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Investigation of the effect of gamma irradiation on the Electrical characteristics of EEPROMs

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Abstract

Radiation damage of some electronic memories of EEPROM type was experimentally studied using ^{60}Co gamma ray source. By selecting two commercial memory models of Atmel Company with part numbers AT24C02 & AT24C02AN, the total ionizing radiation damage caused by gamma rays of ^{60}Co source was investigated. Radiation-sensitive electrical parameters including Standby current and Read operation current were measured. It can be concluded that due to gamma irradiation and increase in absorbed dose in both memory models, the value of these electrical parameters increases.

Keywords: Electronic memory, Radiation damage, ^{60}Co source

Introduction

Semiconductor memories are often classified according to the memory function of the access method and the nature of the data storage mechanism. One method is to partition into volatile and non-volatile memories. The most widely used and newest type of non-volatile memory is EEPROM memory (EEPROM is an electrically erasable and programmable memory). Most EEPROM cells are made of two transistors and belong to floating gate devices. Currently, there are commonly used floating gate tunneling oxide (MOS) structure, referred to as FLOTOX; floating gate electronic tunnel (MOS) transistor structure, referred to as FETMOS; Gate) [1,2]. The structure of electronic components, including memory, is severely damaged by radiation particles. Damage caused by the collision of radiation particles with the structure of a semiconductor material can be divided into three categories: damage due to the effect of total ionization dose (TID), displacement damage, and single event effects. In this article, the effect of total ionization dose was investigated. TID is defined as the amount of energy deposited by ionization or excitation in a material per unit mass of material [3]. In semiconductor devices, ionization creates electron-hole pairs inside the semiconductor and insulators (such as oxides). Some of this charge is trapped in the insulators or leads to the formation of interface states at the semiconductor/insulation level. In MOS structures, trapped charge changes the gate threshold voltage. The traps also increase surface recombination and ultimately lead to a significant increase in leakage current. In addition to e-h pair generation, ionizing radiation can rupture chemical bonds in the SiO_2 structure. Some of these broken bonds may reform, whereas others can give rise to electrically active defects that can serve as trap sites for carriers or as interface traps [4]. In 2018, Samsung's 8Gb Flash memory was exposed to electron beams and ^{60}Co by Farokh Irom and his colleagues. TID was measured using ^{60}Co at a dose rate of 25 rad/s at room temperature. Memory function was lost with increasing dose to 300 krad [5].

Experimental

Total dose testing can be performed in the following two ways: 1) "not in-flux testing" 2) "In-flux testing". Total ionization dose testing on semiconductor devices such as memory is performed in a standard called MIL-STD-883، Method 1019, which defines the requirements for the use of a ^{60}Co gamma-ray source in the evaluation of total ionization dose damage [6]. To study and analyze EEPROM memories, after programming the memories, they were exposed to a ^{60}Co source with an activity of 380 kCi and a dose rate of 0.5 kGy/h at the Iranian beam flux radiation center at doses of 1.5 and 3 kGy. The devices were not biased during irradiation.

I_{SB} and I_{Read} characteristics were measured at intervals of approximately 2 hours after irradiation. Standby current was recorded without connecting a memory IC to the computer by applying VCC، 5V voltage. By connecting the board to the computer with a USB cable and running a reading program in the Arduino software environment, the read operation current was measured. Unfortunately, no information was available on the memory manufacturing technology but the design of AT24C02AN is newer than AT24C02 .

