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Electrically Detected Magnetic Resonance Study of High Field Stress Induced Si/SiO_2 Interface Defects

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High Field Stressing in SiO_2

- Several physical mechanisms have been proposed for the generation of high field stress induced defects in Si/SiO_2 devices [1]–[3]

- Very little evidence [4] exists as to the chemical and physical identity of such defects

- Here, we present electrically detected magnetic resonance (EDMR) measurements of spin-dependent recombination (SDR) currents at the Si/SiO_2 interface of MOSFETs

Background- Electron Paramagnetic Resonance

- The parent technique of EDMR is electron paramagnetic resonance (EPR)

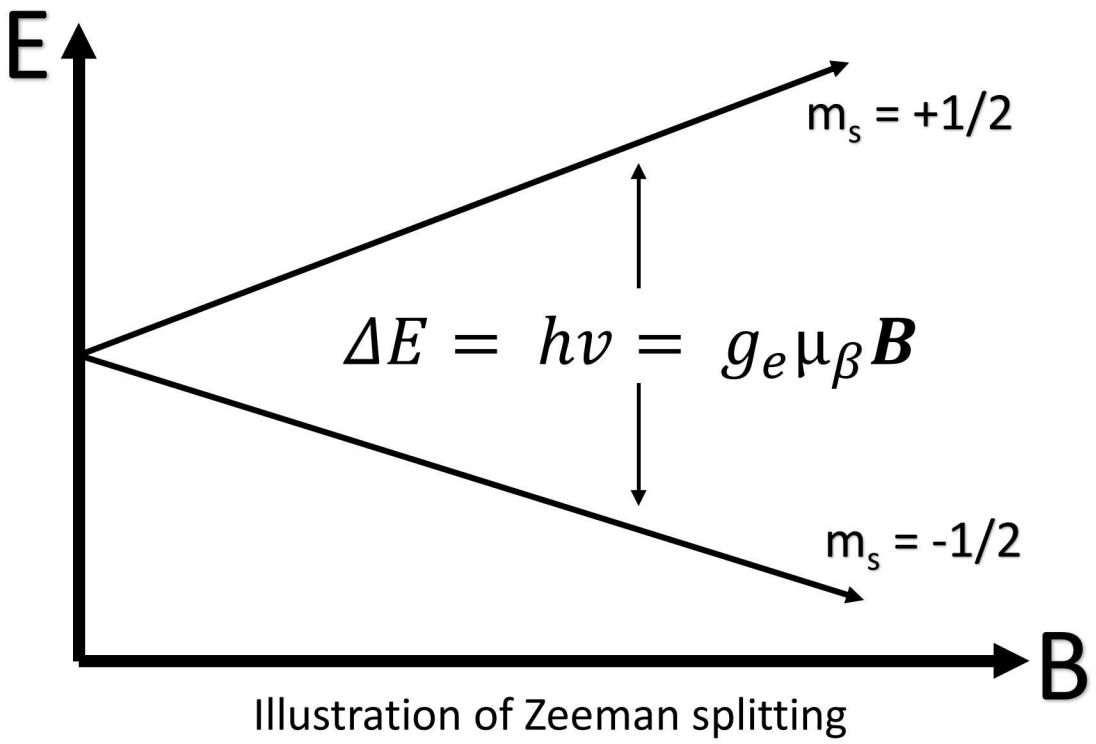


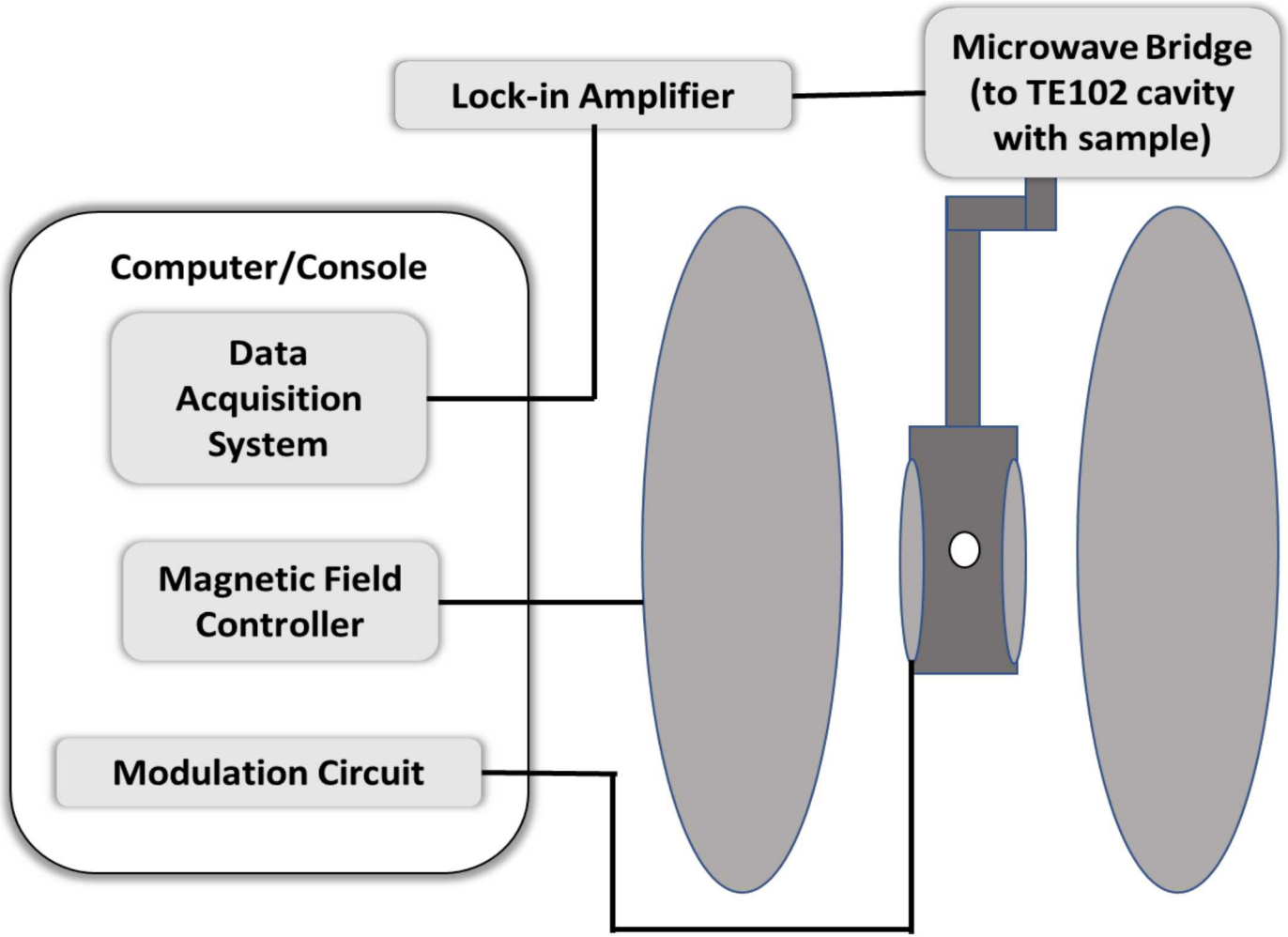
Illustration of Zeeman splitting

Spin-orbit coupling

Electron-nuclear hyperfine interactions

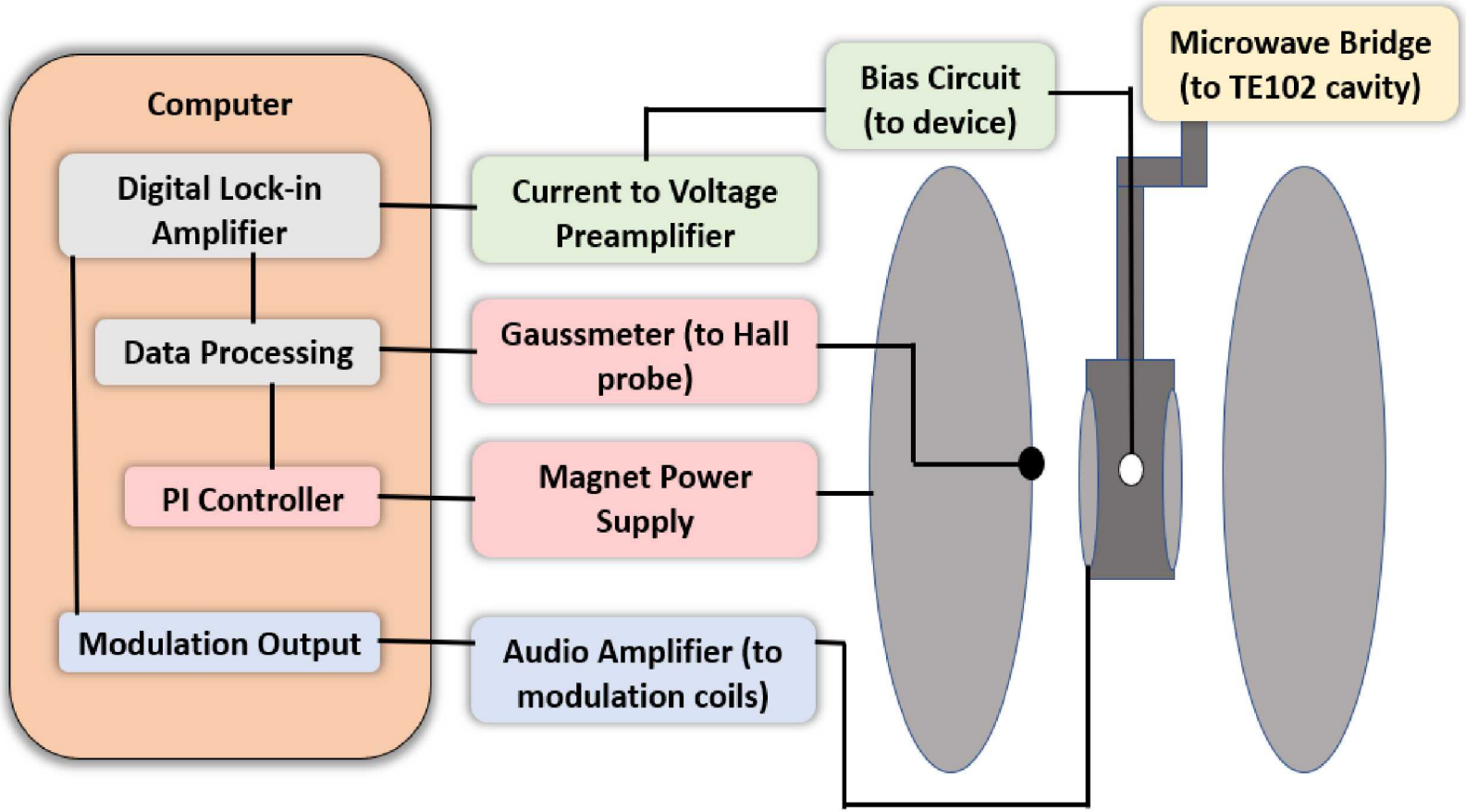
