Radiation Effect on the Parameters of Field Effect Transistors with Schottky Barrier on GaAs

A. Bibilashvili1,2, Z. Kushitashvili2

1Ivane Javakhishvili Tbilisi State University, Chavchavadze ave. 1, 0179 Tbilisi, Georgia
2LEPL Micro and Nanoelectronics Institute, Chavchavadze ave. 13, 0179 Tbilisi, Georgia

Amiran.bibilashvili@tsu.ge

Abstract. In the present work, we report the result of the study of electron and γ-radiation effect on the parameters of normally open and normally closed field effect transistors with Schottky barrier on GaAs. It has been shown that normally closed transistors are more sensitive to the action of radiation than normally opened transistors. Both transistors are more sensitive to the electron radiation. As substrates were used epitaxial structures of GaAs of n-type conductivity doped with tellurium with \( N_D = 2 \times 10^{17} \) cm\(^{-3} \) with surface orientation [100]. Electron irradiation was conducted on the linear accelerator of RELUS type with electron energy 4 MeV at the room temperature, with the intensity of electrons flow of \( 2.5 \times 10^{12} \) e/cm\(^2\) sec. Integral doses made \( 1 \times 10^{14} \) e/cm\(^2\), \( 5 \times 10^{14} \) e/cm\(^2\), \( 1 \times 10^{15} \) e/cm\(^2\) and \( 3 \times 10^{15} \) e/cm\(^2\). The γ-radiation was conducted using the source \( ^{60}\text{Co} \) at the room temperature with the intensity of \( 5 \times 10^{3} \) P/sec. For the γ-radiation, visible changes of saturation flow current are observed at the doses of more than \( 10^5 \) Grey (GaAs). As whole, the γ-radiation makes an action on the parameters of MESFET in the less degree than electron irradiation. The annealing of the irradiated samples of MESFET at the temperature of 573 K in the nitrogen atmosphere for 45 min provides complete restoration of their parameters. The possible reasons for the mentioned effects are given.

1. Introduction
Gallium arsenide due to the number of its specific electrophysical properties is a prospective material for the creation of radiation stable (RS), logical integral schemes with direct link on the basis of normally opened (NO) and normally closed (NC) field effect transistors with the schottky barrier (MESFET). Practical realization of these advantages is difficult because GaAs is two-component material and at high temperatures dissociation of surface structures takes place. Therefore, it is necessary to develop low temperature technology of MESFET creation, which provides co-formation of normally opened and normally closed field effect transistors with increased RS and high qualitative isolation of active elements.

2. Results and discussion
In the present paper, we have investigated the influence of electrons and γ-radiation on the parameters of NO and NC MESFET, prepared with low temperature methods. They were made in a single technological cycle on one substrate with bars from allow of tungsten (W) and platinum (Pt), different
percentage ratio with the following photon processing. Intercomponent isolation of active elements was carried out with proper oxide GaAs obtained by low temperature plasma anodization stimulated with ultraviolet (UV) irradiation [1].

Figure 1 illustrates a cross section of the typical structure of NC and NO MESFET. As substrates were used epitaxial structures of GaAs of n-type conductivity doped with tellurium with \( N_D = 2 \times 10^{17} \) cm\(^{-3} \) with surface orientation [100].

![Diagram of MESFET structure](image)

**Figure 1.** Cross-section of the structure NO and NC MESFET: 1- epitaxial film of GaAs; 2 – Pt-W; 3 – intercomponent isolation; 4 – Ohmic contacts

Electron irradiation was conducted on linear accelerator of RELUS type with electron energy 4 MeV at room temperature, with the intensity of electrons flow of \( 2.5 \times 10^{12} \) e/cm\(^2\) sec. Integral doses made \( 1 \times 10^{14} \) e/cm\(^2\), \( 5 \times 10^{14} \) e/cm\(^2\), \( 1 \times 10^{15} \) e/cm\(^2\) and \( 3 \times 10^{15} \) e/cm\(^2\).

The \( \gamma \)-radiation was conducted using the source \(^{60}\)Co at room temperature with the intensity of \( 5 \times 10^3 \) P/sec.

In figure 2 there are given the dependencies of relative charge of the saturation flow current on electrons flaw for the NO and NC MESFET. Saturation current was measured at zero shift on the bar for the NO and at the shift on the bar +0.6V for NC MESFET. As is seen at the dose of \( 3 \times 10^{15} \) e/cm\(^2\) only insignificant variation of MESFET parameters takes place.
Figure 2. Dependencies of charge of saturation flow current on electron flaw for NC (1) and NO (2) MESFET

Figure 3. Dependencies of charge of saturation flow current on the dose $\gamma$-radiation for NC (1) and NO (2) MESFET

For the $\gamma$-radiation, visible changes of saturation flow current are observed at the doses of more than $10^5$ Grey (GaAs) (figure 3). As a whole the $\gamma$-radiation makes an action on the parameters MESFET in the less degree than electron irradiation.