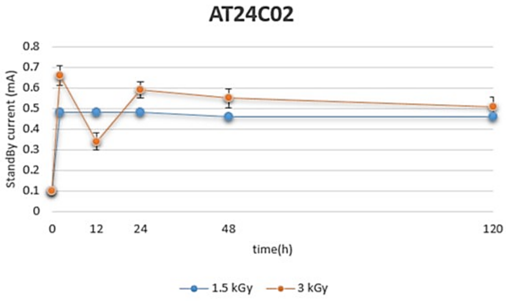
Results and discussion

Due to gamma irradiation and its interactions in a silicon semiconductor, we will encounter changes in the electrical parameters. Two factors influencing the change of electrical parameters in a semiconductor component are the production of electron-hole pairs inside the dielectric layers (for example, oxides) and the location of the charges (within or near the boundaries of different regions). For this reason, we have organized an experiment to measure the electrical parameters. With increasing dose, the electrical parameters were increased. In Table 1, you can see the results for I_{SB} and I_{Read}, for two memories, before and after irradiation.

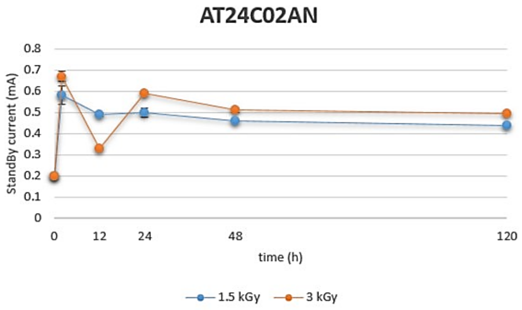
Table 1. I_{SB} & I_{Read} (mA) with error, 2 hours after irradiation

Memory Models	AT24C02		AT24C02AN	
Electricel parameters	Standby current	Read current	Standby current	Read current
No Radiation	0.1± 0.010	0.03±0.004	0.2±0.005	0.06±0.009
1.5 kGy	0.48±0.013	0.18±0.007	0.58±0.008	0.26±0.014
3 kGy	0.66±0.008	0.32±0.006	0.67±0.012	0.35±0.011

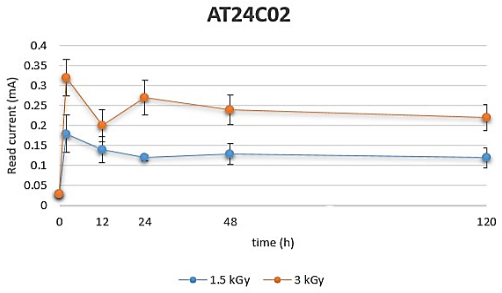
The trend of changes in electrical parameters during times 2, 12, 24, 48 and 120 hours after dose irradiation is shown in Figure 2 ((a),(b), (c),(d)).



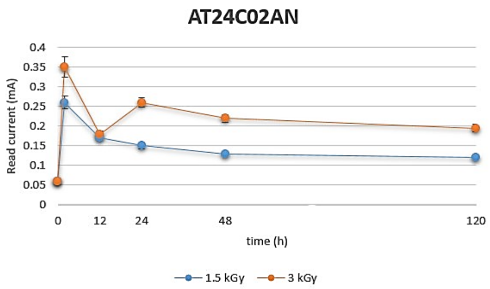
(a)



(b)



(c)



(d)

Figure 2. Variation of current with gamma rays dose, I_{SB} ((b), (a)) and I_{Read} ((d), (c)), For both AT24C02 and AT24C02AN memory models.

Changes in electrical parameters are expected to occur over time due to the neutralization of trapped charges. As you can see, the general trend of changes in electrical parameters decreases over time after irradiation. Also, by doubling the dose, the values of electrical parameters have increased.

Conclusions

The following results were obtained in the study of total ionization dose damage on two important electrical parameters of memories with part numbers AT24C02 and AT24C02AN: 1) Due to gamma radiation, the values of I_{SB} and I_{Read} increased, and the values of I_{SB} and I_{Read} also increased with increasing dose. 2) An almost downward trend was observed in changes in I_{SB} and I_{Read} values over time. In the future, our purpose is to examine other radiation-sensitive parameters ,the degree of memory performance degradation under radiation ,investigation of single event effects and displacement damage in different memories with electron, neutrons, protons and heavy ions.

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