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**Crossover from Spin Accumulation into Interface States to Spin Injection in the Germanium Conduction Band**[1]

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Electrical spin injection from ferromagnetic metals to silicon (Si) and germanium (Ge) is the first and basic requirement for the development of spintronic devices and their integration with mainstream semiconductor (SC) technology. The main obstacle to efficient spin injection is the conductivity mismatch between the ferromagnetic metal and Si, Ge and requires tunneling spin injection through an oxide barrier (Ox). However, tunneling spin injection raises other important issues in the interpretation of spin signals obtained in three-terminal geometry. In particular, the possible presence of localized states within the Ox or at the Ox/SC interface may lead to wrong conclusions. To study the exact origin of the spin signals measured in three-terminal geometry, we have grown Ta/CoFeB/MgO/SOI and GeOI samples with n and p type doping using variable MgO thicknesses. The use of SOI and GeOI substrates allows us to apply back gate voltages to the SC channel to vary its resistivity. Moreover we have used three different techniques to grow the MgO tunnel barrier: by sputtering of MgO or Mg followed by a plasma oxidation and e-beam evaporation of MgO. Using the Mg and plasma oxidation growth of the tunnel barrier, though less flexible than the other techniques, allowed us to show the temperature transition from the spin accumulation into interface states to the spin accumulation into the conduction band of n-Ge. Above 150 K, the magnitude of the spin RA product agrees well with the spin diffusion theory predictions and is proportional to the injected current and to the channel resistivity as expected. Temperature dependent spin pumping measurements showed the same transition. Using the same spin injector, we also found radically different spin signals using p-Ge supporting the fact that spin accumulation occurs into the SC channel. In this presentation, we will extend our spin signal analysis using MgO tunnel barriers of different thicknesses and grown by different methods.

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