A New Write Stability Metric for Yield Estimation in SRAM Cells at Low Supply Voltage

Hao Qiu, Kiyoshi Takeuchi, Tomoko Mizutani, Takuya Saraya, Masaharu Kobayashi, and Toshiro Hiramoto

Institute of Industrial Science, The University of Tokyo; Email: hqiu@nano.iis.u-tokyo.ac.jp

[Introduction] Voltage scaling holds significance for low-power operation in SRAM cells. To give yield estimation in a large capacity of SRAM cells, a good write stability metric is of great importance. Write static noise margin (WSNM) by write butterfly curve (BC) has been a common metric [1], since it directly corresponds to inverter characteristics and is easy to understand. But considering its non-normality, both simulations [2] and experiments [3] have excluded WSNM at low V_{DD} from a good metric. Here [4], a new metric called extended WSNM (E-WSNM) is proposed and evaluated. **[Results]** SRAM device-matrix-array test-element-group (DMA-TEG) [5] with silicon-on-thin-BOX (SOTB) FETs [6] was fabricated by 65 nm technology. All measurements were performed in 1k SOTB SRAM cells at low V_{DD}=0.4V. Conventional WSNM shows "two-mode" distribution (see Fig. 1) [3]. Fig. 2 gives write BCs in which the node voltage is swept between zero and V_{DD}. Mode II differs from Mode I in that WSNM is extracted near the stretched tail of the write voltage transfer curve (VTC) in Fig. 2. Since write failure occurs only when BC shows Mode-II behavior, Mode-II distribution should be used for cell yield estimation. However, it is not always possible to measure sufficient number of cells to fully reveal the Mode-II part of the distribution. To effectively detect Mode-II behavior, a new extended BC is proposed, in which the voltage sweep range of VL is extended below zero and that of VR is extended beyond V_{DD}. Fig. 3 gives one example and E-WSNM is extracted from the red square. Statistically, Fig. 4 shows extended BCs of 1k SRAM cells. Compared to conventional BCs, tails of write VTCs clearly appear in extended BCs. E-WSNM is fully in Mode II and follows normal distribution in Fig. 1. To compare E-WSNM and conventional WSNM, Fig. 5 gives the scatter plot of E-WSNM versus WSNM. Good correlation towards failure edge is found, which means E-WSNM shares the same failure cell with WSNM. In addition, taking combined word line margin (CWLM) [7] as reference metric, E-WSNM is evaluated in Fig. 6. Compared to WSNM, E-WSNM shows good correlation with CWLM, which strengthens our conclusion. **[Conclusion]** The proposed new write stability metric – extended WSNM – is a good candidate for write yield estimation at low V_{DD}.

[References] [1] A. Bhavnagarwala et al., IEDM, p. 659, 2005. [2] H. Makino et al., TCSII., vol. 58, p. 230, 2011. [3] H. Qiu et al., ICSICT, p. 987, 2014. [4] H. Qiu et al., ICMTS, p. 126, 2016. [5] T. Hiramoto et al., IEEE TED., vol. 58, p. 2249, 2011. [6] Y. Yamamoto et al., VLSI, p. T212, 2013. [7] N. Gierczynski et al., ICMTS, p. 91, 2007.

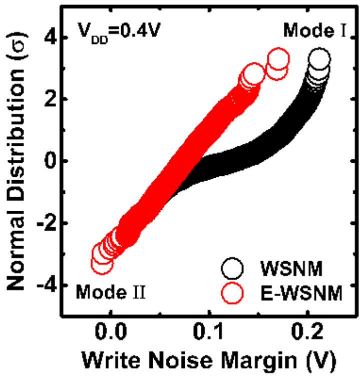

Fig. 1. Cumulative plot of WSNM (black)/E-WSNM (red) in 1k SOTB SRAM cells at V_{DD}=0.4V.

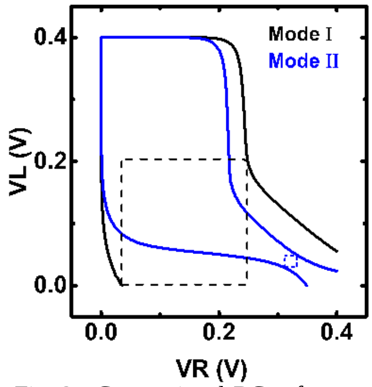

Fig. 2. Conventional BCs of two cells with WSNM in Mode I/ II is extracted as the side of black/ red square.

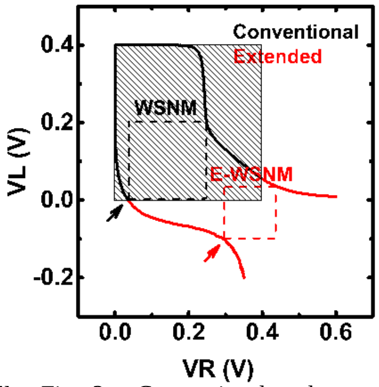

Fig. 3. Conventional and extended BC of one SRAM cell at V_{DD}=0.4V. Patterned area indicates voltage sweep range of conventional BC.

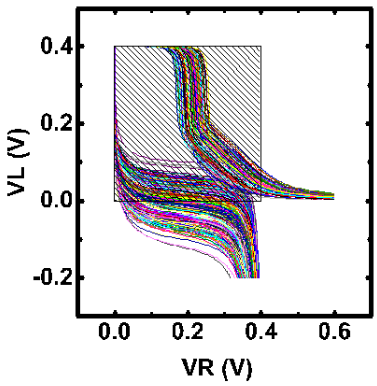

Fig. 4. Extended BCs of 1k SOTB SRAM cells at V_{DD}=0.4V. Patterned area indicates voltage sweep range of conventional BCs.

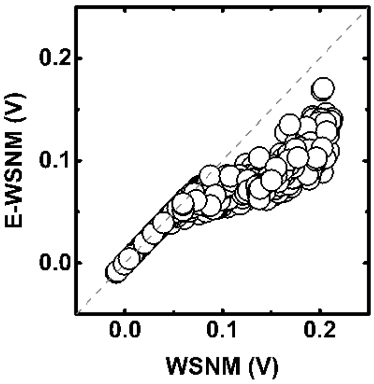

Fig. 5. Scatter plots of E-WSNM versus WSNM in 1k SOTB SRAM cells at V_{DD}=0.4V.

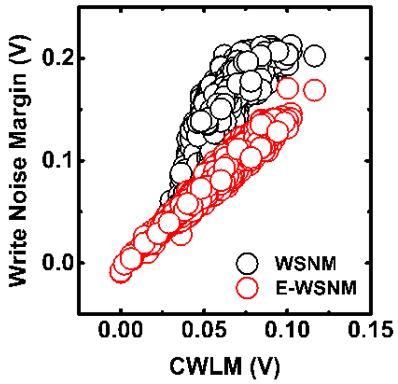

Fig. 6. Scatter plot of WSNM (black) /E-WSNM (red) versus CWLM in 1k SOTB SRAM cells at V_{DD}=0.4V.