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Deep Level Defects Involved in MOS Device Instabilities

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BACKGROUND

Several instabilities play important roles in limiting the reliability of metal-oxide-silicon field effect transistors (MOSFETs).[1-7] These instabilities almost always involve the creation of interface traps at the Si/dielectric boundary and also frequently involve deep level centers within the oxide. Important instabilities have involved the response of MOSFETs to ionizing radiation, hot carrier injection, high oxide field stressing, and the response of p-MOSFETs to moderately elevated temperature and negative gate bias, the negative bias temperature instability (NBTI).

The deep level defects involved in these instabilities can be observed by both conventional electron paramagnetic resonance (EPR)[8-10] and electrically detected magnetic resonance (EDMR) generally with spin dependent recombination (SDR).[10-13] The EDMR approach can allow studies of deep level defect structures in fully processed MOSFETs. Present day conventional EPR and SDR offer sensitivities close to that of standard MOS electrical characterization tools.

THIS PRESENTATION

This presentation will include a very brief introduction to relevant magnetic resonance techniques with emphasis on SDR detected EDMR. The presentation will also include an introduction to trapping centers typically observed in technologically relevant instabilities.[10,13-26] This introduction will include the fairly well understood Si/dielectric interface P_b centers, SiO_2 deep level defects called E' centers, several nitrogen related defects and some recently observed defects in HfO_2 based MOSFETs. This introduction will include a brief description of defect structure and energy levels primarily though not exclusively obtained through EPR studies. A major focus of this presentation will be recent magnetic resonance results on NBTI in conventional SiO_2 and nitrided SiO_2 based devices[21-25] as well as some preliminary results on negative bias stressing of HfO_2 based metal gate transistors.[26]

The conventional SiO_2 and nitrided SiO_2 device NBTI studies indicate that several silicon "dangling bond" defects can clearly play dominating roles in this technologically important problem and further indicate that processing, in particular the introduction of nitrogen into the oxide, leads to gross differences in the structure of the performance limiting defects. Some very recent preliminary EDMR results on negative bias stressed metal gate HfO_2 transistors[26] will also be included in this presentation.

In addition to the introduction to defect structure and electronic properties, a brief discussion of some relevant aspects of the statistical mechanics of the point defects will also be provided.[27]

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