The Effect of Space Radiation on MOSFET

Habin Kim, and Inyong Kwon

Department of Radiological Fusion Engineering, Yonsei University, Korea
**Corresponding author: ikwon@yonsei.ac.kr*
E-mail: vinny6780@yonsei.ac.kr

1. Introduction

The radiation environment in space has severe adverse effects on humans, electronics, and materials [1]. Space radiation is one of the most important topics for electronic devices. Electronic devices are utilized for various purposes in space, including spacecraft equipment, satellites, and space exploration instruments. However, the space environment poses potential risks to these devices due to factors such as high-energy particles and fluctuations in electromagnetic fields.

Space radiation primarily originates from sources such as solar winds and gamma-ray bursts. This radiation can inject charges into the internal circuits of electronic devices or induce faults, leading to issues with power supply or data communication. Additionally, space radiation can damage semiconductor components and cause data loss in storage devices. The response of electronic devices to the space environment is technically very complex. To this end, the focus should be on the enhancement of radiation-hardening materials and circuit design. Furthermore, testing and reliability verification in real space environments are essential for assessing and responding to electronic devices' impact on space radiation. Therefore, understanding the impact of space radiation on electronic devices and developing technical solutions to mitigate these effects are crucial tasks for the advancement of space exploration and space-based technologies. The experimental results and model predictions are described for a wide variety of device types, including NMOS, PMOS, and CMOS /bulk [2].

2. Structural and Operating Characteristics of metal-oxide-semiconductor field-effect transistors (MOSFETs)

2.1 Internal Structure of MOSFETs

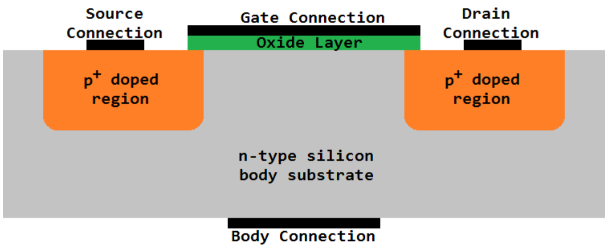

Fig. 1. Internal Structure of MOSFETs.

Figure 1 is the internal structure of the field effect transistor and used an oxide film as an insulator between electrodes. For insulation from the gate, it was separated by an oxide film. N-type silicon was used as a substrate, and P-type silicon was bonded to the drain and source to form a PN junction. Subsequently, impurities were injected [3].

2.2 The Effects of Space Radiation on an Oxide Film

The fabrication process of a p-channel MOSFET involves injecting impurities of positive polarity onto an n-doped substrate under high voltage to form a junction. In the space environment, both electromagnetic radiation and particulate radiation occur [4]. While electromagnetic radiation does not directly affect the oxide layer of metal-oxide-semiconductor field-effect transistors, particulate radiation, when penetrating the gate oxide layer, triggers electron-hole pairs in the oxide layer. This leads to the formation of a high threshold voltage, which is caused by trapped holes.

3. Conclusion

Various equipment operating in the space environment must function properly in the outer space environment beyond Earth's atmosphere. Therefore, for this reason, this study investigated the impact of total ionizing dose on MOSFETs operating in space, and conducted simulations on the electrical characteristic changes observed in MOSFETs during proton irradiation. Additionally, leveraging the results of this research, further studies will be conducted to explore the effects of total ionizing dose on semiconductor components, aiming to contribute to the advancement of the space industry based on data-driven insights. More detailed results will be presented at the conference.

Acknowledgements

This work was supported in part by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (2022M3F3A2A01072855) and the Technology development Program (RS-2023-00322102) funded by the Ministry of SMEs and Startups (MSS, Korea).

References

[1] Stefan K. Höeffgen, Stefan Metzger* and Michael Steffens, Investigating the Effects of Cosmic Rays on Space Electronics, Sec. Medical Physics and Imaging, Volume 8, 2020.

[2] James C. Pickel and James T. Blandford, Jr. **, Cosmic-Ray-Induced Errors in MOS Devices*, IEEE Transections on Nuclear Science, Vol. NS-27, No. 2. April 1980.

[3] Goo-Hwan Shin*, Kwang-Sun Ryu*, Sung-In Chung*, Kyung-In Kang* and Hyung-Myung Kim*, Test-bed of Total Ionizing Dose (TID) Test by Cosmic Rays for Metal Oxide Semiconductor Field Effect Transistor (MOSFET), Journal of the Korean Society for Aeronautical & Space Sciences, Volume 34 Issue 11, Pages.84-91, 2006.

[4] 채종원, “우주방사선 해석 기술 동향 - TID 해석을 중심으로”, 항공우주산업기술동향, 제 2 권 2 호, pp. 84~94, 2004.