Back-bias impact on variability and BTI for 3D-monolithic 14nm FDSOI SRAMs applications

D. Bosch, F. Andrieu, X. Garros, L. Ciampolini, A. Makosiej, O. Weber, J.
Lacord, J. Cluzel, B. Giraud, G. Cibrario, et al.

► To cite this version:

D. Bosch, F. Andrieu, X. Garros, L. Ciampolini, A. Makosiej, et al.. Back-bias impact on variability and BTI for 3D-monolithic 14nm FDSOI SRAMs applications. 2019 Joint International EUROSIOI Workshop and International Conference on Ultimate Integration on Silicon (EUROSIOI-ULIS), Apr 2019, Grenoble, France. pp.1-4, 10.1109/EUROSIOI-ULIS45800.2019.9041890 . hal-02998370

HAL Id: hal-02998370

<https://hal.science/hal-02998370>

Submitted on 19 Nov 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Back-bias impact on variability and BTI for 3D-monolithic 14nm FDSOI SRAMs applications

D. Bosch^{1,3}, F. Andrieu¹, X. Garros¹, L. Ciampolini^{1,2}, A. Makosiej¹, O. Weber^{1,2}, J. Lacord¹, J. Cluzel¹, B. Giraud¹, G. Cibrario¹, L. Brunet¹, P. Batude¹, C. Fenouillet-Béranger¹, D. Lattard¹, J. P. Colinge¹, F. Balestra³, M. Vinet¹

¹CEA-LETI, Univ. Grenoble Alpes, 17 rue des Martyrs, 38054 France ; ²STMicroelectronics, 850 rue Jean Monnet, F38926 Crolles ; ³Univ. Grenoble Alpes, CNRS, Grenoble INP, IMEP-LAHC, F-38000 France

Abstract— We fabricated and characterized 14nm planar Fully-Depleted-Silicon-On-Insulator (FDSOI) 0.078 μm^2 SRAM cells. Temporal and spatial variability as well as sensibility to temperature, supply voltage (V_{DD}) and back bias (V_{well}) are extracted. These data evidence that the 14nm SRAM is read-limited, which could be improved by a smart back-bias management [1]. In this work we demonstrate a 50mV Static Noise Margin (SNM) variability improvement (at $V_{DD}=0.8\text{V}$) by back-bias, without additional BTI stress. Such an assist technique can be eventually leveraged at fine-grain by 3D monolithic integration, owing to local back-planes.

Keywords- 3D-monolithic; FDSOI; BTI stress; Supply Read Retention Voltage; SRAM margins; variability

I. INTRODUCTION

3D-monolithic integration, also named 3D sequential, consists in stacking active device layers on top of each other in a sequential manner on a given wafer substrate. This technology improves digital performance by reducing the wire length [2]. Moreover, it enables the integration of local back-planes (Figs 1-2), which can be dynamically biased in order to improve the performance of standard cells [3] and SRAMs [1] without area overhead. In order to verify if this fine-grain assist can be also used to compensate spatial variability with high reliability, we measure in this work, the impact of back-bias on 14nm planar FDSOI SRAM variability and BTI.

II. CHARACTERIZATION OF 14 FDSOI SRAMs

High-density (HD, 0.078 μm^2) and High-current (HC, 0.098 μm^2) 14nm planar FDSOI SRAMs have been fabricated on silicon channel with a single p-type metal gate and single p-doped well (SPWELL) [4]. SRAM typical figures of merits, SNM and Write Noise Margin (WNM), have been electrically characterized. Considering worst-case measurements at low V_{DD} and 125°C and including global variability considerations, one finds that 14nm FDSOI SRAM stability is read-limited (Fig.3). In fact, to enhance SNM, standard assist technique can be used [5]. More specifically, Fig.4 shows that a Word-line (WL) underdrive by 20% improves the SNM by 37% at $V_{DD}=0.8\text{V}$.

A. SNM spatial compensation with back bias

A 63-50 mV/V threshold voltage sensibility on well bias (V_{well}) was extracted for the HC-HD Pass-Gate (PG),

respectively (Fig.5). This enables either the PG drive current to be boosted by 44% for $V_{well}=2\text{V}$ or its leakage to be reduced below 0.1pA for $V_{well}=-2\text{V}$ on demand (Fig.6). Since the well is shared between all devices in planar FDSOI, $V_{well}<0$ strengthens PMOS Pull-Up (PU) with respect to NMOS (PG, Pull-Down PD), helping the PU to maintain BLTI=1 and BLFI=0 during the read operation. On the contrary, using $V_{well}>0$ improves the PG/PU strength ratio (and so the WNM). Thus, the sensibility of SRAM to the back bias can be used to assist the read ($V_{well}<0$) and write ($V_{well}>0$) operation. This feature can be used as a process compensation technique, to narrow die-to-die variations, as illustrated by the 50mV SNM variability improvement in HD bitcells across wafer (Fig.7).

B. BTI-induced dynamic variability at the bitcell level

In order to check if this bias-bias assist influences the ageing, we measured the so-called Supply Read Retention Voltage SRRV at 125°C and $V_{DD\text{stress}}=2\text{V}$, which is representative of the SNM (Fig.8 and [6]). Our Bit-Line (BL) current fast measurement method is effective to extract the reduction of the read margin induced by stress (Fig. 9 and [6]). ΔSRRV distributions at different stress times for $V_{well} = 0$ and -0.8V are reported in Fig. 10. Same ageing is observed for both positive and negative V_{well} , proving that back biasing does not degrade the BTI reliability. Finally, $V_{well}=-0.8\text{V}$ boosts SRRV by 65.5mV-38.1mV on fresh bitcells and after stress, respectively (Figs 11-12).

III. PERSPECTIVES

We provide guidelines to improve SNM variability in 14nm SRAM cells without ageing drawback. This opens the path towards a fine-grain back-bias assist technique using the unique features of 3D monolithic CoolCubeTM integration.

REFERENCES

- [1] D. Bosch et al., VLSI-TSA, 2019, forthcoming
- [2] F. Clermidy et al., S3S, 2015, pp. 1–4.
- [3] F. Andrieu et al., Tech. Dig. IEDM, 2017, p. 20.3.1–20.3.4.
- [4] O. Weber et al., 2014 Symposium on VLSI Technology, 2014, pp. 1–2
- [5] Guo, Z. et al., IEEE Journal of Solid-State Circuits 44, 2009, 3174–3192
- [6] Hussein et al., IEEE TED 61, 2014, 3991–3999

FOM (mV)	High-Density (HD)	High-Current (HC)
SNM ($T=25^{\circ}\text{C}$, $V_{\text{DD}}=0.8\text{V}$)	139	148
WNM ($T=25^{\circ}\text{C}$, $V_{\text{DD}}=0.8\text{V}$)	320	351
SNM ($T=125^{\circ}\text{C}$, $V_{\text{DD}}=0.55\text{V}$)	68	88.5

Fig.10: Experimental Δ SRRV distribution on ~20 bitcells for two V_{well} polarizations and fitted using the model [6].

Fig.11: Fresh and after stress SRRV distribution for different p-well biasing.

Fig.12: μ_{SRRV} during stress and recovery. A $-0.8 \text{ V } V_{\text{well}}$ biasing achieves better stability.

ACKNOWLEDGMENTS: This work was supported by French Public Authorities through LabEx Minos ANR-10-LABX-55-01.