ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 4, Issue 12 , December 2017

Influence of the injecting pulse and deformation on physical processes at the border of the MDS section structures

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ABSTRACT: The physical processes at the silicon-lead-borosilicate glass interface have been studied by the isothermal relaxation of a nonequilibrium metal-insulator-semiconductor (MIS) capacitance structure. It is established that the main cause of the resulting rate of charge generation in the inversion layer in structures subjected to electron injection is the release of electrons trapped by lead ions and their interaction with the charge of the inversion layer.

I. INTRODUCTION

In the formation of operational characteristics of semiconductor structures of the metal-insulator-semiconductor type, physical processes occurring at the dielectric-semiconductor interface play a decisive role. In turn, physical processes at the interface can be controlled by various methods: high-frequency pulsed, radiation-thermal, correction of parameters by radiation exposure, ultrasonic treatment, or other methods that can purposefully change the characteristics of semiconductor devices in the technological process of their manufacture or at the stage of finished structures [1].
The unique properties of dielectrics depend on the composition and kind, that is, they can be in the form of coatings or films. In electronic engineering, both kinds are used. Dielectric coatings serve as the protection of the semiconductor surface from external influences. The film variant also functions as a layer between the control electrode-metal and semiconductor, for example, in field-effect transistors, memory elements, charge-coupled devices, and are a functional unit serving to form performance characteristics.

The physical processes occurring at the semiconductor-dielectric interface depend significantly on the perfection of the interface, on the parameters of the dielectric layer, and on the properties of the semiconductor surface. Despite the apparent popularity of the dielectric-semiconductor model, problems arise because of the specific differences in the particular structure under consideration. This is the difference in the composition of the dielectric layer, the state of the surface of the semiconductor, the types of defects present [2-4].

In the present work, the results of a study of the effect of impulse action and all-round deformation on physical processes occurring at the interface of a lead borosilicate glass-semiconductor are presented.

II. DESCRIPTION AND RESULTS OF THE RESEARCH

The investigated (MIS) structure is a multilayer transition Al-lead-borosilicate glass-silicon. Silicon doped with phosphorus with a specific resistance of 5 ohms cm and a thickness of 250 μm was chosen as a semiconductor. After machining and polishing the surface of single-crystal silicon, they were processed in a polishing etch. Washed in de-ionized water. The lead-borosilicate glass of the type $PbO–SiO_2–B_2O_3–Al_2O_3–Ta_2O_5$ (PbO–47%, SiO_2–34%, B_2O_3–15%, $A1_2O_3$–3% Ta_2O_5–1%), which is a fine-dispersed batch, was used as the dielectric layer, which was applied to the silicon surface by reflow (T = 680°C) and annealing (T=470°C). The thickness of the glass layer was 2000-2500Å. The

ISSN: 2350-0328

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metal-insulator semiconductor structure was formed by vacuum deposition of aluminum in the form of a circle 3 mm in diameter onto the surface of the glass.
The produced structures were subjected to a pulsed effect of an enriching voltage with an amplitude of 20-50V at a frequency of 150kHz, with a pulse duration of 0.1-0.4 s and a comprehensive hydrostatic pressure (Kbar) (Fig. 1).

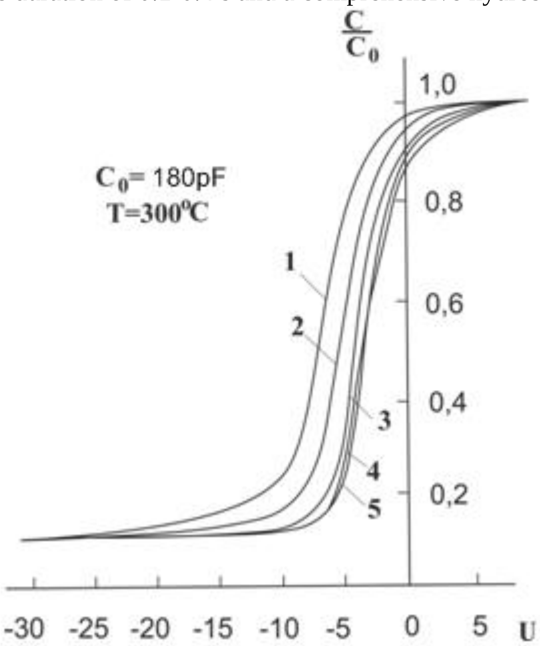

Fig.1. Volt-farad characteristics (normalized to the unit capacity of the glass layer) of one of the studied structures, before the application of impulses of enriching stress (1), after the effect of enriching stress (2-4) and hydrostatic all-round compression with a pressure of 4 kBar (5)

The parallel shift of the volt-farad characteristics of MIP structures towards positive stresses indicates a decrease in the positive charge in the glass structure.

