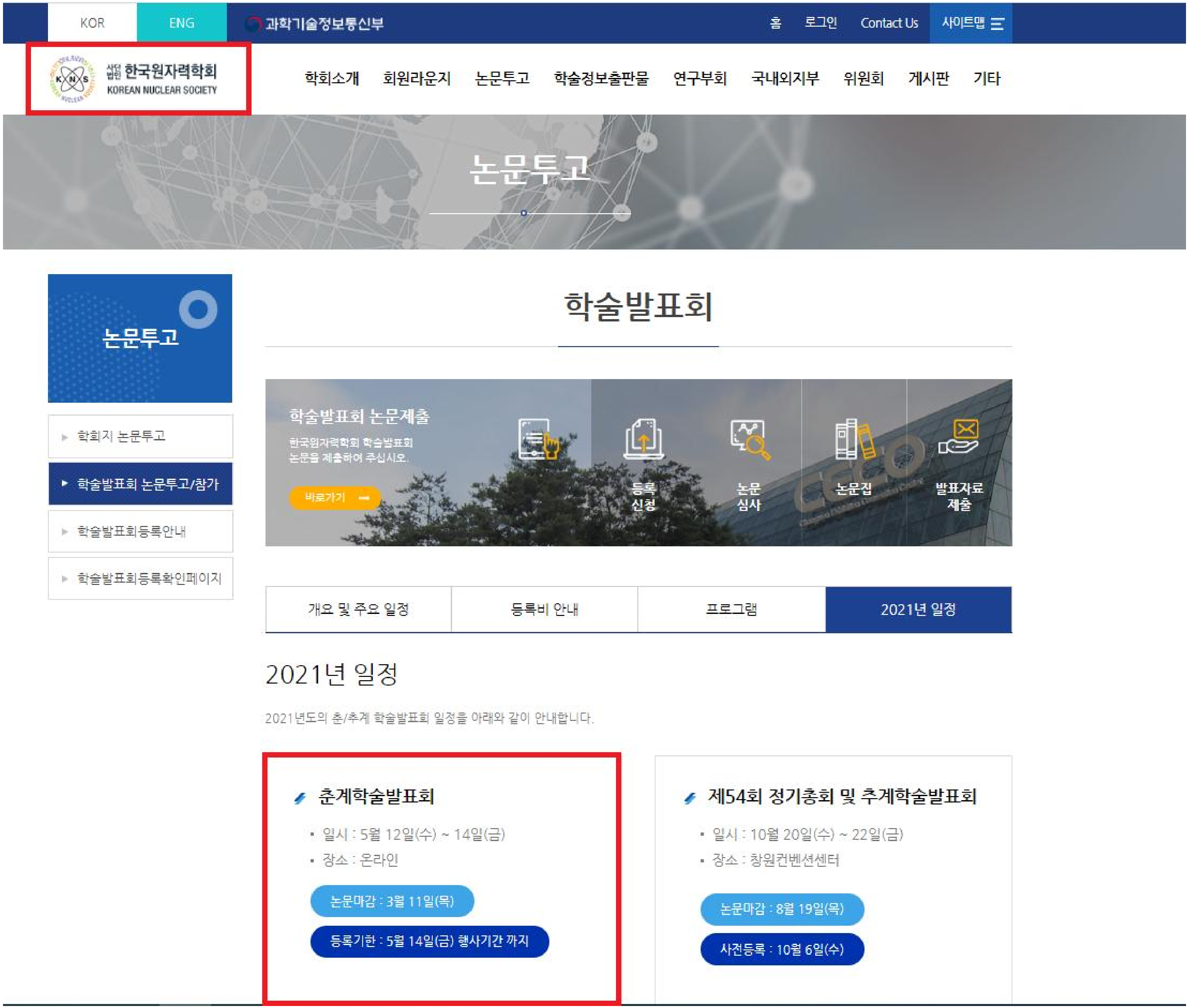

학술발표회

학술발표회 논문제출

한국원자력학회 학술발표회 논문을 제출하여 주십시오.

2021년 일정

2021년도의 춘/추계 학술발표회 일정을 아래와 같이 안내합니다.

춘계학술발표회

- 일시 : 5월 12일(수) ~ 14일(금)
- 장소 : 온라인

논문마감 : 3월 11일(목)

등록기한 : 5월 14일(금) 행사기간 까지

제54회 정기총회 및 추계학술발표회

- 일시 : 10월 20일(수) ~ 22일(금)
- 장소 : 창원컨벤션센터

논문마감 : 8월 19일(목)

사전등록 : 10월 6일(수)

