SOLID-STATE PHYSICS

Spin in the slow lane

Bart van Wees

Electrons were until recently thought to transport their charge and spin equally freely through metals and semiconductors. Now it seems that spin can lag considerably behind charge.

The recognition that electrons can transport through a solid not just charge, but also spin (the intrinsic ‘rotation’ of electrons, which gives rise to their magnetic moment), sowed the now burgeoning field of spintronics. As charge and spin are properties of individual electrons, it is tempting to conclude that both will be transported equally efficiently. But Weber et al., writing on page 1330 of this issue, show that the diffusion of electron spin can be substantially slower than that of electron charge. This could have important implications for spin-based electronics.

The ability to generate, study and use phenomena such as spin injection, spin currents and spin accumulation, in metals as well as semiconductors, has made it imperative to discover how similar — or different — spin semiconductors, has made it imperative to discover how similar — or different — spin currents, these spin-up and spin-down electrons. But it does reduce the diffusion rate of spin diffusion, which dictates that the interaction of a beam of light with a magnetic field — in this case, that induced by the electron spins — will bring about a (slight) rotation of the polarization of the reflected beam. The angle of rotation depends on the induced magnetization and thus the spin density, so the decay of the spin grating can be investigated by varying the delay between the pump and probe pulses. By ascertaining the effective decay time as a function of the spatial period , the authors determined the relative importance of diffusion and relaxation, and obtained values for both and the intrinsic spin relaxation time. They found that the rate of spin diffusion indicated by was considerably slower than the charge diffusion rates obtained from conventional electronic measurements.

In theoretical calculations, spin Coulomb drag is expressed by a parameter known as the spin–drag transresistivity; this relates the current in each of the spin channels (spin up or spin down) to the effective electric field in the opposite spin channel. The significance of the transresistivity depends on the number of spatial dimensions considered, the strength of the various interactions between the electrons, and the conventional electronic resistivity. If this last quantity is small, as it is in good conductors such as metals, the effect of spin drag will be relatively small. In the two-dimensional system used by Weber et al., however, the effect of spin Coulomb drag turns out to be considerable. Reducing further to a one-dimensional system has revealed that spin and charge can even separate, with the two intrinsic electron properties developing their own distinctive transport modes. These findings are bound to stimulate further research. What is already abundantly clear, however, is that spin and charge both move at their own pace.

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