Half Metallic Ferromagnets

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PREFACE

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Since its introduction by de Groot and colleagues in the early 1980s [1], the concept of half metallic ferromagnetism has attracted great interest. Idealized, half-metals have only one spin channel for conduction: the spin-polarized band structure exhibits metallic behavior for one spin channel, while the other spin band structure exhibits a gap at the Fermi level. Due to the gap for one spin direction, the density of states at the Fermi level has, theoretically, 100 % spin polarization. This gap in the density of states in one spin at the Fermi level, for example $\downarrow$ so $N_{\downarrow}(E_F) = 0$, also causes the resistance of that channel to go to infinity. At zero or low temperatures, the nonquasiparticle density of states (electron correlation effects), magnons and spin disorder reduce the polarization from the idealized 100 % polarization. At higher temperatures magnon-phonon coupling and irreversible compositional changes affect polarization further. Strategies for assessing and reducing the effects of finite temperatures on the polarization are now gaining attention. The controversies surrounding the polarization stability of half metallic ferromagnets are not, however, limited to the consideration of finite temperature effects alone. While many novel half metallic materials have been predicted, materials fabrication can be challenging. Defects, surface and interface segregation, and structural stability can lead to profound decreases in polarization, but can also suppress long period magnons. There is a 'delicate balance of energies required to obtain half metallic behavior: to avoid spin flip scattering, tiny adjustments in atomic positions might occur so that a gap opens up in the other spin channel' [2]. When considering 'spintronics' devices, a common alibi for the study of half metallic systems, surfaces and interfaces become important. Free enthalpy differences between the surface and the bulk will lead to spin minority surface and interface states, as well as surface and interface reconstructions. Thus spin injection, i.e. the spin polarization of the current through the interface, may be effectively reduced to very low values, although the non-equilibrium spin polarization of the electron density can have very high values in select devices. Underlying these issues is the need to consider the definition of polarization: not all polarizations are equal. Polarization depends on the measurement. We do not always measure a polarization that follows the usual definition of spin polarization, and in many cases, it is not exactly clear what polarization has been measured. For example, there are corrections for the Fermi velocity $v_{\uparrow,\downarrow}$ and spin relaxation $\tau_{\uparrow,\downarrow}$:

$$P = \frac{N_{\uparrow}(E_F){v_{\uparrow}}^n\tau_{\uparrow} - N_{\downarrow}(E_F){v_{\downarrow}}^n\tau_{\downarrow}}{N_{\uparrow}(E_F){v_{\uparrow}}^n\tau_{\uparrow} + N_{\downarrow}(E_F){v_{\downarrow}}^n\tau_{\downarrow}}$$

where $n = 1$ applies to the ballistic regime and $n = 2$ applies to the diffuse regime [3]. Neglecting interfaces and other complications, the diffuse regime ($n = 2$) should be the spin polarization of the bulk conductivity while ballistic regime ($n = 1$) is the polarization of the tunnel current and, in principle, Andreev reflection. As a result, suitable spin dependent Fermi velocity corrections might overcome an otherwise lackluster polarization for some device structures. Even measurements of polarization that are Fermi velocity independent ($n = 0$) may still depend on the wave vector and details of the interface band structure: as in the case of spin polarized photoemission and inverse photoemission. This special issue cannot possibly give due justice to all the various aspects of the physics of half metallic systems. By including both advocates and critics of half metallic ferromagnetism, the special issue should provide at least a taste of the controversies and challenges that exist in the study of half metallic ferromagnets. It may be that 'nature abhors half-metallicity' [2], and that relatively minor structural and thermal perturbations have a disproportionally strong effect on the density of states at the Fermi level, but in spite of much study half metallicity remains fascinating and much insight is still needed including both experiment and improvements to band structure calculations.

References

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