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Recovery Behaviors of $|V_{th}|$ Shift of pFETs by High-Voltage OFF-State and ON-State Stress for Post-Fabrication SRAM Cell Stability Self-Improvement

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[Introduction] Recently, a new concept of a post-fabrication self-improvement technique of SRAM cell stability by applying high voltage to supply voltage (V_{DD}) terminal has been proposed and demonstrated [1-3]. In this technique, OFF-state stress is selectively applied to a weaker pFET in the cell and $|V_{th}|$ decreases, while ON-state stress is applied to a stronger pFET and $|V_{th}|$ increases, resulting in automatic cell stability improvement [3]. It has been found that pFET reliability after high voltage stress is on of the major concerns but it is not a problem [4]. In this study, the recovery behaviors of pFETs by self-improvement stress are experimentally investigated. The comparison between short and long-time recovery are made. It is found that the recovery is not an issue for the SRAM stability self-improvement technique.

[Method] Device matrix array (DMA) TEG of 6T SRAM cells [2] was fabricated by the 40nm technology. Two types of stress condition were examined at 100^{O}C which are sweep stress and constant stress, the stress time was fixed to 10 s. After the stress application, $|\Delta V_{th}|$ as well as drain current in the linear region ($|I_{Dlin}|$) is measured. During recovery, pFETs are being relaxed with no bias condition. Please note that both OFF-state and ON-state stress in this study has higher V_{stress} and very short stress time.

[Results] Figs. 1(a) and (b) show the recovery of $|\Delta V_{th}|$ in p-OFF and p-ON just after stress application up to 5 days, respectively. It is found that a sudden recovery is observed within 10 s, and then, $|\Delta V_{th}|$ saturate in both p-OFF and p-ON cases. This recovery behavior of p-ON is very different from conventional NBTI stress where the recovery process continues for longer time [5]. Long-time recovery measurement has also been done, $|\Delta V_{th}|$ with various V_{stress} in p-OFF and p-ON after 3 months are measured for sweep stress case only as shown in Figs. 2(a) and (b). From the long-time recovery measurement result, it is shown that the measured $|\Delta V_{th}|$ after 2 and 3 months are almost the same indicating that there is no recovery process after 2 months in both p-OFF and p-ON cases. In OFF-state stress, electrons are injected into gate dielectrics near the drain, resulting in the decrease in $|V_{th}|$ [6]. Therefore, the recovery of p-OFF is related to electrons de-trapped. It is known that the recovery in NBTI stress is related to H diffusion [5]. In this present ON-state stress, the stress is much shorter and higher, and some of the Si-H bonds are permanently dissociated, resulting in more permanent $|\Delta V_{th}|$ part than recovery part.

[Conclusion] In self-improvement stress application, the stress applied is much shorter and higher and it is found SRAM stability self-improvement technique has no critical recovery issue.

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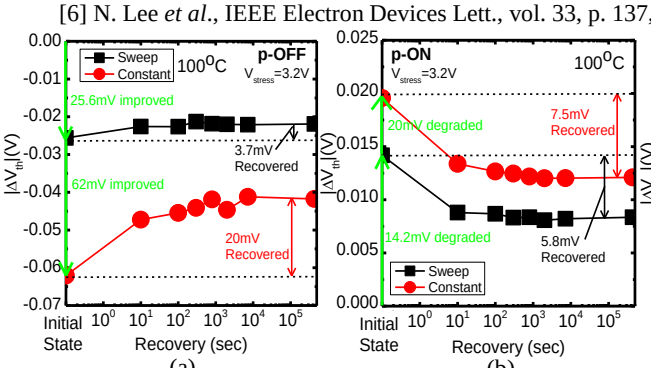

Fig.1. Measured $|\Delta V_{th}|$ after recovery measurementof (a) p-OFF (b) p-ON under constant stress and sweep stress.

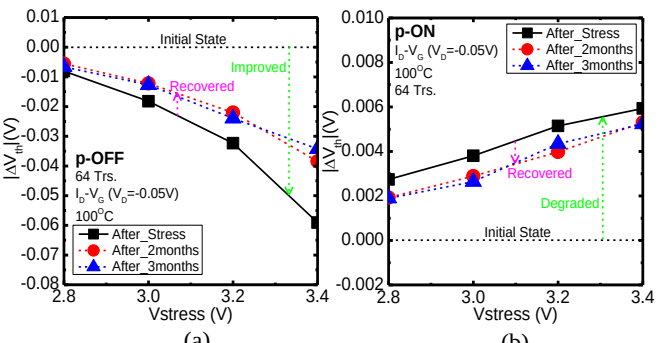

Fig.2. Measured $|\Delta V_{th}|$ after long-time recovery measurement of (a) p-OFF (b) p-ON under sweep stress.