



Radiation Tolerance of GaAs Integration Circuits

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Radiation Tolerance of GaAs Integration Circuits

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The effects of Co-60 gamma-ray irradiation on electrical characteristics of commercially available GaAs ICs have been investigated. The ICs are fabricated by metal semiconductor field effect transistors (MESFETs). Total gamma-rays irradiation dose was 8×10^8 rads(GaAs). Changes in transfer characteristics, output voltage, and gate propagation delay time were measured. Below irradiation of 8×10^7 rads(GaAs), there was no observable change in each parameter. Above 8×10^7 rads(GaAs), a significant change occurred in output voltage, switching threshold voltage shifted to as low as pinch-off voltage, and there was a slight change in gate propagation delay time. The changes in electrical characteristics of GaAs ICs are inferred to be caused mainly by decrease in effective carrier concentration and mobility in GaAs.

1. Introduction

Integrated circuits based on GaAs MESFETs are currently being developed for a variety of applications of highfrequency analog and high speed digital signal and data processing. The importance of this advantage has been increasing because many devices are going to be used in serious radiation environments, such as space development systems and atomic power generation plants.

In order that these circuits can be used successfully in serious radiation environments, It is necessary to promote a better understanding about the degradation of GaAs ICs due to both ionization and displacement damage. Displacement damages of crystal lattice are considered to be dominant irradiation effects in GaAs ICs, and this is an important factor determining the life time of GaAs ICs in radiation environments.

In previous investigations of irradiation effects on GaAs materials, Co-60 gamma-ray induced degradation which is caused by changes in carrier concentration and mobility has been reported¹⁾. Cobalt-60 gamma-ray induced changes in the electrical characteristics of conventional and specially designed highly-doped GaAs

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MESFETs have also been reported previously^{2,3)}. In the papers, pinch-off voltage, drain saturation current, and transconductance were found to be changed by gamma-ray irradiation above 8×10^8 rads(GaAs).

This paper is concerned with the effects induced by Co-60 gamma-ray irradiation up to a total dose of 8×10^8 rads(GaAs) on commercially available OR/NOR gate and D-type flipflop circuits. Measurements were made on transfer characteristics, magnitude of output voltage, and gate propagation delay time.

The paper describes (1) the experimental method, (2) experimental results focusing on changes in transfer characteristics, and (3) discussion.

2. Experimental and Results

Samples used in this experiment are GaAs MESFETs SCFL OR/NOR gate (NEC's μ PG702B), and D-type flipflop (NEC's μ PG700B) fabricated using MESFETs with $0.8\mu\text{m}$ gate-length and WSi gate material. The samples are hermetically sealed in a ceramic package and mounted to a ceramic carrier for testing.

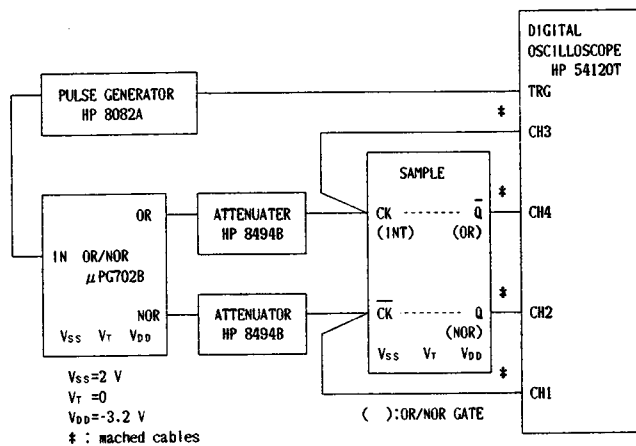


Fig.1 Test system in characteristic parameters of GaAs SCFL OR/NOR gate and flipflop.

Models HP 54120T and HP 8082A systems of Hewlet-Packard in Fig.1 were used for measurements of transfer characteristics, output voltage level, and gate propagation delay time.

Irradiation was carried out by Co-60 gamma rays in the irradiation facility of University of Osaka Prefecture. The dose rate was about 2.4×10^6 rads(GaAs)/hr. All terminals of samples were grounded and set in a well-controlled Ar gas filled metal chamber in order to prevent the electronic leads of the package from cor-

roding. The samples were irradiated with increasing doses of 8×10^6 , 8×10^7 , 1.2×10^8 , and 8×10^8 , rads(GaAs). Surrounding temperature of the sample was lower than 40°C during irradiation.