8C

방사선이용 및 기기 (Radiation Utilization and Instrumentation) – POSTER

| **좌장** 홍진태(Jintae Hong), 임윤묵(Youn–Mook Lim) | **발표장소** 온라인

PO8C01	Preliminary Test of Multi-Layer Faraday Cup for Quality Assurance of Proton Beam Energy Gwang–il Jung, Sang–Pil Yoon, and Myung–Kook Moon(KAERI)
PO8C02	Analysis on Static Noise Margin and Single Event Upset of 10T SRAM for Radiation Tolerance Eunju Jo and Inyong Kwon(KAERI)
PO8C03	Design of Radioactive Krypton Detection System using PIPS Detector Mee Jang, Jinhyung Lee, Hyuncheol Kim, Won Young Kim, and Wanno Lee(KAERI)
PO8C04	Enhancement of Physical Properties of Boehmite/HDPE Nanocomposite Film by Electron Irradiation Ju Hyuk Lee, Heon Yong Jeong, Sang Yoon Lee, and Sung Oh Cho(KAIST)
PO8C05	Fabrication and Performance Test of Scintillator Free-Replaceable Type Detector for Comparison of Inorganic Scintillator Performance Seungbin Yoon, Hyeonmin Lee, Woo Nyun Choi, and Hee Reyoung Kim(UNIST)
PO8C06	Characteristics of 3D Printed Plastic Scintillator for Thermal Neutron Measurement with Pulse Shape Discrimination Kyungmin Kim, Dong Geon Kim, Sangmin Lee, Jaebum Son, and Yong Kyun Kim(HYU)
PO8C07	Apply the Light Guide to Improve the Light Collection Efficiency of the Gamma Ray Suyeon Hyeon, Jihwan Boo, Seoryeong Park, and Manhee Jeong(JNU)
PO8C08	SNM Detection with Coded-Aperture Gamma Imager for Nuclear Security JIHWAN Boo, Seoryung Park, Suyeon Hyeon, and Manhee Jeong(JNU)
PO8C09	Synthesis of Nano-Grained ZnWO4 Thin Film Scintillator by Thermal Evaporating Deposition Method Heon Yong Jeong, Ju Hyuk Lee, and Sung Oh Cho(KAIST)
PO8C10	A Study on the Development of Drum Radioactivity Uniformity Index (DRUX) and Improvement of Drum Scanning Accuracy Jichang Ryu, Chanjun Park, and Jungsuk Park(KEPCO NF), Jaehyun Park and Gyuseong Cho(KAIST)
PO8C11	Development of Remote Monitoring System for Deep Learning-Based Radiation Test Capsule Chul–Ying Lee, Kee–Nam Choo, Man–Soon Cho, Yoon–Taeg Shin, Sung–Jae Park, and Sung–Woo Yang(KAERI)
PO8C12	Gamma-Ray Spectroscopy based on a LaBr3(Ce) Scintillator to Detect Various Kinds of Radionuclides Simultaneously with High Resolution Jae Hyung Park, Si Won Song, Taeseob Lim, Seunghyeon Kim, Jinhong Kim, Jin Ho Kim, and Bongsoo Lee(CAU), Sang Hun Shin(FNC Tech.)
PO8C13	Chlorine, Iron, and Gold Ion Beam Extraction with 1.7 MV Tandem Accelerator at KOMAC Nam Woo Kang, Kye–Ryung Kim, Kyumin Choe, and Hyeok–jung Kwon(KAERI)
PO8C14	Uniformity Evaluation Study Thick Electrode Using Noncontact Mass Estimation Method Jiseok Kim, Hye In Song, Hanjin Kim, Boyoung Han, and Harim Lee(KAERI)
PO8C15	Development of 6-Inch Wafer Loading System 1-MV Electrostatic Accelerator at KOMAC Won–Hyeok Jung, Yong–Sub Cho, Hyeok–Jung Kwon, han–Sung Kim, and Kye–Ryung Kim(KAERI)
PO8C16	Measurements of Light-Output Ratios Using Inorganic and Organic Scintillators to Identify Gamma-Ray Emitting Radionuclides Seunghyeon Kim, Siwon Song, Taeseob Lim, Jae Hyung Park, Jinhong Kim, Jin Ho Kim, and Bongsoo Lee(CAU)

Analysis on Static Noise Margin and Single Event Upset of 10T SRAM for Radiation Tolerance

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1. Introduction

In the space environment, a common problem in memory semiconductors is soft errors. The soft error is a sort of single event effect (SEE) caused by radiation, which means that a single active particle additionally generates electric charges or current inside the semiconductor chip, resulting in malfunction [1].

Static random access memory (SRAM) is now widely used in many digital circuits. The memory device of which cell consists of inverters can retain its stored information as long as power is supplied. Also, it has some advantages in fast processing speed and minimum power consumption. However, SRAMs are also vulnerable to radiation, especially when single event upset (SEU) occurs [2]. The SEU is a type of SEE that makes bits inverted. Therefore, it is critical for SRAM and must be considered when designing for specific applications under radiation environments.

In this study, we propose a new 10T SRAM structure which is simply added a tri-state buffer to a conventional 6T SRAM as shown in Fig. 1 and Fig. 2. The additional tri-state buffer provides more drive strength onto the internal data nodes to prevent a data flip in a situation of SEE. And we compare the performances with the conventional 6T SRAM structure by simulations.

2. Conventional 6T SRAM

2.1 Operation

- *Read mode*

First, the word line (WL) is given a LOW signal to turn off the access transistors. Then bit line (BL) and bit line bar (BLB) are precharged by half of VDD. When the access transistors are turned on by giving HIGH signal to WL again, the values stored in nodes Q and QB are transmitted into BL and BLB. Finally, it is amplified by a sense amp at the end of BL and BLB.

- *Write mode*

In contrast to the read operation, the access transistors are initially turned on by applying a HIGH signal to the WL. BL must get HIGH signal for writing HIGH to memory, and LOW signal for writing LOW. Finally, turning off the access transistors by giving the LOW signal to the WL ends the operation and keeps the memory value until next writing.

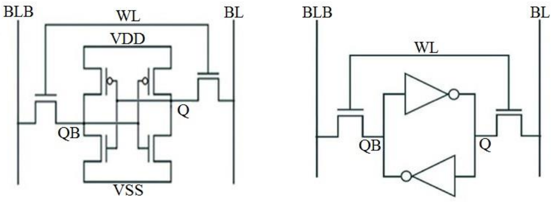

Fig. 1. Schematic and block diagram of the conventional 6T SRAM cell

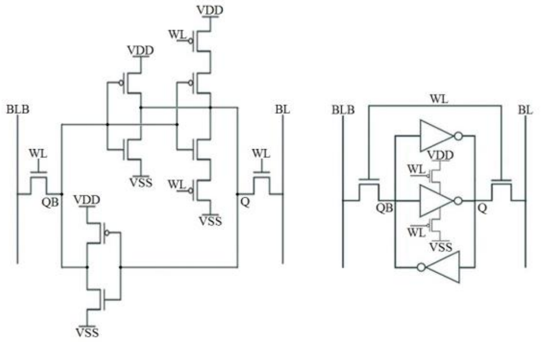

Fig. 2. Schematic and block diagram of the proposed 10T SRAM cell

2.2 Single Event Upset

A data of the conventional 6T SRAM is easily flipped by the radiation. In the worst case, current is generated in a sensitive node due to radiation effects. If the data of the affected node is changed, then the other is instantly changed along. To address this problem, we propose a new radiation hardened SRAM cell using ten transistors.

3. Proposed 10T SRAM

Proposed 10T SRAM consists of three inverters in parallel as shown in Fig. 2. One of them is a tri-state buffer with a PMOS switch at the top and bottom of the inverter, and it raises the drive strength. As a result, a 10T SRAM can stand higher radiation energy level after irradiated than 6T SRAM. So, it has better durability to radiation effects.

