Matrix spin drift-diffusion models for semiconductors: analysis and simulation

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Spintronics became very popular in recent years, boosted by the discovery of the giant magnetoresistance effect by Fert and Gruenberg in 1988. Future applications may include spin-based transistors, such as the spin field-effect transistor proposed first by Datta and Das in 1990. In this talk, we investigate a spinorial matrix drift-diffusion model which was derived from a matrix Boltzmann equation, involving the precession of the spin polarization, in the diffusion limit. Expanding the (macroscopic) electron density matrix in the Pauli basis, the model consists of a cross-diffusion system for the coefficients, self-consistently coupled to the Poisson equation.

The key idea of the analysis is to work with different variables: the spin-up and spin-down densities, which satisfy the usual spin drift-diffusion equations, and the parallel and perpendicular components of the spin-vector density with respect to the precession vector. In these variables, the diffusion matrix becomes diagonal. We show the global-in-time existence of bounded weak solutions to the matrix spin drift-diffusion system and present a finite-volume scheme which preserves the discrete free energy of the system. Numerical simulations in one and two space dimensions illustrate the influence of the precession vector on the electron transport behavior.

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