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INVESTIGATION OF SERIES RESISTANCE AND SURFACE STATES IN Au/n-GaP STRUCTURES

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The variation in series resistance and surface state density of Au/n-Gap Schottky diodes have been systematically investigated at room temperature by using capacitance- voltage *C-V* and conductance-voltage *G/w-V* measurements techniques. The *C-V* and *G/w-V* characteristics of these devices were investigated by considering series resistance (R_S) effects in a wide frequency range. It is shown that the capacitance of the Au/n-GaP Schottky diode decreases with increasing frequency. We assume that the surface states were responsible for this behaviour. The distribution profile of Rs-V gives a peak in the depletion region at low frequencies and disappears with increasing frequencies.

In the past decades, there has been considerable interest in the experimental studies and the investigating of semiconductor device properties of metal-semiconductor diodes and also metal-insulator-semiconductor [1,2]. Native oxide layer and interface states of this type diodes effects their performance, reliability and device characteristic parameters. The formation of oxide layer can have a strong influence on Schottky barrier characteristics such as Schottky barrier height (SBH), the interface state density and ideality factor [2]. These possible error sources cause deviations of the ideal behavior of the structure and must be taken into consideration. The determination of N_{SS} and R_S in (MIS) Schottky diode has become a subject of very intensive research and reported in the literature for more than four decades.[3-6]

In this work, sample diodes were fabricated using n-type (S- doped) single crystal GaP wafer with <100> surface orientation, 300μm thickness, 2 inchs diameter and $1x10^{18}$ cm^{-3} donor concentration. The GaP wafer was degreased for 5 min in boiling trichloroethylene, acetone and ethanol consecutively. Preceding each cleaning step, the wafer was rinsed thoroughly in de-ionized water of 18 MΩcm resistivity. Immediately after surface cleaning, high purity Au metal (99,995%) with a thickness of 150 nm was thermally evaporated from the tungsten filament onto the whole back surface of the wafer in ultra-high vacuum system (10^{-6} Torr). The ohmic contacts were prepared by sintering the evaporated Au back contact at 400 ˚C for 10 minutes in flowing dry nitrogen ambient. The Schottky contacts formed by evaporating Au as dots with diameter of about 1 mm onto GaP surface. The *C-V* and *G/w-V* measurements were performed by the use of HP 4192A LF impedance analyzer. The measurements of C-V, G/w-V characteristics of device have been carried out at various frequencies at room temperature.

Fig. 1 and 2 show a typical forward and reverse bias frequency dependent *C-V* and *G/w-V* characteristics at room temperature. The measured capacitance and conductance characteristics show the frequency dependent behaviors in the depletion and accumulation regions. The *C-V* curves give a peak in the depletion region due to particular distribution of interface states. The presence of the capacitance peak in the forward capacitance voltage plot is investigated by a number of experimental results on metal-oxide-semiconductor structures [8,9]. The peak of capacitance shifted to inversion region with decreasing frequency. The origin of such peak has been ascribed to the series resistance by Chattopadhyay and Raychaudhuri [8,9] and Ho et al [10] to the interface states effect. The values of the capacitance and conductance depend on a number of the oxide layer, series resistance and density of interface states.

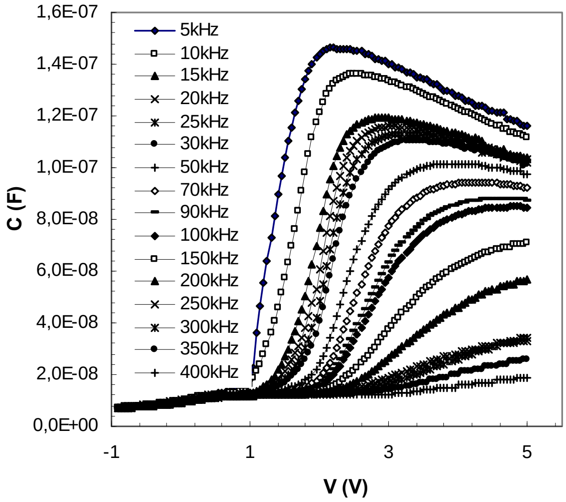

*Fig.1.*Frequency dependent capacitance-voltage characteristics of Au/n-GaP.