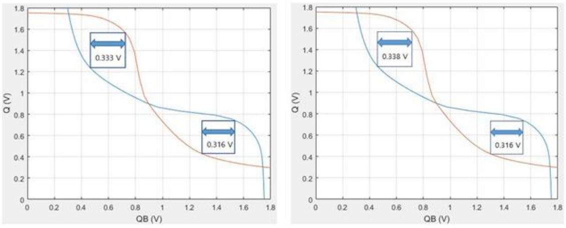

Fig. 3. Read SNM of 6T SRAM (left) and 10T SRAM (right)

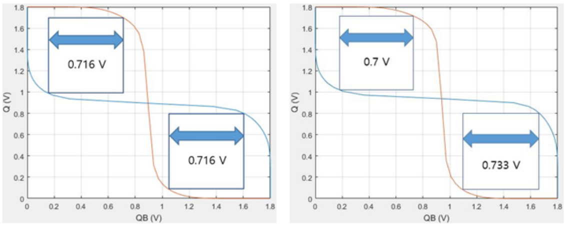

Fig. 4. Hold SNM of 6T SRAM (left) and 10T SRAM (right)

4. Simulation Results

4.1 Static Noise Margin

Static noise margin (SNM) is one of the indicators to determine the stability of SRAM operation [3]. As shown in Fig. 3, read SNM is 0.316 V for both of conventional 6T SRAM and proposed 10T SRAM. But hold SNM of the 10T SRAM is reduced than the 6T SRAM as shown in Fig. 4. However, it does not affect normal operation of SRAM.

4.2 SEU Test Simulation

To verify radiation resistance, we injected the exponential current source to the sensitive node Q or QB in hold mode [4]. As shown in Fig. 5, 6T SRAM data is flipped when 220 μA is injected to the sensitive node Q unlike 253 μA of 10T SRAM. The exponential current source of 220 μA has 43.6 fC and that of 253 μA has 49 fC. Linear energy transfer (LET) can be obtained by: 1 MeV/μm = 4.31 MeV·cm^2/mg = 44 fC/μm [5]. As a result, the proposed 10T SRAM can stand higher radiation energy level of 27.2 MeV·cm^2/mg than the conventional 6T SRAM of 23.7 MeV·cm^2/mg. On actual irradiation tests, we anticipate that a LET value for the bit flip will be obtained much larger because of less leakage current generation induced by radiation than the ideal current source enforcing the node in the simulation.

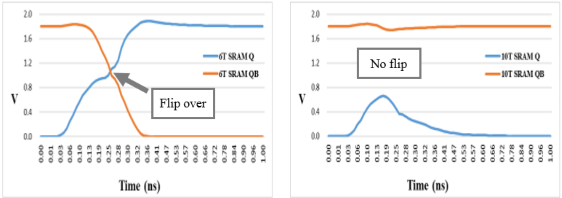

Fig. 5. SEU test of 6T SRAM and 10T SRAM when current is 220 μA.

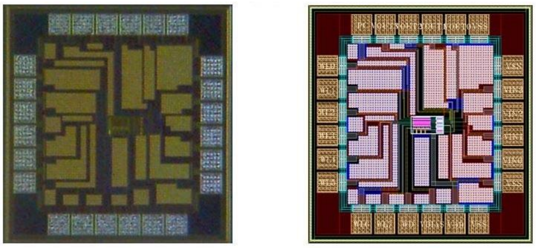

Fig. 6. Proposed 10T SRAM: Test chip photo and Layout

TABLE I
COMPARISON OF 6T SRAM AND 10T SRAM

	6T SRAM	10T SRAM
Cell size (μm^2)	41.69	65.83
Hold SNM (V)	0.716	0.7
Read SNM (V)	0.316	0.316
Cell power consumption (pW)	83.942	97.006
Threshold LET at SEU failure (MeV·cm^2/mg)	23.7	27.2

5. Conclusions

For memory semiconductor devices such as SRAM, soft errors must be considered for harsh radiation environments. So, we design a new 10T SRAM which has an additional tri-state buffer compared to conventional 6T SRAM as shown in Fig. 6. This 10T SRAM cell size is 65.83 μ m^2 and the cell power consumption is 97.006 pW as shown in Table I. The proposed 10T SRAM has SNMs of 0.7 V and 0.316 V and LET of 27.2 MeV· cm^2/mg. Although the hold SNM is reduced by 2.28 %, it does not affect normal operation and LET of the 10T SRAM is 14.8 % better than the conventional 6T SRAM due to the additional tri-state buffer. The simulation results show that the proposed 10T SRAM has better radiation tolerance than the conventional 6T SRAM.

After performing the actual radiation test on the tape-out chip, the results will be announced in conference.

Acknowledgements

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[1] R. C. Baumann, "Radiation-induced soft errors in advanced semiconductor technologies," in IEEE Transactions on Device and Materials Reliability, vol. 5, no. 3, pp. 305-316, Sept. 2005.
[2] L. D. Trang Dang, M. Kang, J. Kim and I. Chang, "Studying the Variation Effects of Radiation Hardened Quatro SRAM Bit-Cell," in IEEE Transactions on Nuclear Science, vol. 63, no. 4, pp. 2399-2401, Aug. 2016.
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[4] L. D. Trang Dang, J. S. Kim and I. J. Chang, "We-Quatro: Radiation-Hardened SRAM Cell With Parametric Process Variation Tolerance," in IEEE Transactions on Nuclear Science, vol. 64, no. 9, pp. 2489-2496, Sept. 2017.
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Analysis on Static Noise Margin and Single Event Upset of 10T SRAM for Radiation Tolerance

