# RADIATION EFFECTS ON PMOS DEVICES

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## ABSTRACT

A Cesium-137 gamma radiation source was used to irradiate PMOS capacitors and transistors with doses of 7.50E4, 1.50E5, 3.0E5. The devices were tested for C-V and I-V data before and after irradiation. Results show that all doses created changes in the electrical characteristics, however comparison to literature was inconclusive.

## INTRODUCTION

Radiation can be broken down into three different groups. Group 1 is photons which consist of gamma-rays and x-rays. Group 2 consist of electrons, protons, alpha particles, beta particles and ions. The third group consist of neutrons. These three groups cause the two major forms of radiation damage seen in electronic devices, namely displacement and ionization damage.

Displacement damage is the displacing or dislodging of atoms from their lattice site causing them to take up interstitial positions within the crystal. The former site of the now displaced atom in the lattice is a vacancy. This displaced atom, if it acquires enough energy can cause the displacement of other atoms compounding the defects within the lattice structure. Those atoms, that have not slipped back or recombined, go on to form defect complexes which act as recombination or trapping centers for minority carriers, ultimately reducing minority carrier lifetime.

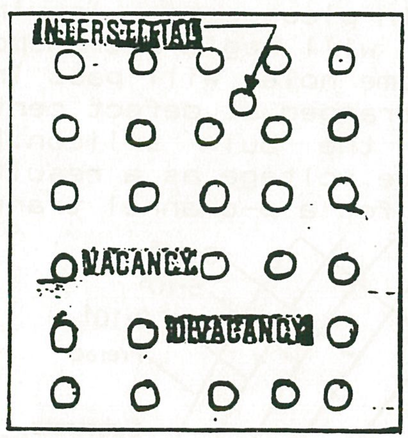


**Figure 1 illustrates three types of simple defects in a lattice. [1]**

The results are somewhat different for ionization damage. Generally ionization in the silicon portion of the structures causes no permanent change and can be neglected. The effects caused by ionization are more severe in oxides where charged traps are produced and filled during irridation.[2] The ionizing process is illustrated in Figure 2 along with corresponding shifts in C-V curves.

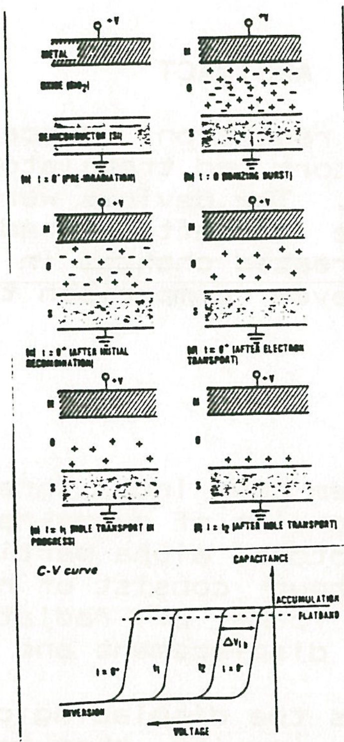


Figure 2 illustrates the ionizing process along with corresponding C-V curves. [1]

At t=0- the condition prior to irradiation is shown. At t=0 the ionizing energy is delivered to the SiO2, and the electron hole population is generated. Immediately after ionization, the process of electron-hole recombination will occur, but so will electron transport. Electron mobility in SiO2 at room temperature is approximately 20 cm2/v-sec while hole mobility is approximately 2E-5 cm2/v-sec. Because of the applied voltage, any electron that does not undergo recombination will be swept to the gate and removed in picoseconds, leaving behind less mobile holes. These holes will begin a transport process towards the Si-SiO2 interface. Some holes will pass into the silicon, while others will become trapped at defect centers near the interface of the gate oxide and the bulk silicon.[1] Figure 3 depicts actual shifts in gate voltage as a result of ionizing radiation as a function of dose for a p-channel transistor.