$$h\nu = g\mu_B B + \sum_i A_i I_i$$

Background: The EPR Measurement



- EPR has been used for decades to study paramagnetic defects in bulk semiconductors and insulators [5-9].
- EPR is limited in sensitivity (a minimum of 10^{10} paramagnetic defects are needed to detect an EPR singal) – NOT GOOD for measurements at the device level

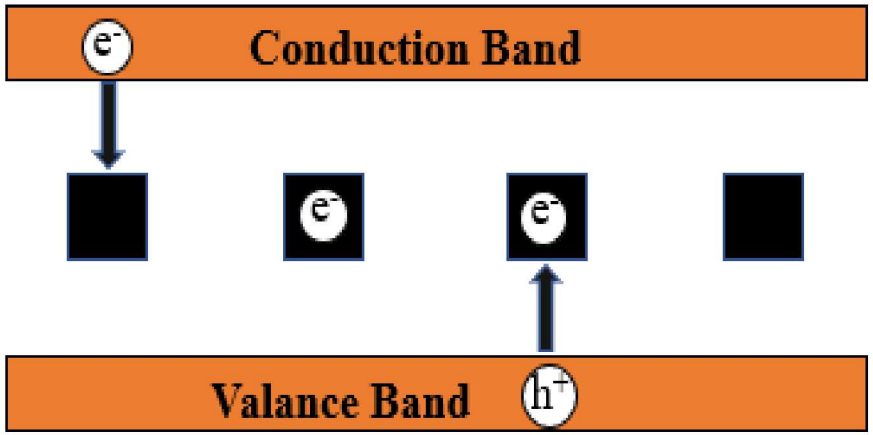
Background: EDMR



- EDMR overcomes EPR limitations by changing the way the magnetic resonance signal is detected

