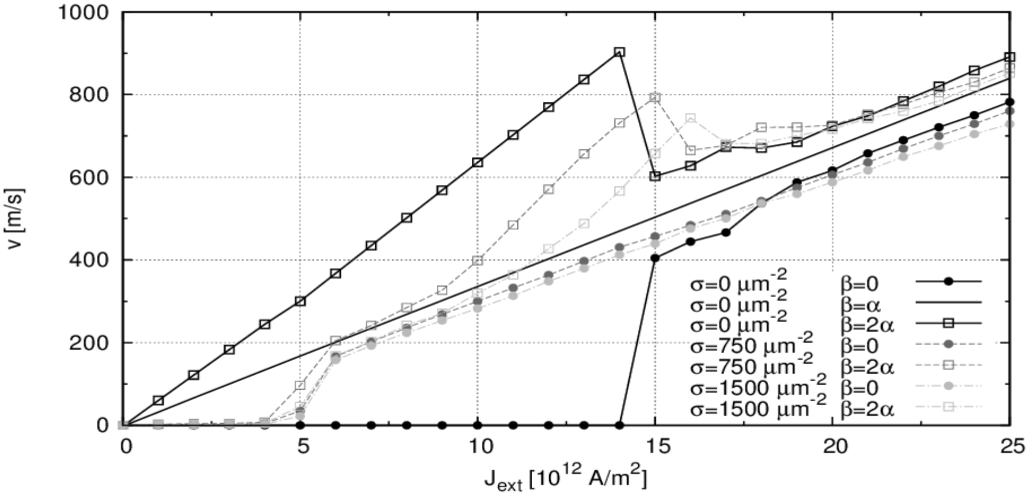

Figure 1: Average speed versus applied current for adiabatic ($\beta=0$) and non-adiabatic ($\beta=2\alpha$) case with varying disorder density σ. The curves tend to converge to the ($\beta=\alpha$) case without disorder, $\sigma=0$, which could explain the large variety of experimentally obtained values for β.

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[2] A. Vansteenkiste and B. Van de Wiele, J. Magn. Magn. Mat., 323, No. 21 (2011).
[3] B. Van de Wiele, *et al*. Phys. Rev. B 86, 144415 (2012).