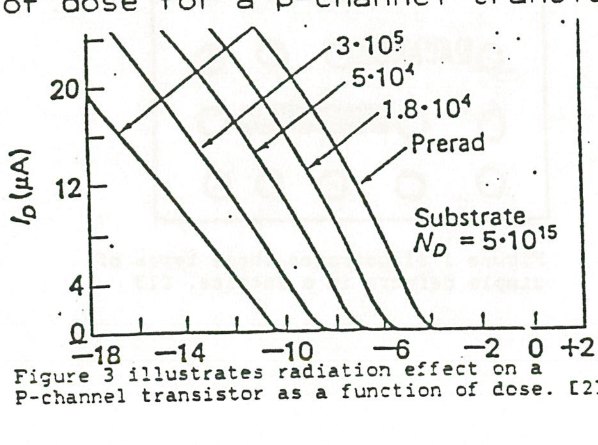


Figure 3 illustrates radiation effect on a P-channel transistor as a function of dose. [2]

EXPERIMENT

A Cesium-137 gamma radiation source was used to irradiate samples. The maximum dose output of the supply was 27000 rad(si)/hr with a photon energy of 662kev. Doses of 7.50E4, 1.50E5 and 3.0E5 were used. These doses were chosen in an attempt to simulate the results in Figure 3. Capacitors and transistors with oxide thicknesses of approximately 1000A were used. These capacitors and transistors were fabricated using RIT's standard PMOS process. After each radiation dose both capacitors and transistors were tested returning to the exact same devices on the wafer. Id vs Vg curves were obtained using the HP 4145A parameter analyzer and C-V curves were obtained using Princeton Applied Research Model410 C-V plotter.

RESULTS/DISCUSSION

Figure 4 is representative of the three curves generated for the three transistors tested.

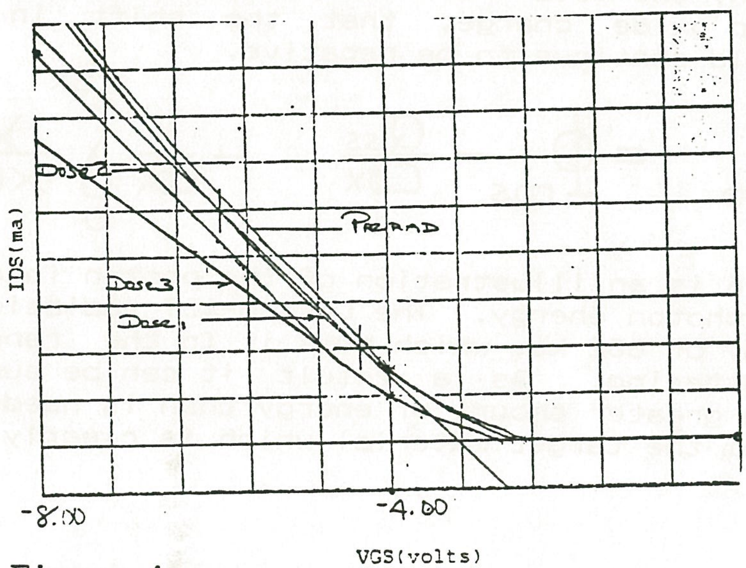


Figure 4

The curves for Figure 4 gave results similar to Figure 3, Leading to the conclusion that ionization is the probable cause of damage. The actual gate voltage shifts were somewhat lower than predicted however this is believed to be due primarily to the dose output of the source varying by approximately 10% as a result of a malfunction of the rotating platform that is supposed to ensure uniform doses over the entire sample.

The results for the capacitors were somewhat peculiar. Theoretically what was expected to occur was an increasingly negative shift in the flatband voltage with increasing irradiation. Figure 5 is a representative of the three capacitors tested. The data was extremely repeatable for all three capacitors. The C-V curve for the first dose shifted more

negative which is in agreement with theory. Any subsequent dose actually shifted the additional curves more positive.

