DEPENDENCE OF THE DIELECTRIC PROPERTIES OF THE Al-TiW-PtSi/n-Si SCHOTTKY DIODE ON THE ALTERNATING SIGNAL

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Dielectric properties and the dissipate of power in a Al-TiW–PtSi/n-Si Schottky barrier diode in the amplitude of ac-signal (V_{ac}) range of 5mV–1V (500kHz) and voltage range of (-2 V) to (4 V) have been investigated at the room temperature in detail by using experimental $C-V$ and $G-V$ measurements. Experimental results show that the values of ε' , ε″ and $tan\delta$ at (V_{ac}) = 200 mV have sharp peak. For other values of V_{ac}, the dependence on the amplitude of the test signal is practically not observed. It can be concluded that, at certain values, the amplitude of the ac-signal can significantly affect the interfacial polarization even at high frequencies. The power dissipated in the dielectric (i.e., dielectric losses) increases sharply with increasing ac-signal amplitude.

Keywords: Silicide–silicon contact, PtSi/n-Si Schottky diodes, Dielectric properties, dielectric loss, power dissipated.
PACS: 73.30.+y, 73.40.Qv, 73.40.Ns

1. INTRODUCTION

At the choosing the object of study, the advantages of Schottky barrier diodes (SBD) in comparison with p-n junctions were taken into account: simple technology, a wide choice of contacting materials [1-3]. Schottky diodes on the basis silicide-silicium contact attract wide attention of researchers due to high temperature stability. On the other hand, the silicide-silicon interface shifts deeper into the semiconductor, which affects the electrical and dielectric properties of this structure.

The purpose of our research is due to several reasons. First, the investigated diodes have small geometric dimensions (~10^{-6}cm^2) and are equipped with a diffusion barrier (the amorphous TiW alloy). Second, previous studies of these diodes revealed the presence of self-organized spots [4]. Third, the influence of the temperature and frequency of the test signal on the dielectric parameters of the PtSi/n-Si diodes was studied early [5]. At the same time there is no information in the scientific literature about the study of the influence of the amplitude of an alternating signal on the power dissipated in a PtSi/n-Si Schottky diodes.

2. MATERIALS AND METHODS

As a semiconductor wafer was chosen a single crystal of n-type silicon (P doped) with diameter of 3 inches, a resistivity of 0, 7 Ω·cm and a thickness of 3,5 µm. Silicide film has been fabricated by the magnetron-sputtering method [4,5]. Between Al and PtSi was deposited TiW alloy as diffusion barrier. Area of investigated barrier structure was 8x10^{-6} cm^2.
Investigation of Schottky barrier diode (SBD) were carried out at room temperature and sinusoidal test signal (500 kHz) using an HP 4192A LF impedance analyzer. The signal amplitude of which varied from 5 mV to 1V was applied to the sample from an external pulse generator.

3. RESULTS AND DISCUSSION

In the present paper by the using impedans spectroscopy method was investigated the influence of amplitude of ac-signal on dielectric loss of Al-TiW-PtSi/n-Si SBD. The dependence of the real and imaginary parts of dielectric constants (ε′, ε″) values of Al-TiW-PtSi/n-Si (SBD) on voltage and amplitude of ac-signal (V_{ac}) were obtained in the wide range of amplitude (from 5 mV to 1x10^3mV) and voltage (-2÷4V) using C and G/ω data at room temperature for the sample №8 (A= 8x10^{-6} cm^2) .

To describe the electrical and dielectric properties of the studied Al-TiW-PtSi/n-Si SBD, to separate the bulk and the surface phenomena of the material the formalism of the complex permittivity was applied [6]

$$\varepsilon * = \varepsilon' - i\varepsilon'' ,$$

where real (ε′) and imaginary parts (ε″) of complex permittivity, i is the imaginary root of -1 . At different value of (V_{ac}) parameters was calculated using the measured capacitance C and conductance G values from the expression

$$\varepsilon' = \frac{C}{C_0} = \frac{Cd_i}{\varepsilon_0 A}; \qquad \varepsilon'' = \frac{Gd_i}{\varepsilon_0 \omega A}; \qquad tan\delta = \frac{\varepsilon''}{\varepsilon'}$$

where C_0 is the capacitance of an empty capacitor, d_i is the thickness of the dielectric gap, A is the rectifier contact area of the structure (A= 8x10^{-6} cm^{-2}) and ε_0 is the permittivity of free space charge (ε_0 = 8.85 · 10^{-14} F/cm) (Fiq.1,2).

