Chapter 10

Overview of Radiation-Hardened SRAM Cell Design Techniques

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ABSTRACT

In deep space high-energy particles and fluctuation in temperature lead to single-event upsets (SEUs) in SRAM. It is difficult for traditional 6T SRAM cell to withstand this space environment. Therefore, we use different types of SRAM cells such as RHMD10T, QUCCE 10T, QUCCE 12T, HRRT 13T SRAM, NS10T, PS10T, RHBD10T, RHRD 12T, SRRD12T and QUATRO 12T. Moreover, there is a brief description of each SRAM cell with their respective advantages and disadvantages in comparison to other SRAM cells used in this harsh environment. It is essential to select materials that can tolerate this extreme environment and operate as radiation resistant materials. It includes HfO2 and GaN.Alternatively, materials having larger permittivity, which are known as high-k materials such as Al2O3, ZrO2, and La2O3, can replace SiO2which can replace SiO2 as the gate dielectric.

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1. INTRODUCTION

Digital systems frequently include static random-access memories (SRAMs), which are significant storage components. SRAMs are being utilized more and more in the electronic systems for spacecraft and satellites because of the advancement and ongoing development of aerospace technologies. Energetic particles in space environments can result in a single event upset/soft error, which can cause system failure. Various sources of radiation such as ionizing Galactic Cosmic Radiation, Van Allen Radiation Belts (which is also called Trapped Radiation Belts), Solar Energetic Particles and non-ionizing ultra-violet radiation are substantially available in deep space weather. The inner trapped radiation belt has plenty of electrons and protons. The protons' energyis in the range from 0.1 to 400 MeV and the energy of electrons is lower than 0.78 MeV. The energy of electrons in the outer trapped radiation belt is in the range from 0.04 to 7 MeV. A sudden emission of powerful radiation from the exterior of the sun is called Solar Particle Event (SPE). The reason for the occurrence of SPE is the acceleration of solar particles. When a big explosion of plasma (free ions and electrons gas), which is proton-rich, is accelerated outward with ultrasonic speeds of 50-1200 km/s, we call that coronal mass ejection (CME) has occurred. The solar particles in Coronal Mass Ejection are mainly protons (96.4%), alpha particles (i.e., electrons and positrons) (3.5%) and 0.1% heavy ions (high-energy ions of any element, electrons of which are stripped away). Galactic Cosmic Radiation (GCR) is emitted from the milky way galaxy, which exists at far locations beyond our solar system. The particles in GRC exhibit very high energy and their energy is as high as several hundred GeV. GCR is composed of the bare nuclei, which are atoms from periodic table's any element from hydrogen to uranium. By bare nuclei we mean that they are the atoms with their electrons removed and this happens when they travel nearly at the speed of light. The GCR contains such high energy particles that they can ionize atoms, through which they pass. Electronic devices and circuits are subjected to this harsh environment. An energetic radiation particle produces electron-hole pairs (EHPs) when it hits Integrated Circuits (ICs). These EHPs are split up by the applied reverse bias and accumulate at the sensitive node giving rise to up or down spikes and if these spikes are wider and of sufficient amplitude, they may alter the original node voltage resulting in catastrophic system failure (Pal et al., 2021, pp. 2470-2480). Radiation hardening is a critical design consideration for electronic circuits operating in high-radiation environments such as space, nuclear facilities, and aerospace applications. The primary approaches include Hardening by Design (HBD), Hardening by Process (HBP), Hardening by Material (HBM) and additionally, Hardening by Software (HBS). The choice of hardening technique depends on the specific application and type of radiation threat. For instance, circuits dealing with SEUs might benefit more from HBD.

The last five decades have witnessed a gradual reduction in device dimension and supply voltage (V_{DD}), which is generally called technology scaling. Because of this reason capacitance of a circuit node has reduced drastically and hence the amount of charge that could be stored has also decreased tremendously. Owing to the decrement of joint capacitance and the node charge the nodes, especially SRAM cell storage nodes extremely vulnerable to positive or negative spikes induced by various energetic radiation particles (Lin et al., 2021). A Single-Event upsets (SEU) occurs when energetic particles flip the storage node content (Onoda et al., 2013; Rostewitz et al., 2013; Kotni et al., 2021; Pandey & Islam, 2021; Aakansha et al., 2021; Sahu et al., 2021; Koushik et al., 2021). This undesirable phenomenon is also called soft error because this is a temporary error. This is not a hardware or permanent failure. If a new correct value is stored on to the storage node, problem of soft error will not exist. A high-energy radiation strike may also eventually result in multiple bit upset (MBU) or Single event multiple node upset (SEMNU).