The decrease in the positive charge in the structure of lead-borosilicate glass can be due to the localization of electrons injected from the semiconductor near easily polarizable lead ions and their accumulation on potential barriers of inclusions of the crystalline phase. The following data testify to this proposal. To do this, control structures were produced using a similar technology, but with a decrease in PbO content. In this case, glass was used with a mass percentage of the components: PbO-42%, SiO_2 -39%, B_2O_3 -15%, Al_2O_3 – 3%, Ta_2O_5 – 1%. The impulsive effect of the PbO content on the structures by the enriching voltage showed that the shift of the volt-farad characteristics toward the positive voltage decreases substantially, and in some structures it is not even observed.

In Fig. 2. Relaxation dependences of the capacity of metal-glass-semiconductor structures (made on the basis of glasses with an increased content of PbO -47%) obtained after switching the inversion voltage V1→V2 (25-30B), taken before (1) and after (2) impulse action, and also under pressure, curve 3.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 12 , December 2017

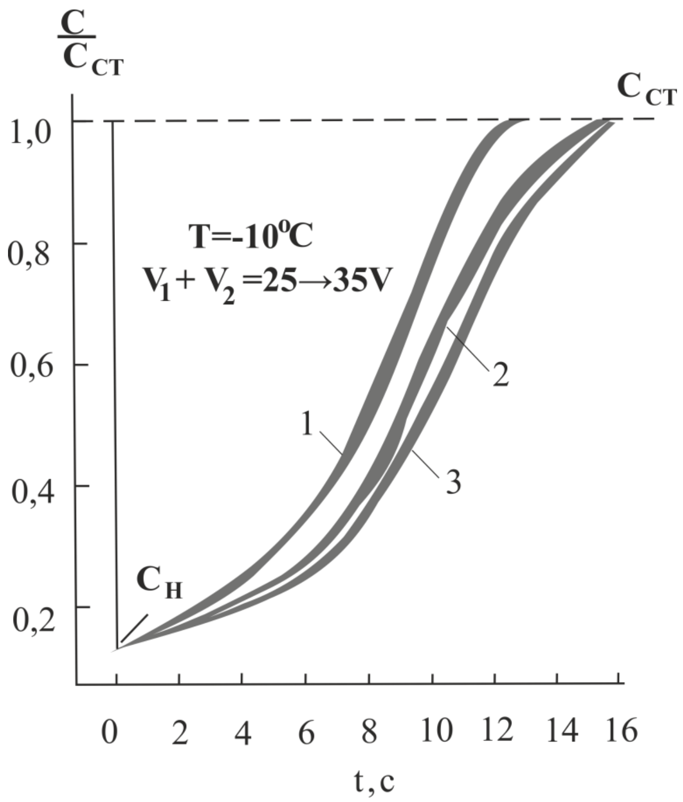

Fig. 2. Relaxation dependences of the capacity of the metal-glass-semiconductor structures taken before (1) and after (2) by the action of impulse voltage and subjected to a pressure of 4 kBar and pulse voltage (3)

It can be seen that after the injection of electrons into the glass layer the structure capacitance relaxes more slowly to its equilibrium state. At the same time, an increase in the amplitude of the enriching voltage applied to the structure to 50 V or more led to breakdown of the structure. These circumstances can be explained on the basis of the following.
As the pulse width of electrons injected into the glass increases, they are localized to polarized lead ions located at considerable distances from the glass-semiconductor interface. When the polarity of the applied voltage changes, the trapped electrons are ejected back into the semiconductor. The presence of electrons injected into the glass, and the effect of pressure, leads to a change in this time dependence.
So at the first moment after application of the inversion voltage, the electrons localized on the surface states are thrown into the conduction band of the semiconductor. This process takes place quite quickly. Then electrons are released, localized on polarized lead ions, which are captured by the charge of the inversion layer, reducing the rate of charge formation. The magnitude of the volumetric generation currents after the impulse action and pressure practically does not change.

III. CONCLUSION

The main factor leading to a decrease in the rate of formation of the charge of the inversion layer in the structures subjected to electron injection is the release of electrons captured by the lead ions and their interaction with the charge of the inversion layer. The effect of all-round compression affects the glass layers adjacent to the interface with the semiconductor, leading to a decrease in the density of surface states and a decrease in the rate of formation of the charge of the inversion layer.
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ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 12 , December 2017

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