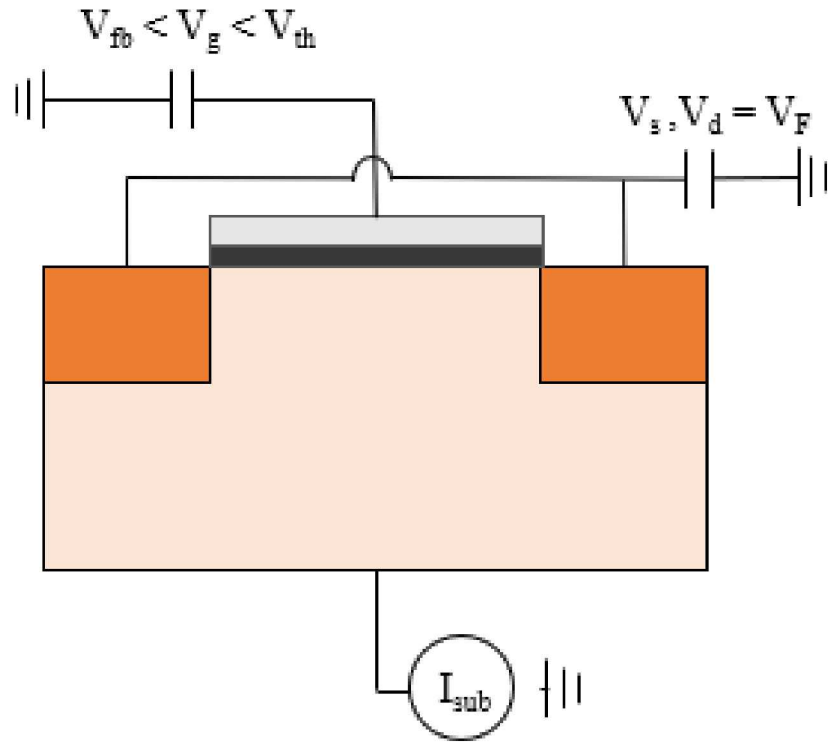
Spin Dependent Recombination (SDR) Current

- Here, we measure the EDMR signal through an SDR current
- SDR is best understood from the SRH model for recombination in deep level defect sites [10].
- In order for an electron to fall into a deep level, paramagnetic defect, the conduction electron and defect electron must have opposite spin
- At the resonance condition, electron spins “flip” allowing previously forbidden recombination events to occur