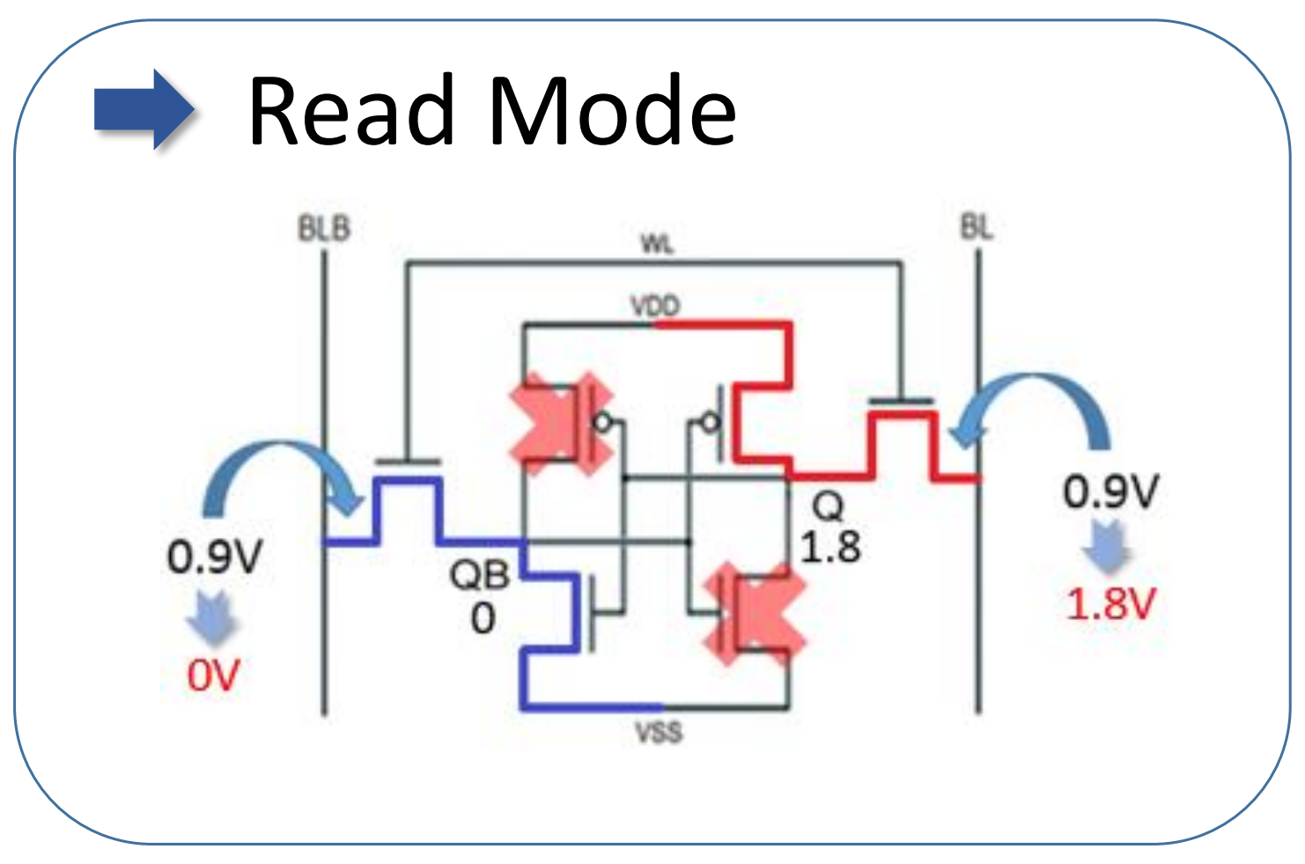
Eunju Jo[a,b], Wooyoung Choi[a], Inyong Kwon[b]*
[a] *Department of Electrical and Electronic Engineering, Yonsei University*
[b] *Korea Atomic Energy Research Institute*

