# High Temperature Annealing of the Interface State Component of Negative-Bias Temperature Instability (NBTI) in MOSFET Devices

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The microelectronic reliability of advanced metal-oxide-semiconductor field effect transistors (MOSFETs) has shown increasing sensitivity to degradation phenomena and, in particular, to negative bias temperature instability (NBTI). Previously [1] we have reported on a methodology to extract three distinct components of NBTI; recoverable charge (oxide traps which discharge once the gate bias is zero), field recoverable charge (switching traps which seemingly discharged under positive gate bias), and interface state charge. The interface state (IS) charge was associated with the breaking of silicon-hydrogen bonds at the interface and did not discharge in an experimental time frame for temperatures between room temperature and 150° C. Here we will report on new results for higher temperatures which suggest an annealing of the interfacial states at high temperatures, and will compare the temperature dependence of the NBTI IS charge with the component of radiation charging associated with interface state formation.

NBTI measurements have been made at various temperatures up to 220° C on p-channel MOSFETs with SiON gate dielectrics having 130 nm channel lengths and 5 μm widths. Measurements of the source – drain current, $I_{ds}$, were made in the linear regime with a source-gate voltage, $V_{gs}$, ~ -0.51 V. Bias stressing was carried out at a gate bias of -3.25 V with the source, drain and body contacts shorted at 0 V for a total stressing time of 1500 s. This was followed by 3000 s of recovery at a gate bias of +1.5 V. The measured $I_{ds}$ variations with stress were converted into threshold voltage shifts, $\Delta V_{th}$ [1].

The experimental results of this set of measurements are shown in Fig.1. The charging data shows a similar shape and consistent growth for all temperatures below 180° C. However, the results for higher temperatures show the growth slowing and eventually turning around, so that there is less threshold voltage shift at 220° C than at 180° C. This can be explained by the presence of a recovery mechanism in the interface states which is only active at high temperatures.

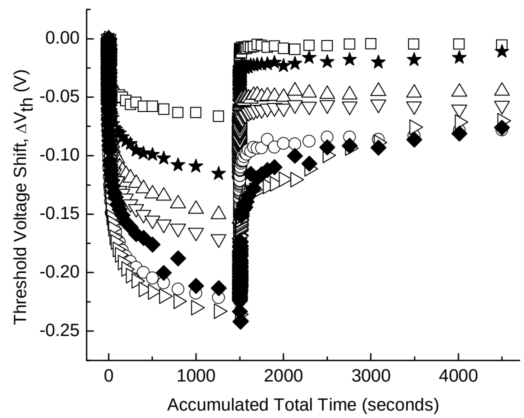


Fig. 1: The measured threshold voltage shift due to NBTI with $V_{gs}$(stress) = -3.25 V for 1500s and $V_{gs}$(rec) = +1.5 V for multiple temperatures 50° C (□), 90° C (★), 120° C (△), 150° C (▽), 180° C (○), 200° C (▷), and 220° C (◆).

There is a corresponding change in the shape of the recovery data. At temperatures below 150° C, there is a rapid recovery followed by a flat plateau representing the charged interface states because the device has discharged both the recoverable and field recoverable charge. The shape of the curve at higher temperatures shows a second recovery slope during what at lower temperatures was a plateau, showing recovery of previously permanent charge and supporting the idea that the interface states are annealing at high temperatures

[1] C. Mayberry, D. D. Nguyen, C. Kouhestani, K. E. Kambour, H. P. Hjalmarson and R. A. B. Devine, "Measurement and Identification of Three Contributing Charge Terms in Negative Bias Temperature Instability," ECS Trans., **50 (4)**, 223-232 (2012).

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