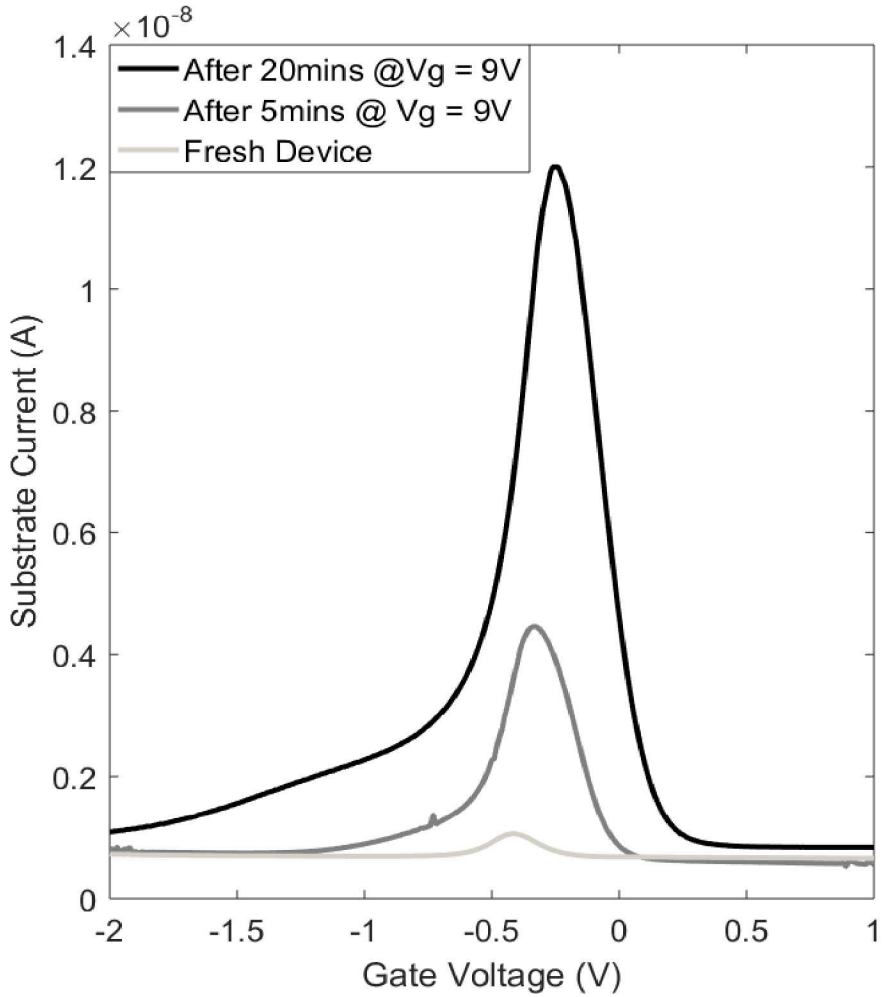


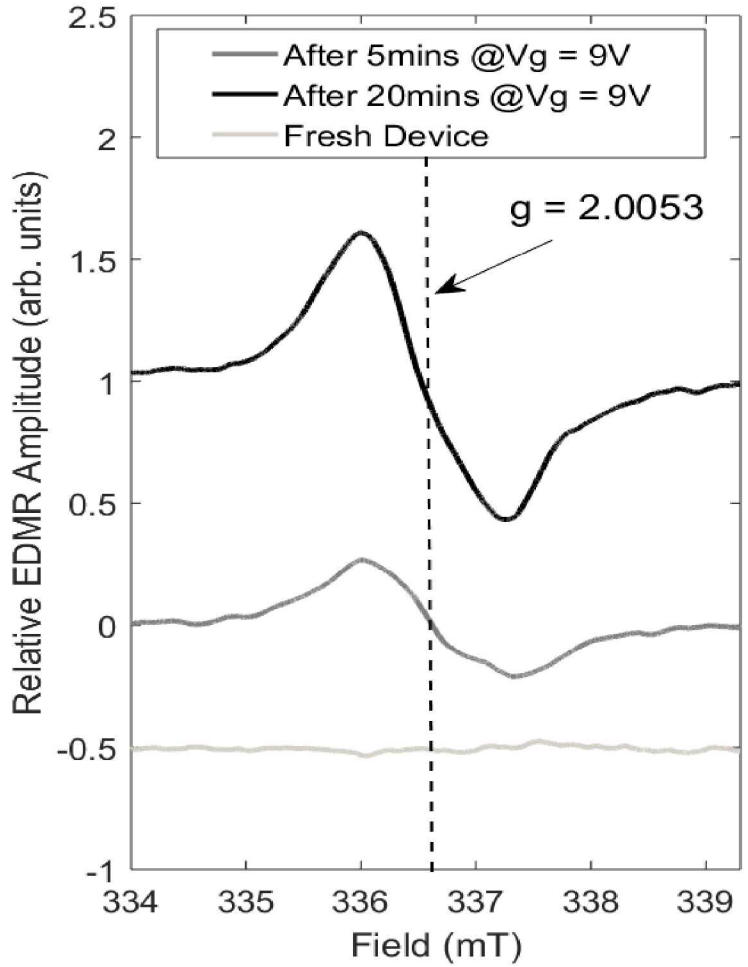
SDR at MOSFET Interfaces

- We report measurements of spin dependent interface recombination currents on arrays of 126 Si/SiO_2 MOSFETs, with 7.5nm gate thickness
- We utilize the DCIV biasing scheme [11] to create SDR current at MOSFET interfaces, measuring the recombination current from the substrate