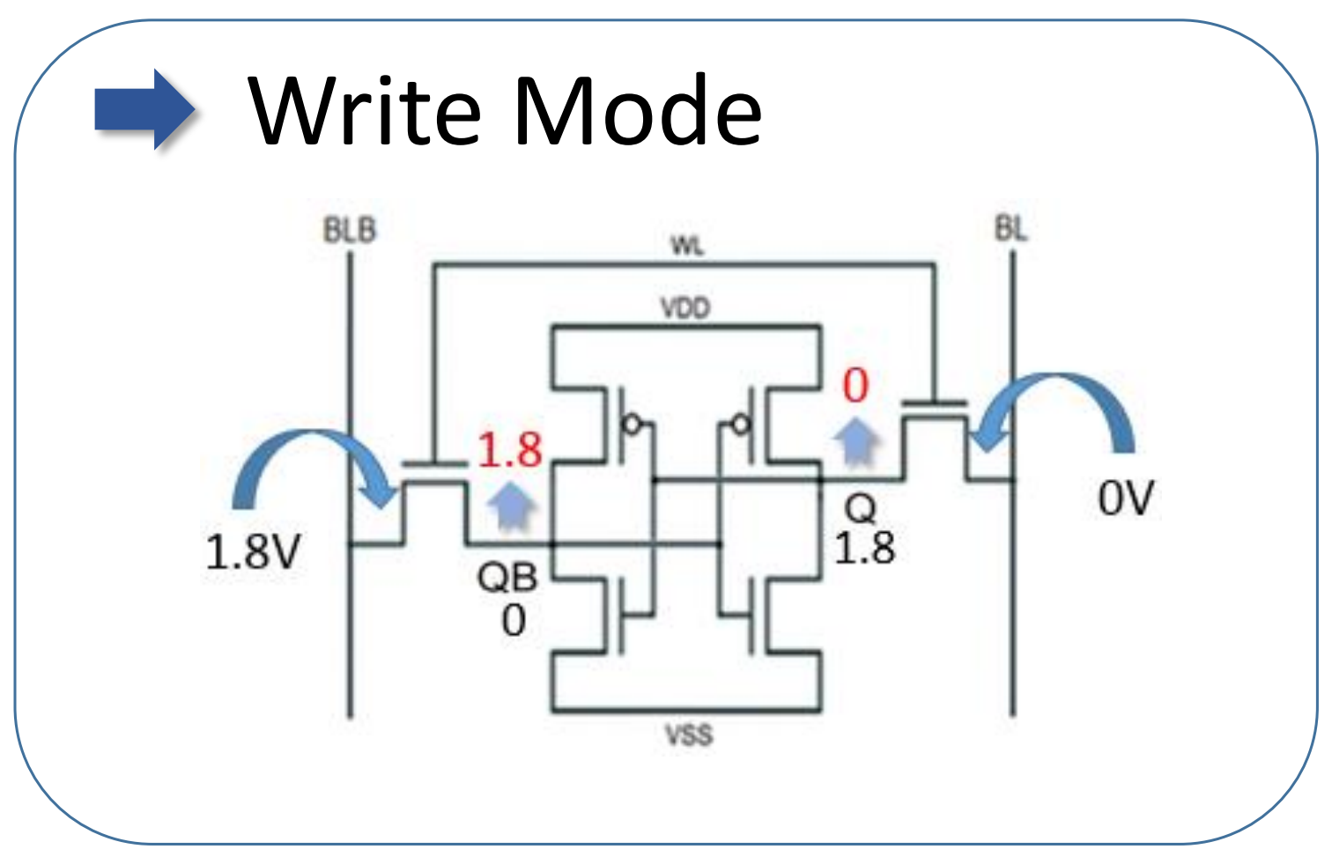
I. Introduction

- In the space environment, a common problem in memory semiconductors is soft errors.
- The soft error is a sort of Single Event Effect (SEE) caused by radiation, which means that a single active particle additionally generates electric charges or current inside the semiconductor chip, resulting in malfunction [1].
- SRAMs are vulnerable to radiation, especially when single event upset (SEU) occurs. The SEU is a type of SEE that makes bits inverted [2].
- Proposed 10T SRAM structure has stronger radiation resistance than conventional 6T SRAM in the SEU simulation.

