AN APPROACH TO SPIN BASED QUANTUM COMPUTING: SPIN DEPENDENT RECOMBINATION AT VERY HIGH MAGNETIC FIELDS

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Introduction

Spin based quantum computation involving electron and/or nuclear spins offers considerable promise; however, it is not yet clear that the control and detection of small numbers of spins (preferably one) can be carried out in a remotely practical time frame. We are developing a technique to detect very small numbers of paramagnetic sites within a SiC metal-oxide-silicon field effect transistor (MOSFET) in an integrated circuit. The detection of spins in such a device is particularly promising because the paramagnetism of a specific site could be turned on or off via application of a voltage. We utilize an EPR detection technique called spin dependent recombination (SDR) which detects EPR through changes in device current caused by the spin dependent capture of charge carriers at paramagnetic sites. At modest magnetic field strength, the SDR effect is, to zero order, field independent. However, the effect comes about because (due to the Pauli exclusion principle) a deep level paramagnetic center cannot capture a charge carrier if both the deep level and conduction electron have the same spin quantum number. Thus, the very high spin polarizations possible at high magnetic field should make the SDR effect very large.

Experimental

We have utilized “qausi-optical” EPR systems developed by for high field (4.3 Tesla) SDR. Our initial measurements were made “in the dark” and were therefore restricted to near room temperature. Lower temperature measurements offer the obvious advantages of an increase in polarization of both conduction electron and deep level spin and an increase in spin lattice relaxation times of the deep level center. (The SDR effect requires at least partial saturation of the deep level spin system; the more complete the saturation the larger the effect.) In our most recent measurements we were able to work at somewhat lower temperature by (incompletely) exposing the transistors to photons with energy exceeding the semiconductor band gap. Representative traces are illustrated in figure 1: a large amplitude trace with the light on and a much smaller amplitude trace in darkness. These traces were taken at 210K. The photo-excitation greatly enhances the SDR response. The sensitivity with the light on is about 10^4 spins/Gauss in about 3 minutes. These results suggest that it will be possible to achieve even higher SDR sensitivity by making the measurements at much lower temperature in the presence of photo-excitation. We attempted to extend our measurements to much lower temperatures. Unfortunately, probably due to the incomplete penetration of light to all of the active areas of the transistors, we found that further lowering of the temperature results in a net decrease in SDR amplitude. The experiments indicate that with optimized device geometry, and much lower temperature it may be possible to achieve extremely high, possibly single spin, sensitivity. (We plan to extend this study with an optimized device geometry.)

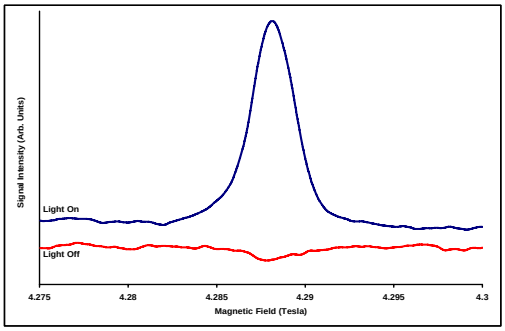

Figure 1: SDR traces in a MOSFET with light exposure (above) and in darkness (below). The traces were taken at 210K. The data indicates a sensitivity of about 10^4 spins/Gauss of linewidth in a 200 second trace.