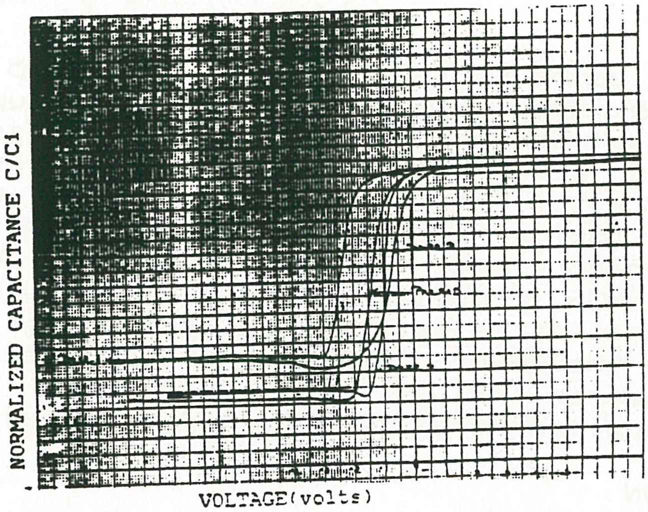


FIGURE 5

This is contradictory to what was expected. If an examination of the equation for the flatband voltage is performed it is evident from this equation that when each individual term is taken into consideration, the metal work function, the surface state density and the field oxide charge, that the shift in the flatband voltage should continue to be negative.

$$V_{Flatband} = \Phi_{ms} - \frac{Q_{ss}'}{C_{ox}'} - \frac{1}{C_{ox}} \int_{0}^{x_{ox}} \frac{x}{x_{ox}} \rho(x) dt$$

Figure 6 is an illustration of the photon interaction as a function of photon energy. The Cesium-137 radiation source has a photon energy of 662 kev which puts it in the range of causing Compton scattering. As a result it can be summized that the photon has a greater amount of energy than is needed to free an electron from the target material which is clearly in the line of ionization.

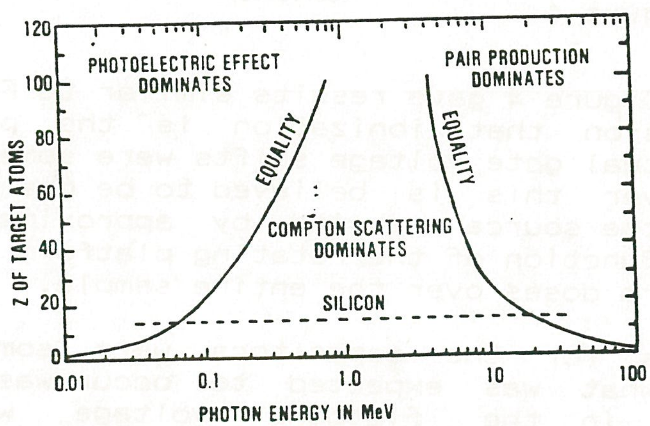


Illustration of the relative importance of the three photon interactions as a function of Z and photon energy. The solid lines correspond to equal interaction cross sections for the neighboring effects. The dashed line illustrates the situation for photon interactions with silicon.

FIGURE 6 [1]

## CONCLUSION

Radiation damage was observed in the curves of both transistors and capacitors, however in the case of the capacitors it was evident that there was more occuring in terms of radiation damage than simply ionization. A more careful examination of this phenomenon must be sought for it is known that it is possible for a device to undergo a type of self anneal "REBOUND" in which case the post radiation exposure gradual annealing of the oxide trapped charge may cause the device characteristics to behave contradictory to theoretical expectations.[3]


## ACKNOWLEDGEMENTS

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## REFERENCES


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[2] G.C. Messenger, M.S. Ash, "The effects of Radiation on electronic Systems", Van Nostrand Reinhold Company Inc., New York, 1986

[3] W.R. Dawes, Jr., Hardened Technologies for Hazardous Environments", IEEE Tutorial Short Course.