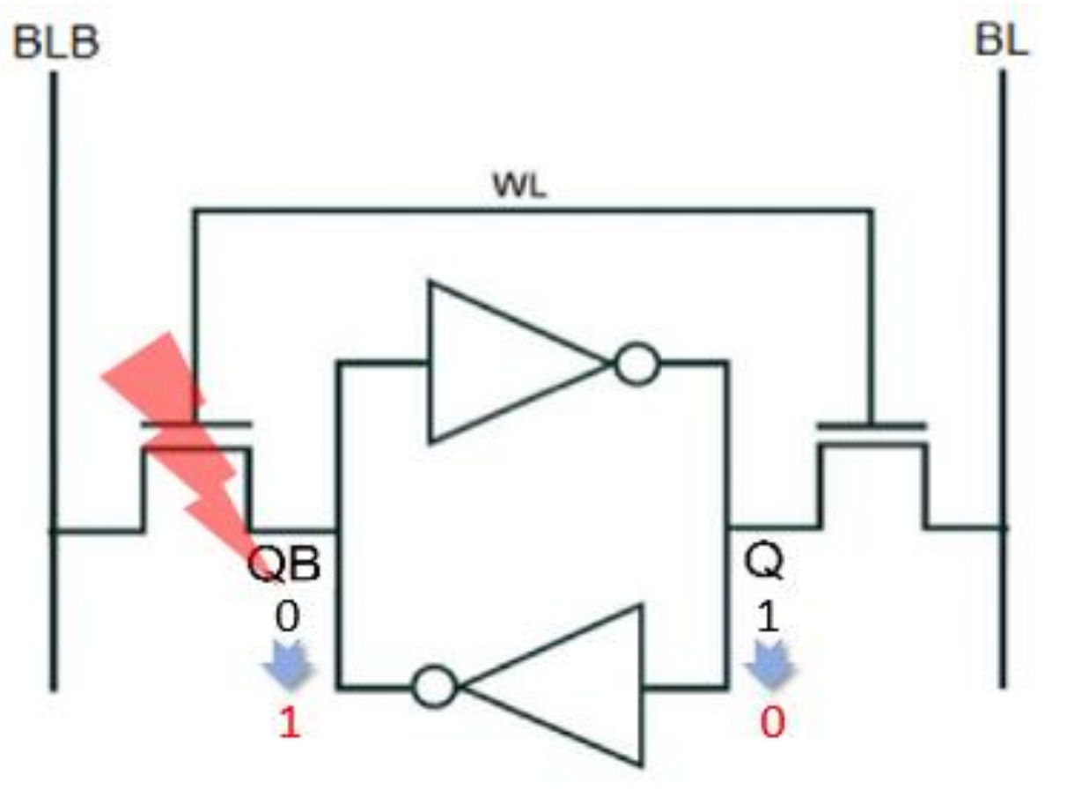
II. Conventional 6T SRAM

- Operation


Read Mode

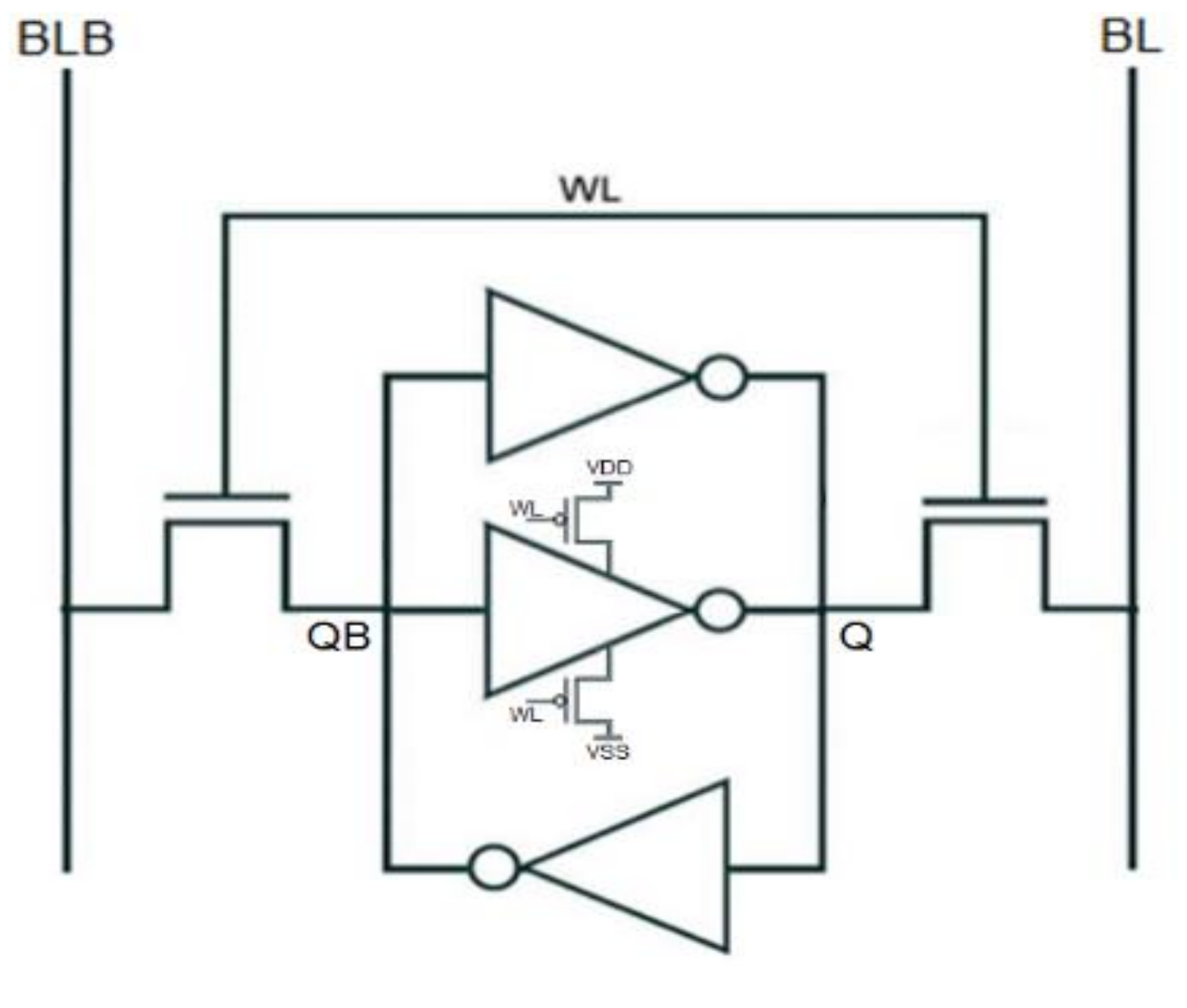

Write Mode

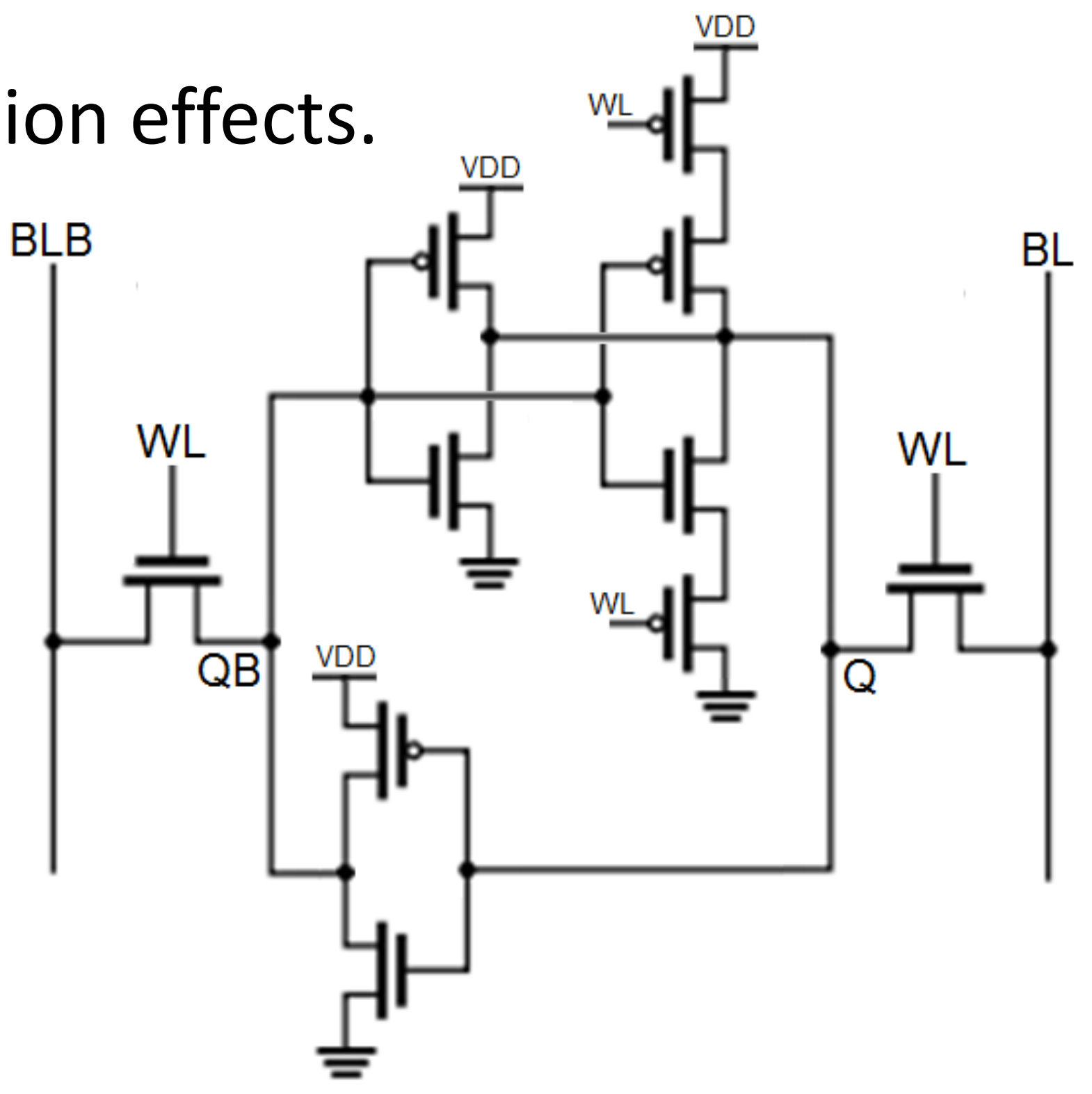
- Single Event Upset (SEU)
  - If the induced current by radiation is injected to these sensitive volumes, the bit of affected node is changed due to the influence of radiation, and then the other is instantly changed along.
  - Therefore, the bit is easily flipped by the radiation in 6T SRAM cell.



