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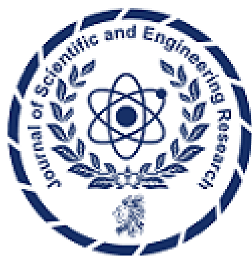
Journal of Scientific and Engineering Research, 2017, 4(4):11-13



Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Nonequilibrium processes in MIS-structures on the basis of silicon, doped with hafnium

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Abstract By means of methods of capacitance spectroscopy CC-DLTS and is high-frequency capacitance-voltage characteristics non-equilibrium processes in the bulk and at the interface $Si\text{-}SiO_2$ of MIS-structures on the basis of the silicon-doped hafnium are investigated. It is revealed, that presence of electro-neutral impurity Hf at structures leads to increase N_{ss}, but appreciable change in distribution N_{ss} on E_g is not observed. It is established, that presence electroactive Hf leads to a further increase N_{ss} of structures and occurrence of the peaks connected with levels hafnium in silicon.

Keywords Nonequilibrium processes, MIS-structures, silicon, hafnium

Introduction

In last years, the study of the properties of impurities that create a variety of defective centers in semiconductors has received considerable attention in view of the significant role of refractory impurities in the formation properties of silicon (Si) – basic material for micro - and optoelectronics. It is known that the doping of Si with refractory elements significantly affects the performance of semiconductor devices [1-2], but data about their electrical activity and interaction with other defects and also about influence on characteristics of silicon structures are inconsistent.. The purpose of this work was to study non-equilibrium processes in the bulk and at the interface $Si\text{-}SiO_2$ multilayer structures of the type metal-insulator-semiconductor (MIS) on the basis of silicon, doped with hafnium.

Experimental Setup

Below are the results of a complex research CC-DLTS and capacitance-voltage characteristics (C-V characteristics) in MIS-structures with impurity of Hf.

Initial Si it was doped with Hf in the process of growing from the melt, and diffusion method. After doping Hf on the Si plates with orientation <100> and a resistivity of 15 Ohm.cm was created by MIS-structures according to the technology described by us earlier [3-4]. Concentration of possible deep levels (DL) was measured in volume Si by method CC-DLTS on Schottky barriers fabricated on Si after etching of the layer SiO_2.

Results and Discussion

These measurements showed that the introduction of Hf in Si the process of growing from the melt does not form any GU in a prohibited area of a silicon substrate. Measuring C-V characteristics of MIS structures based on Si<Hf> (Figure1, curve 2) showed that they are shifted toward negative displacements in comparison with control samples (Fig.1, curve 1). This suggests that the introduction of Hf in Si leads to a change in the lasing characteristics of structures: to increase the density of surface states N_{ss} of MIS structures and the formation of positive charge at the interface $Si\text{-}SiO_2$.

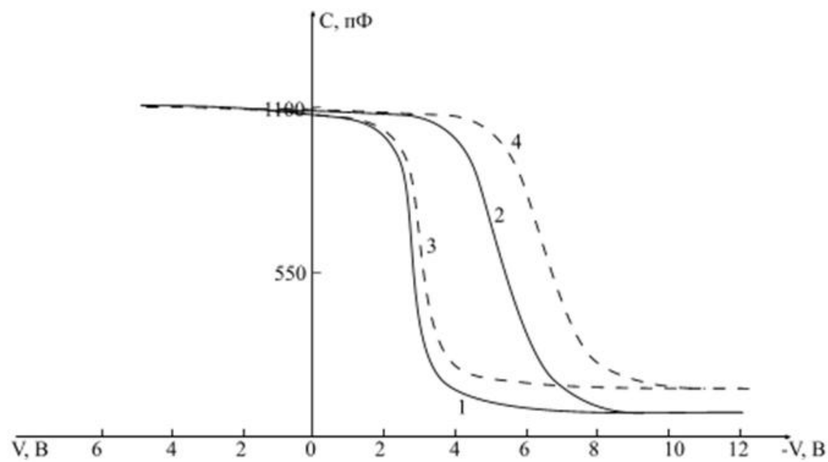

Figure 1: Capacitance-voltage characteristics of a silicon MIS- structures with an impurity of hafnium:
curves 1,3 – test MIS -structures without an impurity of Hf ,
curve 2 - MIS -structure based on Si, doped Hf when growing;
curve 4 - MIS -structure based on Si, the diffusion-doped Hf

Measurements of the spectra of CC-DLTS in MIS-structures on the basis of Si<Hf> and test MIS-structures (without an impurity of Hf) showed that their spectra practically coincide, any peaks in the visible concentration not founded (Figure 2, curve 1). Measurements of distribution N_{ss} on width of forbidden zone E_g of the semiconductor of structures with impurity Hf have shown that the spectrum of distribution of dependence N_{ss} from E_g has typical U-shaped character.
A different pattern is observed in MIS structures with diffusion introduced Hf. Preliminary Si it was doped with Hf by a diffusion method in the range of temperatures 1000-1200°C within 2 hours from the layer put on surface Si metal Hf. Then, on the wafers n-Si <Hf> with resistivity of ρ=5÷20 Ohm·cm made MIS-structures T [3-4].
Measuring C-V characteristics of MIS structures with diffusion introduced Hf (Figure 1, curve 4) showed that they are even more shifted towards negative offsets relative to control samples (Figure 1, curve 3). It is known that the shift of C−V characteristics towards negative voltages indicates an increase in the density of surface states (DSS) structures [5]. This suggests that the presence of the electrical active hafnium atoms in the silicon substrate of the investigated structures leads to a further increase of N_{ss} and the formation of positive charge at the interface Si-SiO_2.