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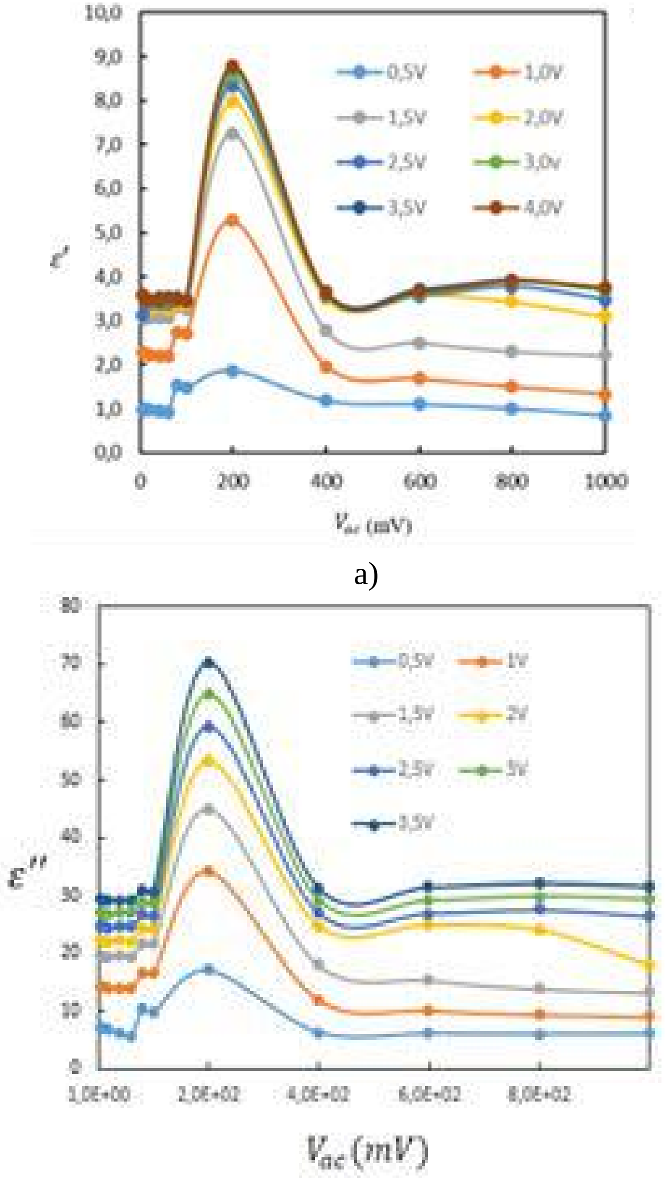

a)

b)

Fig.1. The dependence of ε' (a) and ε" (b) on V_{ac} of Al-TiW-PtSi/n-Si SD for various applied voltage.

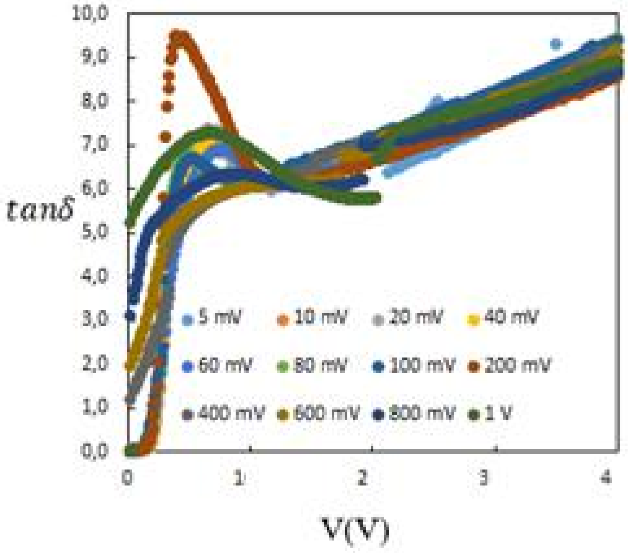

Fig. 2. The dependence of $tan\delta$ on V Al-TiW-PtSi/n-Si SD for various V_{ac}

Fig.1a),b) and Fig.2 shows the $\varepsilon' - V$, ε"-V and tanδ-V dependences for Al-TiW-PtSi/n-Si SBD when amplitude of ac-signal (V_{ac}) changed from 5mV to 1V at frequency 500kHz, respectively.