III. Proposed 10T SRAM

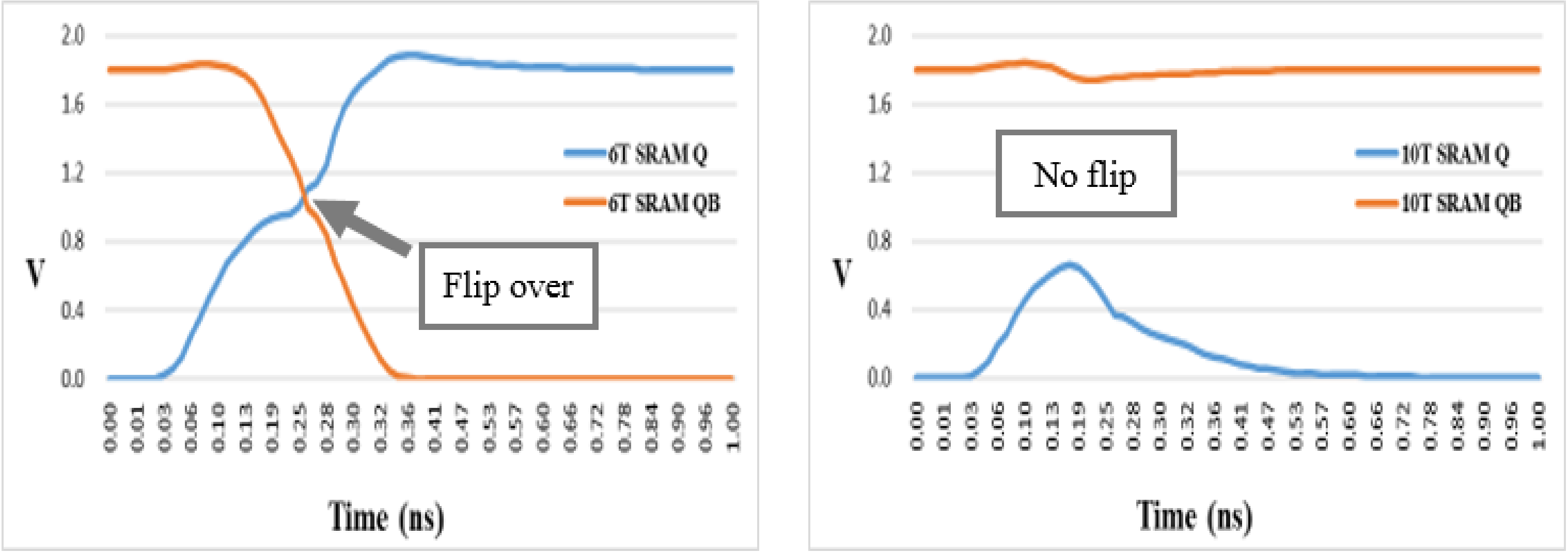
- Proposed 10T SRAM consists of three inverters in parallel.
- One of them is a tri-state buffer with a PMOS switch at the top and bottom of the inverter, and it raises the drive strength.
- As a result, a 10T SRAM can stand higher radiation energy level after irradiated than 6T SRAM.
- So, it has better durability to radiation effects.


Block diagram of 10T SRAM


Schematic of 10T SRAM

IV. Results

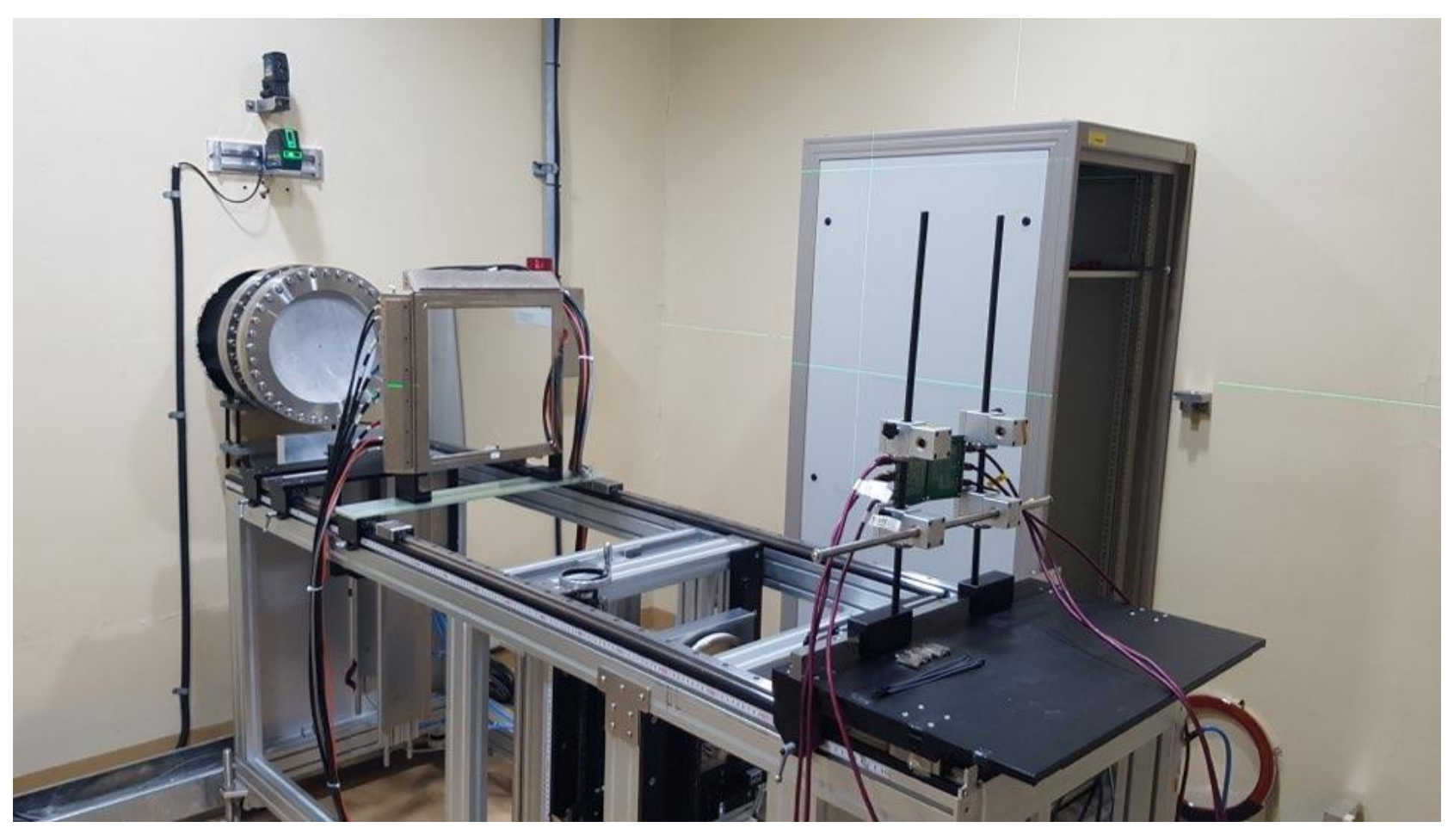
- **Simulation test**
- SEU test of 6T SRAM and 10T SRAM when current is 220 μA.

