

Understanding Dielectric Breakdown using EDMR and NZFMR

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Time dependent dielectric breakdown (TDDB) is a fundamental problem in solid state electronics which is still not fully understood. Different models in the literature provide very different expected lifetimes. A deeper understanding of the physical mechanisms of TDDB can be gained from using electrically detected magnetic resonance (EDMR) and near zero field magnetoresistance (NZFMR). This abstract shows data from such a study. We report a fundamental advance in our understanding of TDDB in SiO₂ and the first direct observation of the generation of a specific point defect, the E' center, due high field gate stress using EDMR, NZFMR, and other techniques at room temperature. EDMR and NZFMR are spectroscopic techniques sensitive only to electrically active defects.

In this study, gate oxides in large arrays of silicon on insulator (SOI) n-MOSFETs were subjected to high electric field stress at 7.5V. Damage caused by the stress was characterized using the Fitzgerald-Grove gated diode method [1], capacitance vs voltage (CV), EDMR, and NZFMR measurements [2]. The gate oxides were 7 nm thick and the gate areas of the transistor arrays were between 5,000 μm^2 and 50,000 μm^2 . The early increase in peak DCIV current in figure 1 indicates that the first stage of damage is characterized by interface state generation, specifically P_b centers, with no appreciable increase in bulk oxide defects. The generation of interface states is accompanied by the redistribution of hydrogen away from recombination centers [2] shown by the NZFMR results in figure 2. The interface state density eventually starts to saturate, followed by an increase in bulk oxide defects, specifically E' centers, represented by a shift in the voltage of the DCIV peak current. The P_b and E' centers were identified via their EDMR signals [3,4] as shown in figure 3. The E' spectrum only appears after long stress durations. This new understanding of the different stages of damage provides a fundamental insight into the physics of damage mechanisms during the leadup to TDDB.

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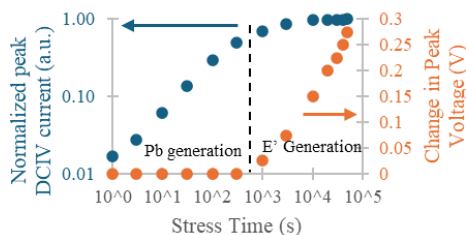


Figure 1: DCIV peak current value (blue, left axis) and voltage at which peak current occurs (orange, right axis)

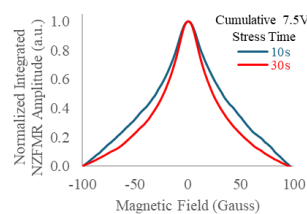


Figure 2: Integrated NZFMR indicating redistribution of hydrogen

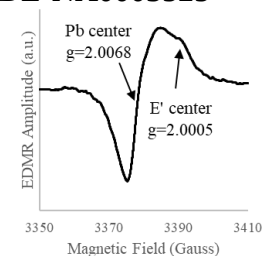


Figure 3: Measured EDMR spectrum of P_b and E' centers

[1] D. J. Fitzgerald and A. S. Grove, *Surface Science*, vol. 9, no. 2, pp. 347-369, (1968).

[2] S.J. Moxim et al., *Appl. Phys. Lett.* 7; 120 (6): 063502 (2022)

[3] E. H. Poindexter, P. J. Caplan, B. E. Deal, and R. R. Razouk, *J. of App. Phys.*, vol. 52, no. 2,879 (1981)

[4] P. M. Lenahan and J. J. Mele, *J of Vac Sci & Tech B*, 18.4, 2169, (2000)

Supplementary Pages

The original DCIV and CV data is shown here to corroborate the buildup of negative charge in the oxide at later stress times. Much more data was collected than can be shown in a 1 page abstract.

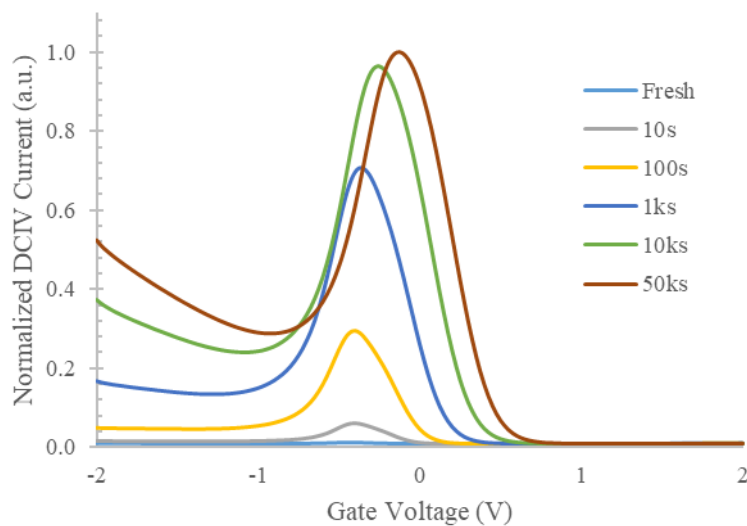


Figure 4: DCIV curves measured as a function of stress time. The size the DCIV peak increases until it saturates, when the size of the peak stops increasing and the peak starts shifting right, indicating negative charge buildup in the oxide.

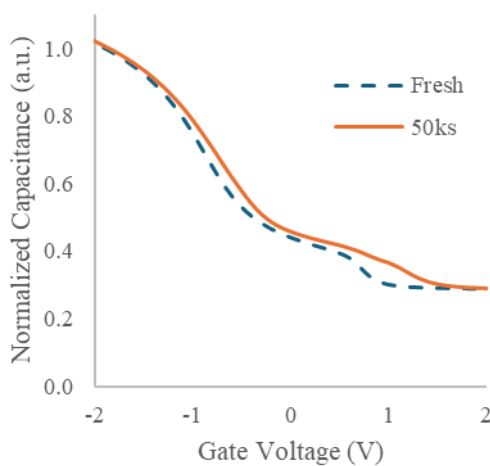


Figure 5: Capacitance vs voltage plots of the transistors before and after the stress. The curve is slightly stretched out and shifted to the right, indicating interface states and negative trapped charge in the oxide at the later timestamps.