It should be mentioned that NC is more sensitive to the radiation than NO MESFET. Maximal doses of electron $3 \times 10^{15}$ e/cm$^2$ and $\gamma$-radiation $10^5$ Grey (GaAs) are thresholds since beginning form them generation of point defects in the substrate takes place.
A similar study of the other static parameters points out to their insignificant change with the increase of the irradiation dose. This obstacle might be the result of the consequence of a much stronger influence of radiation on the concentration of the carriers in the epitaxial layer of GaAs.

The annealing of the irradiated samples of MESFET at the temperature of 573 K in the nitrogen atmosphere for 45 min provides complete restoration of their parameters.

Recent years, research has been undertaken on the basis of the prospective semiconductor gallium arsenide (GaAs) [2] for creating high frequency devices. These devices are designed such that they can work at high frequency with higher power outage than the corresponding devices created on the silicon semiconductor. It has also been established that with the reduction of active sizes of the devices, improves not only their high-quality characteristics, but also radiation sustainability. This effect is sharply reflected on the schottky field effect transistors, which have been experimented with different channel length [3], mobilities [4], charge carrier concentration [5] and gate materials [6].

In this article is discussed the effect of electron and \( \gamma \) −radiation on the normally opened and normally closed schottky field effect transistors parameters when the channel length and the charge carrier concentration are the same and they are received on the GaAs in a single technological process. Conduction of the channel in such transistors depends on the charge under the gate [7] and therefore strongly depended on the applied voltage.

In figure 3 and figure 4 seems volt-amphoric (I-V) characterization of the NO and NC MESFETs before electron irradiation (a) and after irradiation with dose \( 3 \times 10^{15} \) e/cm\(^2\) (b).
Figure 4. (a) NO MESFET before electron irradiation and (b) after irradiation with dose $3 \times 10^{15}$ e/cm$^2$. (c) NO MESFET before electron irradiation and (d) after irradiation with dose $3 \times 10^{15}$ e/cm$^2$.

From the analysis of the I-V curves, it seems that practically in both types transistors parameters are changed after irradiation them with electron doses $10^{15}$ e/cm$^2$. Comparing I-V graphs we can assume that for NO MESFET saturation current decreases 2 times, but for NC MESFET – decreases 2.7 times (figure 5).

Figure 5. Dependence of normalizes saturation current vs irradiation doses of NO (1) and NC (2) MESFETs.

These differences are negligible, because these kinds of MESFETs are used generally in integral schemes for fast load and effectiveness reduces in small values.

The radiation stability of MESFET can be explained by deposition Pt-W metals combination on the GaAs surface and it makes impurity free space in the interlayer GaAs – metal and creates intermetal alloys.
3. Conclusions

Thus, MESFET on GaAs obtained by low temperature means distinguish with high RS. It may be the reason that there is more perfect interface between the semiconductor and the bar conditioned by the character of the interrelation of the alloy films Pt-W with GaAs in the process of photon processing and high velocity of removing of radiation stimulated charge from the interface due to its high mobility in GaAs.

References

[1] A. Bibilashvili and Z. Kushitashvili, “Low Temperature Oxidation of GaAs by UV Stimulated Plasma Anodizing,” IOP Conf. Series: Earth and Environmental Science 44, 2016.

[2] E. V. Kisiliova, S. V. Obalensky et all, “Radiation resistance of gallium arsenide perspective Schottky field effect transistors,” Journal of technical physics, v.75. No 4, pp. 136 – 138, 2005.

[3] I. Pojela, “Physics of high-speed transistors,” Vilnius, Mocsla, pp. 264, 1989.

[4] E. L. Pankratov and S. V. Obalensky, “Dynamics of Radiative Defects in Gallium arsenide During Relaxation of Local Heating,” Int.Journal of Bifurcation and Chaos, v.18, No 9, pp. 2845 – 2849, 2009.

[5] N.G. Einspruch, W.R. Wisseman, “Gallium Arsenide in Microelectronics”, Academic Press, Inc; Orlando, FL(USA), pp. 464, 1985, ISBN 0-12-234111-2.

[6] G. I. Zebrev, “Simulation of ionizing radiation exposure to gallium arsenide Schottky field effect transistors,” Microelectronics, v.35, No3, pp. 217 – 229, 2006.

[7] J. T. Moran, J. W. McClory, J. C. Petrosky and G. C. Farlow, “The effects of Temperature and Electron Radiation on the Electrical Properties of GaAs HFETs,” IEEE Transactions on Nuclear Science, Vol. 56. №6, pp. 3223-3228, 2009.