Negative Bias Stressing Observations of Interface Trapping Centers in Fully Processed Metal Gate Hafnium Oxide Field Effect Transistors Using Spin Dependent Recombination

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Although great progress has recently been made in the development of HfO_2 based metal oxide field effect transistor (MOSFET) technology, very little is known about the reliability problems associated with this new materials technology. One of the most vexing problems of conventional Si/SiO_2 and SiO_2/nitrided oxide MOS devices is the negative bias temperature instability (NBTI) which causes reduced drain current and shifts in threshold voltage when pMOSFETs are subjected to modest negative gate bias, typically at an elevated temperature [1-2]. NBTI may also be a serious problem in new HfO_2 based MOSFETs.

We combine conventional MOS gated diode measurements and very sensitive electrically detected electron spin resonance (ESR) measurements to detect and identify NBTI generated defect centers in fully processed HfO_2 pMOS field effect transistors (pMOSFETs). These HfO_2 based MOSFETs have an equivalent oxide thickness of slightly greater than one nm. The spectra of short term stressed devices (fig. 1) were found to be significantly different from those spectra generated by the long term stressed devices (fig. 2). Not only do these spectra differ in g value, but also in width. We speculate that this is because two different defects are being generated at short and long stressing periods. Neither of these spectra resemble those of NBTI generated spectra in conventional Si/SiO_2 based devices [3-5]. However, the long term NBTI generated defect spectra are somewhat similar to those observed in plasma nitrided oxide Si/SiO_2 based devices [3-5] in that the g values g (HfO_2) = 2.0026 and g (nitrided SiO_2) = 2.0020 are virtually identical.

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Both the short and long term NBTI generated "interface" trapping defects, of the HfO_2 devices, are almost certainly **not** located precisely at the Si/dielectric boundary but slightly beyond it in the SiO_2 interfacial layer. The breadth and g values of the lines suggest that the defects may consist of oxygen deficient silicons bonded to oxygens, and involving some interaction with hafnium atoms.

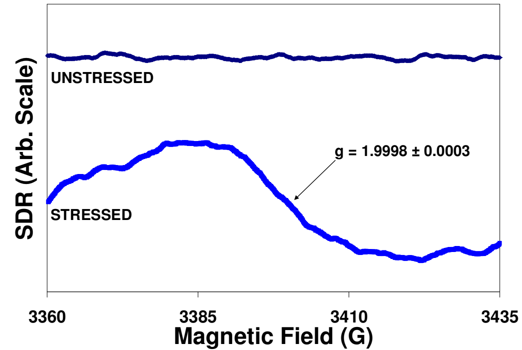

Figure 1: SDR results for an unstressed and 5 second room temperature negative bias stressed device (25°C and -2.0 volts).

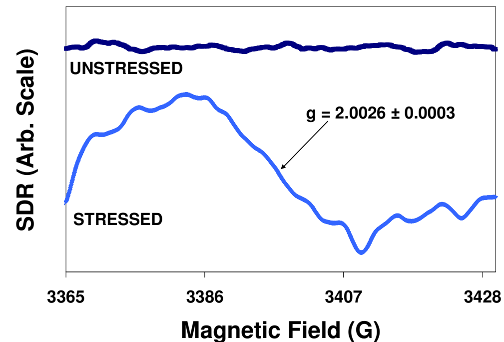

Figure 2: SDR results for an unstressed and high temperature stressed (140°C at -1.8 volts for 10,000 seconds) device. Note that the long term high temperature stressing creates a significantly different SDR response than the brief room temperature stressing.

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