Pure Spin Currents: Discharging Spintronics

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As semiconducting electronic devices are miniaturized to ever-smaller dimensions, power dissipation becomes an ever-increasing problem due to leakage charge currents. Spintronics may help addressing some of these issues by utilizing besides the charge degree of freedom also the electron spin. Conventional spintronics approaches are used for non-volatile devices, such as magnetic random access memory, where spin currents are mainly considered as spin-polarized charge currents and as a result the spin and charge currents are in parallel and directly coupled. Looking further into the future, the question arises, whether eliminating charge currents altogether could provide additional benefits for applications. Towards addressing this question, non-local device geometries allow for separating spin and charge currents, which in turn enables the investigation and use of pure spin currents [1]. This approach opens up new opportunities to study spin-dependent physics and gives rise to novel approaches for generating and controlling angular momentum flow.

In this lecture, I will discuss different approaches for generating pure spin currents, such as non-local electrical injection from a ferromagnet, charge-to-spin current conversion via spin Hall effects, and spin pumping from ferromagnetic resonance. Furthermore, I will show how spin currents can then be used for gaining new insights into spin dependent phenomena. In particular, the temperature dependence of spin and charge relaxation times allows to identify different spin relaxation mechanisms [2]. In addition, spin pumping facilitates the generation of macroscopically large pure spin currents. This permits to quantify spin Hall effects with great precision, even in materials where these effects are relatively weak [3,4]. Finally, I will conclude with a brief outlook on the current scientific and future technological opportunities for pure spin currents.

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