3. Results and discussion

The transfer characteristics of the OR/NOR gate and the D-type flipflop were measured at room temperature as a function of irradiation. The measured values did not depend on the time after irradiation.

The results are shown in Figs. 2 and 3. The switching threshold voltage of the OR/NOR gate decreased about -2 dB after irradiation of 8×10^8 rads(GaAs). The gain of the OR/NOR gate (slope of transfer curve at mid point) decreases. In the D-type flipflop, the switching threshold voltage decreases by about -1 dB from their preirradiation value as well as GaAs MESFETs. The changes in transfer characteristics and output voltage suggest that the effective carrier concentration decreases with increasing irradiation-induced defects which act as electron

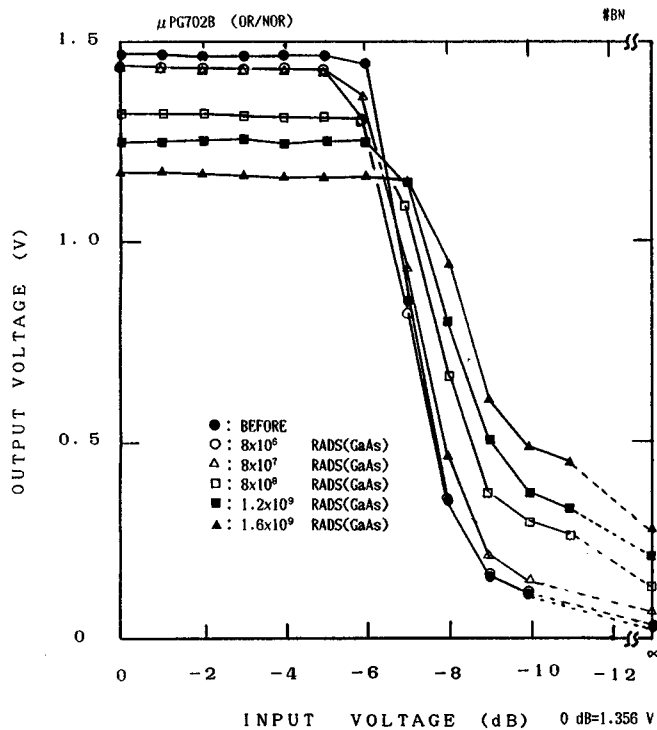


Fig. 2 Change in transfer characteristic of GaAs SCFL OR/NOR gate with Co-60 gamma-ray irradiation.

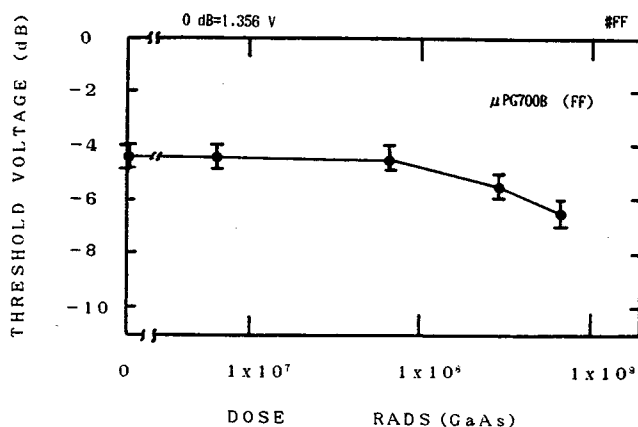


Fig. 3 Change in transfer characteristic of GaAs SCFL flipflop with Co-60 gamma-ray irradiation.

traps¹⁾, as well as changes in pinch-off voltage of GaAs MESFETs. Figure 4 shows a plot of output voltage of D-type flipflop as a function of gamma-ray dose. Below the irradiation of 8×10^7 rads(GaAs), there is no observable change in both high state and low state output voltage levels. However, low state output voltage level shifts to higher voltage level above the irradiation of about

