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Tunnel Magnetoresistance, Spin Accumulation, and Spin Hall Effect

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In a tunnel junction consisting of two ferromagnetic (F) electrodes, the tunneling current depends on the relative orientation of the magnetization of F electrodes. This so-called tunnel magnetoresistance (TMR) has been extensively studied for various device applications. When a non-magnetic metal or semiconductor (N) is introduced in such a tunnel junction, the spin-polarized current is injected into N, and the spin current and spin accumulation occur in the region of the order of the spin diffusion length (λ), which is in the range of a few 10 μm $\sim$ a few μm depending on materials. Therefore, in a device with the size of the order of λ, the spin current and spin accumulation give size to a variety of novel spin dependent phenomena [1]. The spin current is scattered by the spin-orbit interaction and induces the charge current in the perpendicular direction. It is also possible that the charge current is converted into the spin current in the perpendicular direction by the spin-orbit interaction. These conversions are the Spin Hall effects. If N is superconducting in the tunnel device, the situation is more dramatic. The effects of spin current and spin accumulation are strongly enhanced in the superconducting state. Some of the unique experiments are proposed.

[1] "Concepts in Spin Electronics," ed. S. Maekawa (Oxford University Press, 2006).