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The importance of Fe interface states for ferromagnet-semiconductor based spintronic devices

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I present our recent theoretical studies of the bias-controlled spin injection, detection sensitivity and tunneling anisotropic magnetoresistance in ferromagnetic-semiconductor tunnel junctions. Using first-principles electron transport methods we have shown that Fe $3d$ minority-spin surface (interface) states are responsible for at least two important effects for spin electronics. First, they can produce a *sizable* Tunneling Anisotropic Magnetoresistance in magnetic tunnel junctions with a *single* Fe electrode. The effect is driven by a Rashba shift of the resonant surface band when the magnetization changes direction. This can introduce a new class of spintronic devices, namely, Tunneling Magnetoresistance junctions with a single ferromagnetic electrode that can function at room temperatures. Second, in Fe/GaAs(001) magnetic tunnel junctions they produce a *strong* dependence of the tunneling current spin-polarization on applied electrical bias. A dramatic *sign reversal* within a voltage range of just a few tenths of an eV is found. This explains the observed sign reversal of spin-polarization in recent experiments of electrical spin injection in Fe/GaAs(001) and related reversal of tunneling magnetoresistcance through vertical Fe/GaAs/Fe trilayers. We also present a theoretical description of electrical spin-detection at a ferromagnet/semiconductor interface. We show that the sensitivity of the spin detector has *strong* bias dependence which, in the general case, is *dramatically different* from that of the tunneling current spin-polarization. We show that in realistic ferromagnet/semiconductor junctions this bias dependence can originate from two distinct physical mechanisms: 1) the bias dependence of tunneling current spin-polarization, which is of *microscopic* origin and depends on the specific properties of the interface, and 2) the *macroscopic* electron spin transport properties in the semiconductor. Our numerical results show that the magnitude of the voltage signal can be tuned over a wide range from the second effect *alone* and thus identifies a universal method for enhancing electrical spin-detection sensitivity in ferromagnet/semiconductor tunnel contacts.