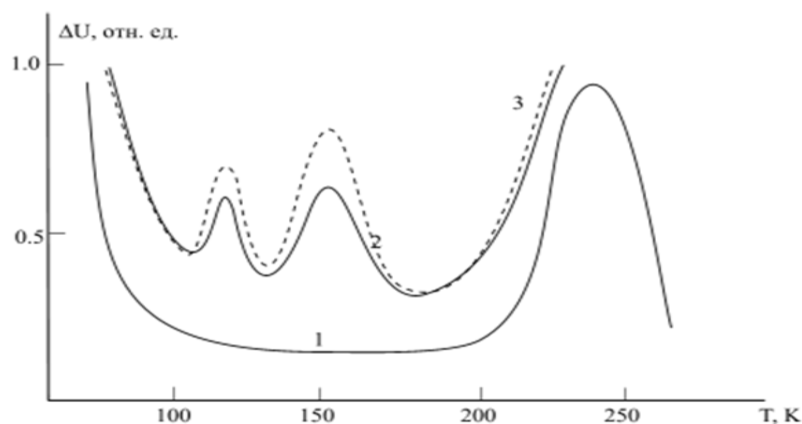

Figure 2: DLTS spectra of the control (curve 1) and doped hafnium MIS structures (curves 2 and 3)

Measurements of the spectra of CC-DLTS in the doped (Fig.2, curves 2 and 3) and the control (Figure 2, curve 1) MIS structures showed that the spectra of doped samples are observed 2 peaks with maxima at temperatures of T_{max} = 110 K and T_{max} = 146 K, and their amplitude increases with increase in the concentration of electroactive Hf. In the control samples, these peaks are not detected. Numerical calculations of the parameters of the defects caused by these peaks showed that the peak with a maximum at T = 110 K corresponds to a level with an ionization energy of E_c - 0.23 eV, and the peak at T = 146 K - level with an ionization energy of E_c - 0.28 eV.

It was also studied the change of distribution of N_{ss} on width of forbidden zone E_g of the semiconductor of MIS structures with impurity of hafnium and without hafnium. The spectra of distribution of N_{ss} on width of the forbidden zone U of the semiconductor structures with impurity hafnium are somewhat complicated nature.

It is shown that on the spectrum of distribution of N_{ss} on width of forbidden zone E_g, in diffusion-doped structures observed three distinct peak in the energy values E_c - 0.23 eV, E_c - 0.28 eV and E_v + 0.35 eV. In the control MIS-structures, this distribution as a typical U-shaped character.

To identify the detected defects with certain impurities in the investigated MIS - structures based on n-Si<Hf> etched oxide and on them barriers Schottky were created.

Measurements of spectra CC-DLTS on the received barriers have shown, that in all samples the recharge of two deep levels in the top half of forbidden zone Si with energies of ionization E_c - 0.23 эВ and the E_c - 0.28 эВ is observed. Scanning of all width of the forbidden zone on the same samples by means of photocapacity was shown, that on spectra of the induced photocapacity the recharge near hν ≈ 0.35 эВ is observed. These results also have been confirmed by means of measurements of spectra CC-DLTS [6]. The analysis of results shows, that parameters of these deep levels do not differ from parameters of the corresponding DL, observed in silicon doped hafnium.

Conclusions

Thus, the presence of electroneutral impurities hafnium in the silicon substrate of MIS-structures leads to an increase in N_{ss}, but a noticeable change in the distribution of N_{ss} in E_g is not observed. The presence of the electrical active hafnium in MIS-structures leads to a further increase of N_{ss} and the emergence of three distinct DLTS peaks associated with the deep levels of hafnium in silicon.

References

[1]. Berman, L. S., Lebedev A. A. 1981 Capacitive spectroscopy of deep centers in semiconductors (Moscow: Nauka) (in Russian)

[2]. The Rumak N. 1986 In. The system silicon-silicon dioxide in MOS structures (Minsk; Science and technique)

[3]. Vlasov I. S., Daliev Sh.Kh. 2004 Proc. of VNKSF-10, pp. 1171-1172 Moscow (in Russian)

[4]. Daliev Kh.S. Utamuradova Sh.B., Daliev Sh.Kh. 2004 Proc. of the VIII International conference "Solid State Physics" Alma-Ata (in Kazakhstan)

[5]. Lebedev A. A., Ecke, W. 1985 Semiconductors 19 1087 (in Russian)

[6]. Daliev Kh.S. Utamuradova Sh.B., Daliev Sh.Kh. 2006.Technical Physics Letters, 32 469 Pleiades Publishing, Inc