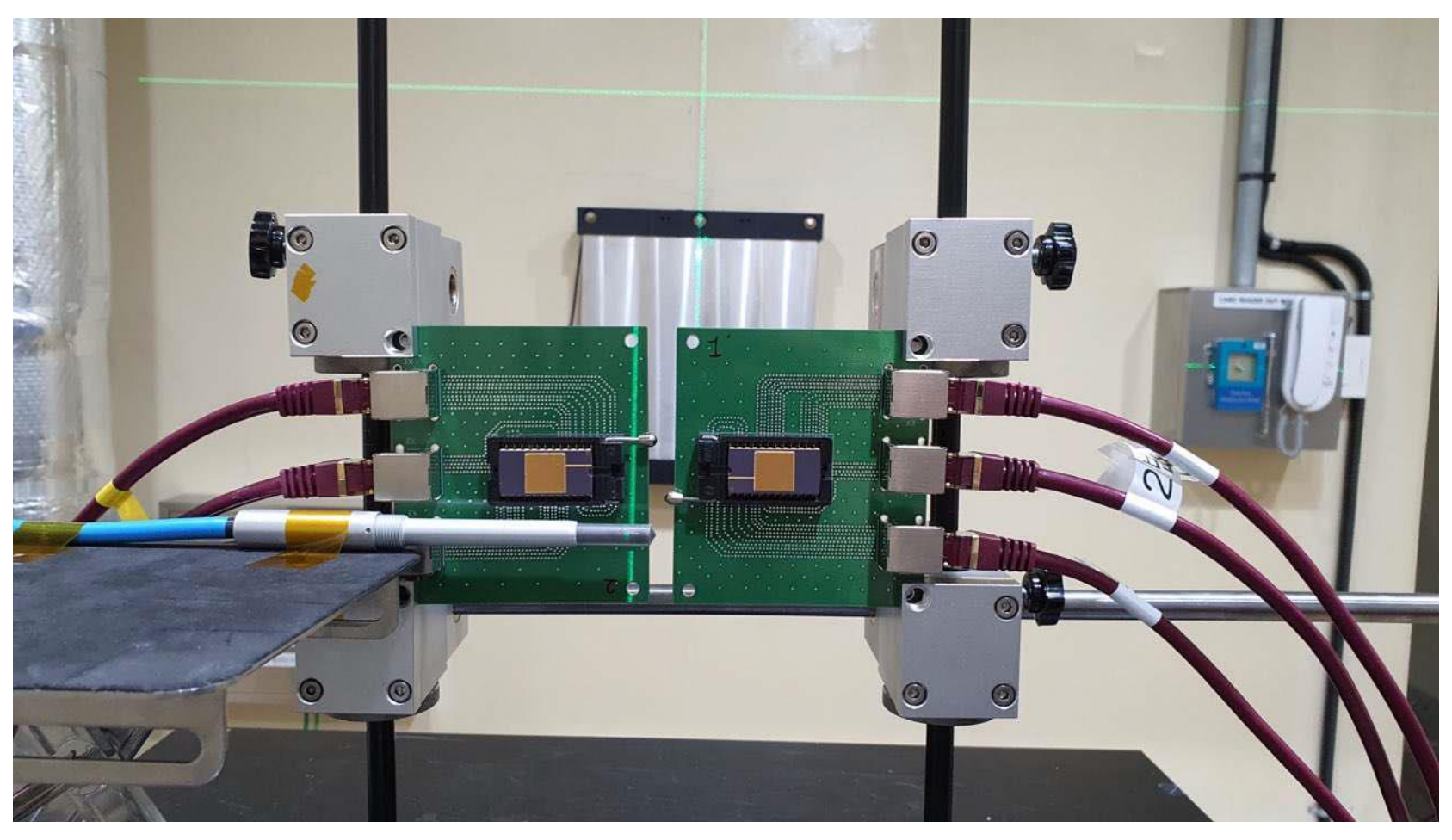


SRAM	Transistors	Hold SNM	Read SNM	Minimum Current
6T	6	0.716 V	0.316 V	220uA
10T	10	0.7 V	0.316 V	253uA

Table. Comparison of 6T and 10T SRAM

- **Actual irradiation test**
- Radiation test at KAERI KOMAC (Korea Multi-purpose Accelerator Complex)





  - We irradiate the tape-out chip of 6T and 10T SRAM with energy level 69MeV and 100MeV.
  - As a result, there were many soft errors found in the irradiated chips but some issued on data acquisition blocks.
  - The second test will be performed with upgraded SRAM chips this summer.

V. Conclusion

- Conclusion
  - For memory semiconductor devices such as SRAM, soft errors must be considered for harsh radiation environments.
  - So, we design a new 10T SRAM which has an additional tri-state buffer compared to conventional 6T SRAM.
  - Although the hold SNM is reduced by 2.28 %, it does not affect normal operation and LET of the 10T SRAM is 14.8 % better than the conventional 6T SRAM.
  - Result of actual irradiation test on the tape-out chip is not what I expected. And this result shows that there are some effects.
- Future work
  - We have designed the upgraded SRAM chip. And then, the irradiation test will be performed again to obtain the desired results.

Acknowledgement

This work was supported in part by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (2017M2A8A4056388 and 2020M2A8A1000830).

References

[1] R. C. Baumann, "Radiation-induced soft errors in advanced semiconductor technologies," in IEEE Transactions on Device and Materials Reliability, vol. 5, no. 3, pp. 305-316, Sept. 2005.
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제2021-170호

증명서

아래의 논문이 한국원자력학회 2021 온라인 춘계학술발표회에서 발표된 논문임을 증명합니다.

- 아 래 -

□ 학술발표회명 : 한국원자력학회 2021 온라인 춘계학술발표회

□ 학술발표회 일정 : 2021년 5월 12일(수) ~ 14일(금)

□ 논문제목 : Analysis on Static Noise Margin and Single Event Upset of 10T SRAM for Radiation Tolerance

□ 저자명 : Eunju Jo, Inyong Kwon

2021년 5월 17일

사단법인 한국원자력학회장