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Ionizing-Radiation Response of the GaAs/(Al, Ga)As PHEMT: A Comparison of Gamma- and X-ray Results

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Abstract—An experiment is reported on the effect of ^{60}Co gamma rays or 45-keV x-ray photons on the GaAs/(Al, Ga)As PHEMT. It is shown that x-ray treatment can improve the dc performance of the device in some cases. This finding is attributed in part to the annealing or modification of DX centers.

INTRODUCTION

The pseudomorphic high-electron-mobility transistor (PHEMT) is an advanced type of field-effect transistor based on a heterostructure with large carrier mobility and high carrier drift velocity. Such transistors are used in both analog and digital circuits. They can operate at several tens of gigahertz, being among the fastest semiconductor devices [1]. Previous investigations into the gamma-ray response of PHEMTs have shown that their parameters vary monotonically with absorbed dose [2–4].

This paper reports an experiment on the effect of ^{60}Co gamma rays or 45-keV x-ray photons on GaAs/(Al, Ga)As PHEMTs, whose direct-current (dc) performance was examined against absorbed dose. The same relationships were also measured on standard GaAs metal–semiconductor field-effect transistors (MESFETs) for comparison.

EXPERIMENTAL

Figure 1 shows the cross section of the PHEMTs under study, which were formed by molecular-beam epitaxy. The PHEMT gate is 0.3 μm long and 65 μm wide. For the MESFETs the gate length and width are 1 and 50 μm, respectively.

Radiation effects were measured on normally on and normally off PHEMTs and MESFETs.

The gamma-ray measurements employed a ^{60}Co source providing a dose rate of 380 rad(GaAs)/s, the dose being varied from 2.2×10^5 to 2.0×10^8 rad.

In the x-ray case, we used the REIS source [5] generating 45-keV photons, the doses ranging from 1.8×10^5 to 2.7×10^6 R. The specimens were irradiated in three runs under zero- and nonzero-bias dc conditions as illustrated in the table for normally off PHEMTs.

RESULTS AND DISCUSSION

Figures 2 and 3 represent postirradiation drain current as measured against dose for gamma irradiation at low and high drain voltages, respectively, the current being normalized by its preirradiation value.

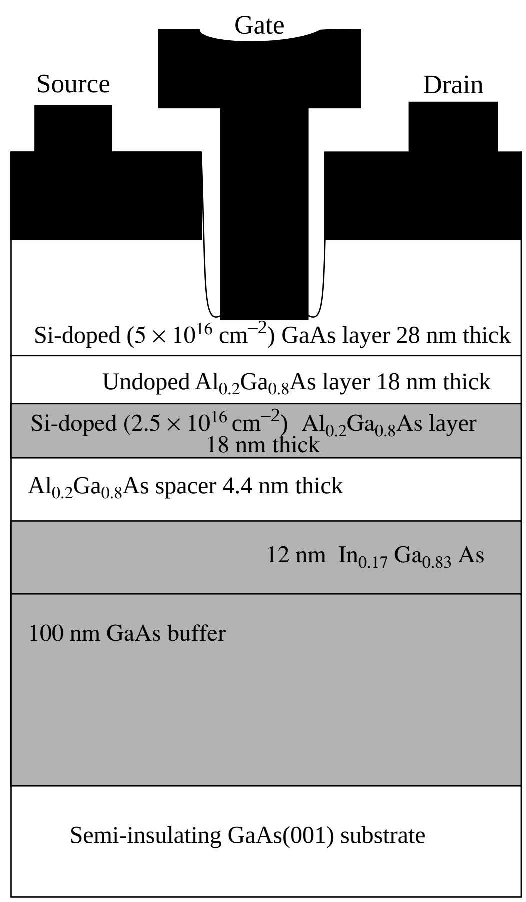

Fig. 1. PHEMT cross section.

