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Spin Relaxation in Materials Lacking Coherent Charge Transport[1]

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As semiconductor spintronics research extends to materials beyond intrinsic or lightly doped semiconductors (e. g. organic materials, amorphous semiconductors, and impurity bands), the need is readily apparent for new theories of spin relaxation that encompass highly disordered materials, where charge transport is incoherent. We describe a broadly applicable theory of spin relaxation in materials with incoherent charge transport. The theory is based on continuous-time-random-walk theory and can incorporate many different relaxation mechanisms. We focus primarily on spin relaxation caused by spin-orbit and hyperfine effects in conjunction with carrier hopping. Analytic and numerical results from the theory are compared in various regimes with Monte Carlo simulations. Three different systems were examined: a polymer (MEH-PPV) [1], amorphous silicon [2], and heavily doped n-GaAs. In the organic and amorphous systems, we predict spin relaxation and spin diffusion dependences on temperature and disorder for three different mechanisms (hyperfine, hopping-induced spin-orbit, and intra-site spin relaxation). The resulting unique experimental signatures predicted by the theory for each mechanism in these disordered systems provide a prescription for determining the dominant spin relaxation mechanism. We find our theory to be in agreement with available measurements in these materials. We also predict that large disorder modifies certain mechanisms to be algebraic instead of exponential in time. Our results should assist in evaluating the suitability of various disordered materials for spintronic devices. All work done in collaboration with Michael E. Flatté. Timothy Peterson and Paul Crowell collaborated as well on the n-GaAs study.

[1] N. J. Harmon and M. E. Flatté, Phys. Rev. Lett., 110, 176602 (2013)
[2] N. J. Harmon and M. E. Flatté, Phys. Rev. B 90, 115203 (2014)

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