Can be noticed that the values of ε' increase with increasing voltage, then reaches a constant value. At the same time, the dependence $\varepsilon' - V$ is distinguished by a sharp increase in ε' at the amplitude of the ac signal V_{ac} =200 mV, although the nature of the dependence is preserved. A sharp peak at 200mV can be attributed to the increasing of polarization. Dependence ε"-V_{ac}, characterizing the density of conduction currents, also takes a maximum value at V_{ac}=200mV. The $tan\delta - V$ characteristics have cutting peak only at V_{ac}=200mV. It is well known that the peak behavior of the ε'' and $tan\delta$ depend on a number of parameters such as doping concentration, interface state density, series resistance of diode and etc. In addition, the capacitance and conductance are extremely sensitive to the interface properties and series resistance. This occurs because of the interface states that respond differently to test ac-signal. The change of parameters can be attributed to Maxwell–Wagner type interfacial polarization, i.e. charge carries accumulate at the boundaries of less conducting regions, thereby creating interfacial polarization.

It should be noted that dielectric losses determine the dissipate of power in a dielectric. This parameter determined by the amplitude of ac-signal (V_{ac}) [7-9]. According to the theory active power of dielectric losses for device with parallel equivalent circuit (Schottky diodes) described as

$$P = V_{ac}^2 \omega C tan\delta$$

Thus, the dielectric losses are proportional to the square of the effective value V_{ac} , $tan\delta$, the frequency and the capacitance of the capacitor.The dependence of the P of Al–TiW–PtSi/n-Si SBD on amplitude of V_{ac} at different voltage are presented in Fig. 9. As can be seen from the figure, the power dissipated in the dielectric (i.e., dielectric losses) increases sharply with increasing ac-signal amplitude. In addition, one can notice the appearance of a small peak at 200 mV. The obtained dependence of the active power of dielectric losses on the amplitude ac-signal is characteristic of an inhomogeneous structure consisting of regions with different resistivity. This structure is identical to the Maxwell-Wagner two-layer dielectric [10].

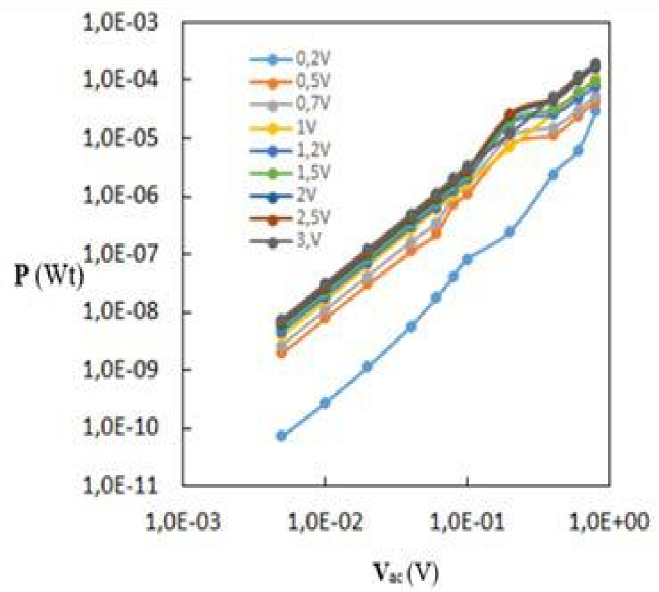

Fig. 3. The dependence of the active power of dielectric losses (P) in the Al–TiW–PtSi/n-Si SBD on the amplitude of ac-signal V_{ac}

In our previous article has been revealed the existence of selfassembled patches similar the quantum wells. These patches formed due to the process of PtSi formation on semiconductor and the presence of hexagonal voids of Si(111).

In such structure, patches play the role of macrorelaxators. It is known that relaxation phenomena are associated with the recharging of surface states [11]. The features of the obtained amplitude dependences indicate that the dissipation power at 200 mV is related to the maximum density of surface states

4. CONCLUSION

By the using of impedance spectroscopy for Al–TiW–PtSi/n-Si SBD were investigated ε', ε'' and $tan\delta$ for various ac-signal amplitudes (V_{ac}) in the range from 5x10^{-3} V to 1 V at room temperature versus applied voltage from − 2 to 4 V and frequency 500 kHz. Based on the obtained characteristics, the dependences of the dielectric constant on the dc-voltage and amplitude of ac-signal have been calculated. All characteristics shows that parameters only at V_{ac}=200mV a sharp increase in values. The dependence of the power dissipation (dielectric losses) revealed a strong dependence on the amplitude of the ac-signal. Comparison of the results revealed a local heterogeneous structure of contacts according to the Maxwell-Wagner type.

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