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Spin-orbit damping in transition metals

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Magnetization dynamics are routinely described with the Landau-Lifshitz-Gilbert (LLG) equation. However, it is expected that the LLG equation fails to properly describe the large amplitude dynamics that occur during magnetization reversal. Improving switching speeds in nanoscale devices by tailoring materials requires both a qualitative understanding of the relaxation processes that contribute to damping and the ability to quantitatively calculate the resulting damping rates. We consider small amplitude LLG damping in transition metals as a prelude to approaching the more complicated mechanisms expected in complete reversal events. LLG damping rates in pure transition metal systems have non-monotonic temperature dependencies that have been empirically shown by Heinrich et al. [1] to have one part proportional to the conductivity and one part proportional to the resistivity. Kambersky [2] postulated that both contributions result from a torque between the spin and orbital moments. We have conducted first-principles calculations that validate this claim for single element systems [3]. Our calculations for Fe, Co, and Ni both qualitatively match the two trends observed in measurements and quantitatively agree with the observed damping rates. We will discuss how the spin-orbit interaction produces two contributions to damping with nearly opposite temperature dependencies and compare calculations of the damping rate versus resistivity with experimental results.

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[2] V. Kambersky, Czech. J. Phys. B, 26, 1366 (1976).
[3] K. Gilmore, Y.U. Idzerda, and M.D. Stiles, Phys. Rev. Lett., 99, 027204 (2007).