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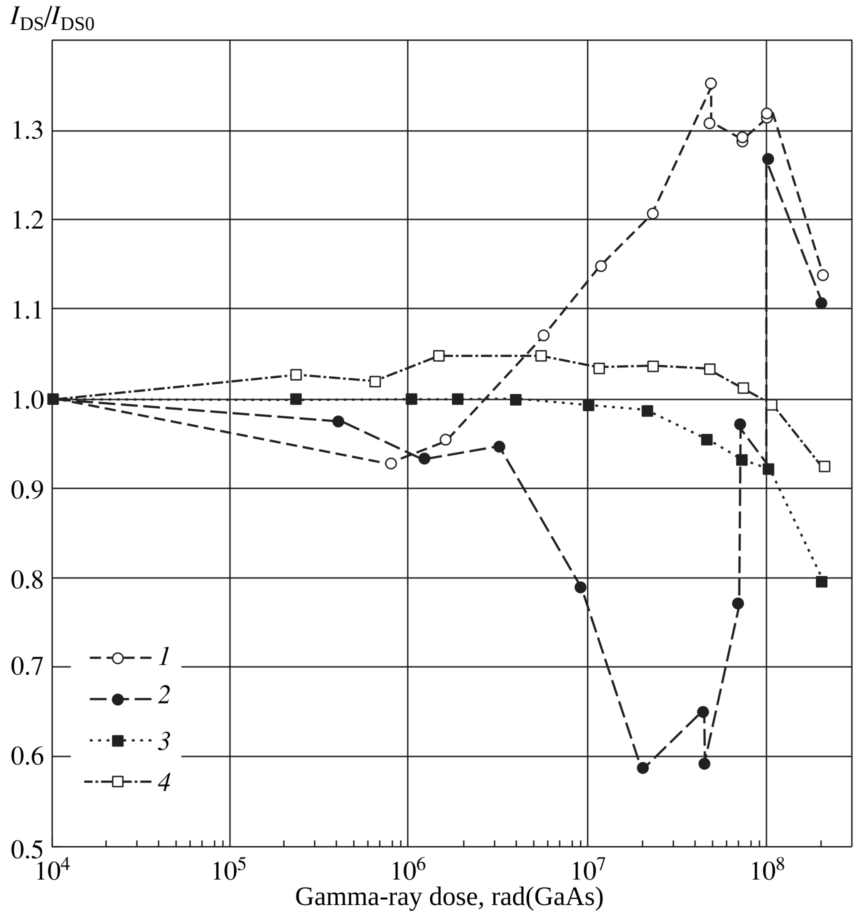

Fig. 2. The gamma-ray case: the ratio of post- to preirradiation drain current vs. absorbed dose for *low* drain voltages. Curves *1* and *2* refer to the normally off and the normally on PHEMT, respectively. Curves *3* and *4* correspond to the normally on and the normally off MESFET, respectively.

Figures 4 depicts the same relationship for the case of x rays and high drain voltages. Figure 5 displays the measured dose dependence of radiation-induced threshold-voltage shift and that of postirradiation peak transconductance normalized by its preirradiation value, for the same case. Figures 2 and 3 refer to the PHEMTs and MESFETs, while Figs. 4 and 5 to the normally off PHEMTs only.

X-ray treatment conditions for two normally off PHEMTs

Dose range, R	Bias			
	specimen 1		specimen 2	
	V_{GS}, V	V_{DS}, V	V_{GS}, V	V_{DS}, V
1.8×10^5–1.26×10^6	0	0	±0.4	+0.4
1.26×10^6–2.16×10^6	0	0	±0.4	+0.4
2.16×10^6–2.70×10^6	–0.4	+0.4	0	0

Figures 2–5 indicate dissimilarity between the responses to the two forms of radiation.

In the gamma-ray case the PHEMTs show a current–dose characteristic that is not monotonic and depends on the slopes at the corresponding points on the current–voltage characteristic as governed by the drain voltage. The drain current first decreases with increasing dose for both low and high drain voltages, the performance being degraded. If the dose is between 2.0×10^7 and 10^8 rad, postirradiation values approach preirradiation ones. At doses above 10^8 rad, consistent performance degradation is observed as the dose is increased.

The MESFETs, both normally on and normally off ones, display steady degradation with gamma-ray dose, starting at 10^7 rad; this should be due to decreasing carrier density in the channel.

In the x-ray case, irradiated PHEMTs exhibit increasingly better performance as the dose is raised. Under certain irradiation conditions, some degree of