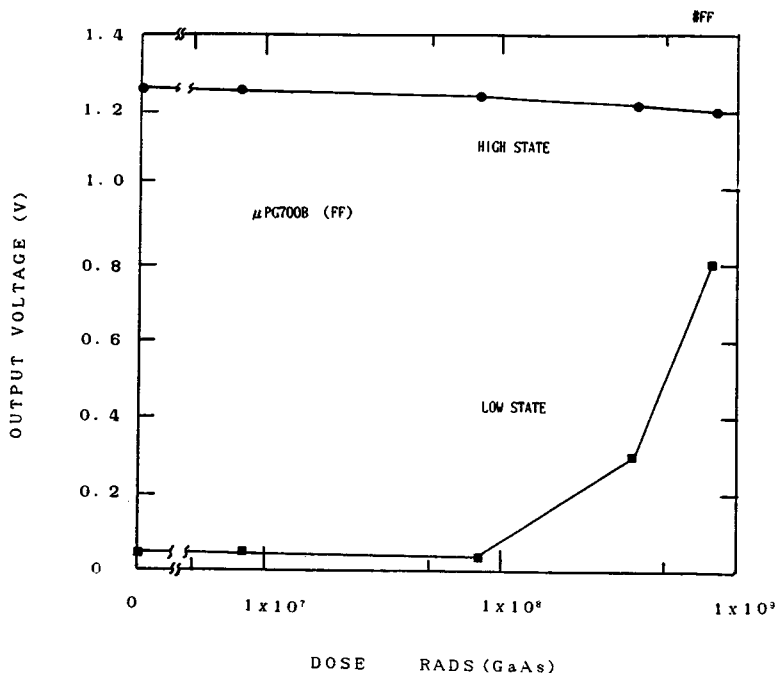


Fig. 4 Change in high state and low state output volages of GaAs SCFL fliflop with Co-60 gamma-ray irradiation.

1×10^8 rads(GaAs).

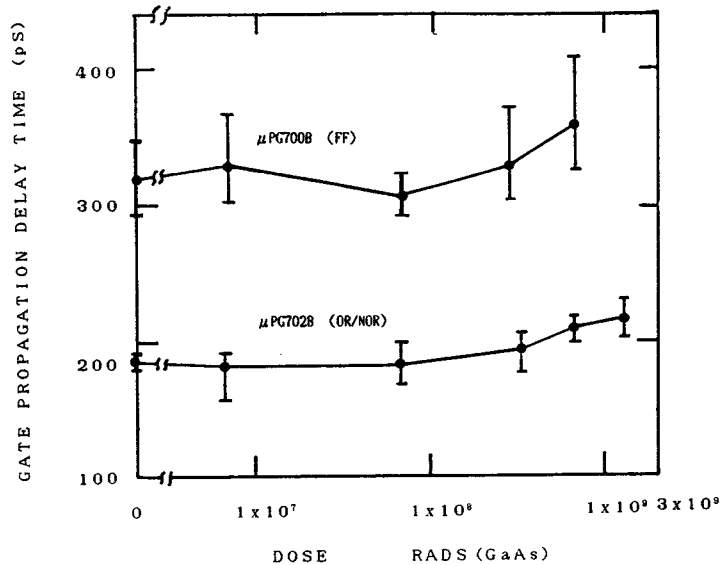


Fig. 5 Change in gate propagation delay time GaAs SCFL OR/NOR gate and flipflop with Co-60 gamma-ray irradiation.

Figure 5 shows the change in gate propagation delay time as a function of gamma-ray dose. Gate propagation delay time which is inversely proportional to transconductance increases slightly with irradiation⁴⁾. There is no remarkable change in gate propagation delay time as well as transconductance at GaAs MESFETs^{2, 3)}.

It has been found that GaAs ICs are degraded with Co-60 gamma-ray irradiation as well as GaAs MESFETs, but the GaAs MESFET SCFL OR/NOR gate and D-type flipflop are still functional under gamma ray dose of 8×10^8 rads (GaAs).

4. Conclusion

From the results of Co-60 gamma-ray irradiation testing on GaAs MESFET SCFL NOR/NR gate and D-type flipflop, we conclude the followings: Below irradiation of 8×10^7 rads(GaAs), there is no change in transfer characteristics and gate propagation delay time, except a small change in switching threshold voltage. Between irradiation doses of 8×10^7 and 8×10^8 rads(GaAs), there is a change in switching threshold voltage in gate propagation delay time. High state output voltage of D-type flipflop changes slightly, but a significant change

occurs in low state output voltage and also in high state output voltage of OR/NOR gate. These changes are consistent with carrier removal effects and mobility degradation by irradiation. It is confirmed that GaAs ICs have the higher radiation tolerance as well as GaAs MESFETs in comparison with Si devices.

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