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Spin Accumulation and its Detection in Ferromagnet/III-V Semiconductor Devices[1]

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As the field of semiconductor spintronics has developed, there has been increasing interest in quantitative measurements of spin accumulation. Successful demonstrations of spin transport have now been reported in various heterostructures combining semiconductors and transition metal ferromagnets. In this talk, I will address the interpretation of spin transport experiments in transition metal ferromagnet/III-V semiconductor heterostructures. These are the most well-developed class of ferromagnet-semiconductor devices, and it is therefore possible to compare different types of measurements made on a single sample. These include the classic non-local spin valve measurement, the local, or "three-terminal" measurement, spin Hall and inverse spin Hall experiments, and a new type of microwave measurement suitable for measuring spin accumulations when the spin lifetime is short. The high quality interfaces that can be achieved in epitaxially grown Fe/GaAs as well as Heusler alloy $Co_2Mn_{1-x}Fe_xSi$/GaAs heterostructures allow for spin accumulations of the order of 50% to be achieved. I will focus on two essential observations. First, the basic drift-diffusion model on which our understanding of spin transport is based provides an excellent description of the physics in the bulk of the semiconductor. In particular, the non-local spin valve and spin-Hall measurements establish the existence of bulk spin currents, which propagate as expected given the relative weights of drift and diffusion and ordinary mechanisms of spin relaxation. Second, there are significant complications that must be considered when the spin accumulation is large and/or a charge current is present, as is the case for a three-terminal measurement. These types of measurements are a double-edged sword, allowing for new methods of detecting spin accumulation even when a simple quantitative determination of a spin accumulation is not always available. I will highlight how these new approaches have enabled the measurement of spin accumulation with non-magnetic electrodes as well as the successful demonstration of Heusler alloy/III-V semiconductor spin valves operating at room temperature.

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