Spin Dependent Variable Range Hopping and Spin Dependent Charge Pumping in Metal- Insulator- Semiconductor Systems

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The utilization of several very sensitive electrically detected magnetic resonance (EDMR) techniques can provide quite sensitive measurements of electrically active defects within fully processed present day metal oxide semiconductor (MOS) devices and integrated circuitry. EDMR studies can provide direct atomic scale information, including defect structure, chemistry, density and, to some extent, physical location. This approach may be of growing interest due to the development of MOS technology with new materials and geometries. The performance limiting defects within these new technology devices are often poorly understood. It is likely that a fundamental physical understanding would lead to the amelioration or elimination of problems caused by these defects. For example, MOS technologies based upon silicon carbide/silicon dioxide interface have great potential in high power and high temperature applications but the utilization of such devices is limited by high densities of as yet poorly understood defects at and very near to the silicon carbide/ silicon dioxide interface. Another example, new interlayer dielectrics, such as low dielectric constant SiOC:H offer increased speed in MOS integrated circuitry. However, the ultimate utilization of such systems is limited by imperfections within the dielectrics which lead to dielectric leakage current related reliability issues.

For quite some time, the family of electron paramagnetic resonance (EPR) techniques have offered unrivalled analytical power to identify the physical and chemical nature of point defects within semiconductors and insulators. Unfortunately, conventional EPR measurements have several serious limitations in the study of nanotechnology problems. The most obvious shortcoming of conventional EPR is its sensitivity, about ten billion defects within the sample under study. There are generally far fewer than ten billion defects within any nanotechnology device of technological interest. A second problem with conventional EPR measurements is that they are generally sensitive to all paramagnetic defects within a sample under study; one would typically be interested only in those defects within the active area of a device and only those defects which in some way affect electronic transport within the device structure.

This presentation will explore the utilization of spin dependent charge pumping (SDCP) in multiple MOS systems including SiC MOSFETs. SDCP can provide direct identification of interface trapping centers with levels in almost any part of the semiconductor band gap at the semiconductor/ insulator interface and, under some circumstances, it can also provide both energy level and defect concentration data. The presentation will also explore the utilization of spin dependent variable range hopping, a technique based upon spin dependent tunneling (SDT) which allows the identification of defect centers involved in leakage current phenomena in multiple dielectrics of current technological interest. The presentation will include a very brief introduction to the physical mechanisms involved in SDCP and SDT as these techniques are not yet widely utilized in electronic materials physics.