DCIV electrical and DCIV EDMR Results

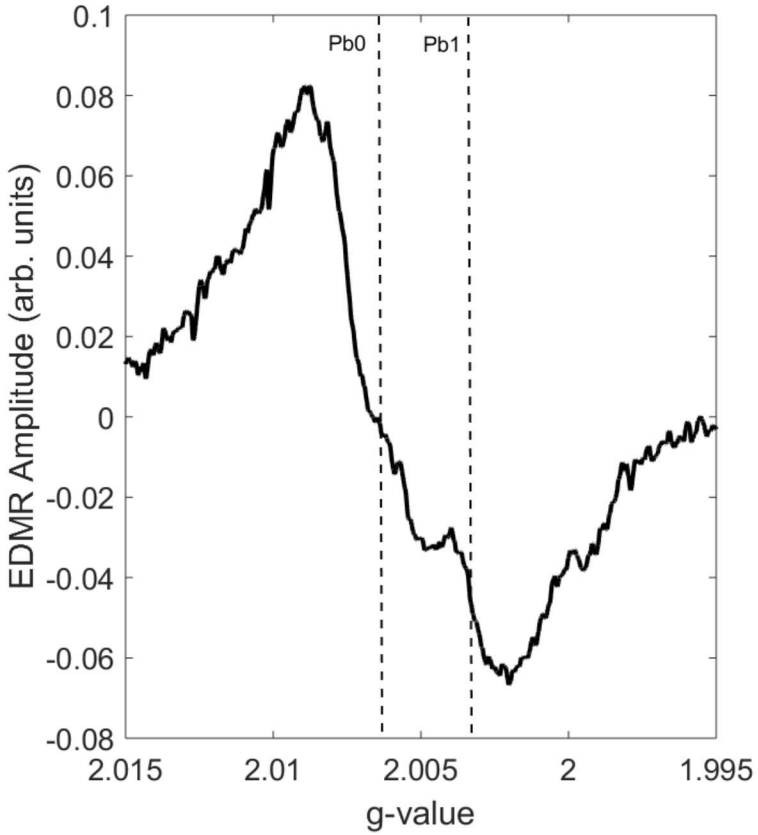




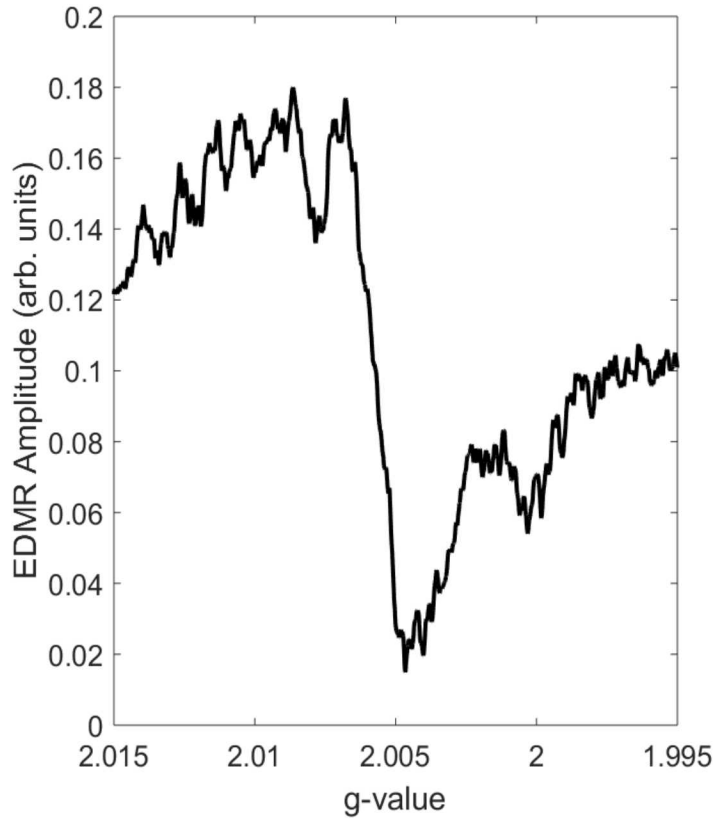
DCIV Electrical and DCIV EDMR Results

- It is clear from the DCIV electrical results that increased high-field stressing leads to an increase in interface recombination
- g = 2.0053 is similar to that of common Si/SiO_2 interface defects, the P_{b0} center (g=2.0059) and the P_{b1} center (g=2.0032), at this sample orientation [12,13]
- Lowering the modulation amplitude and rotating the sample can reveal additional information about the nature of this EDMR signal

Low Modulation Amplitude Results



B perpendicular to interface



B parallel to interface

- DCIV EDMR measurements were repeated for the sample stressed for 20 mins at lower modulation amplitude
- EDMR measurements were made with the magnetic field perpendicular and parallel to the MOSFET interfaces

Conclusions

- We have measured the DCIV EDMR response before and after high field gate stressing in Si/SiO_2 MOSFETs
- The g-value and orientation dependence of the stress induced EDMR response indicate that it is dominated by some combination of P_{b0} and P_{b1} interface defects

Questions?

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