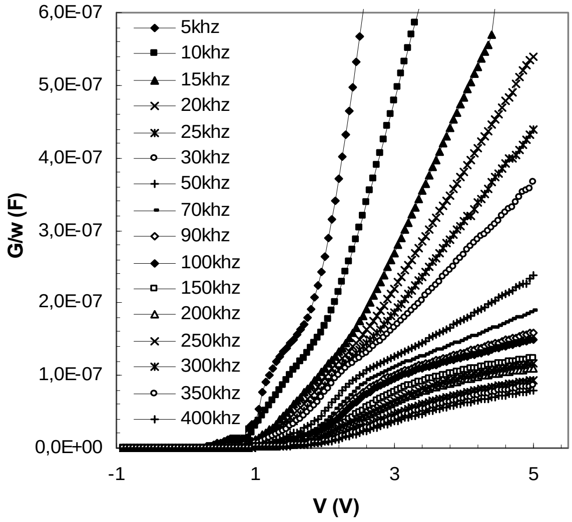

Fig.2. Frequency dependent conductance-voltage characteristics of Au/n-GaP.

The series resistance is an important parameter which causes the electrical characteristics of MIS structures to be non-ideal. There are several methods to determine the series resistance R_s of MIS or MOS structure. The real series resistance of metal-oxide-semiconductor structures can be determined from the measured capacitance and conductance in strong accumulation region. The series resistance is given by [11]

$$R_s = \frac{G_m}{G_m^2 + (\omega C_m)^2} \tag{1}$$

where C_m and G_m represent the measured capacitance and conductance in strong accumulation region, respectively. Therefore, both the real values and voltage dependence of the series resistance were calculated from Eq. 1 and are given in Fig. 3. The *Rs* plots give a peak in the voltage range of 1 - 2 V. The peaks shifted from the 2 V to 1 V with the decreasing frequency and amplitude of the peaks decreased with increasing frequency.

The value of the series resistance decreases with increasing frequency. The native oxide layer capacitance was found through relation [12],

$$C_{ox} = C_c \left[1 + \left(\frac{G_m}{\omega C_m} \right)^2 \right] \tag{2}$$

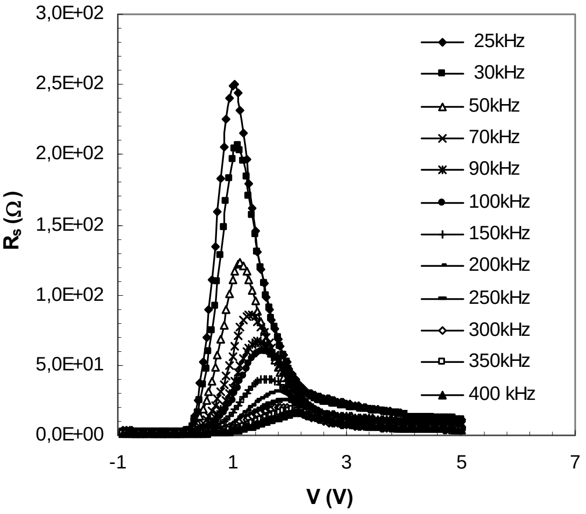

Fig. 3. The series resistance for various frequency at room temperature.

A fast and reliable way to determine the density of interface states is the Hill-Coleman method [13]. According to this method, N_{SS} can be calculated by using the following equation:

$$N_{SS} = \frac{2}{qA} \frac{(G_{m,\max}/w)}{\left[((G_{m,\max}/w)C_{ox})^2 + (1 - C_m/C_{ox})^2 \right]} \tag{3}$$

where A is the area of diode, *w* is the angular frequency, C_{ox} is the capacitance of native oxide layer, $G_{m,\max}$ conforms to maximum measured *G-V* curve, C_m is capacitance of diodes corresponding to $G_{m,\max}$. This method is very useful in understanding the electrical quality of the interface and the obtained values are shown as a function of frequency in Fig. 4. As can be seen from Fig. 4, interface state density of the sample depends on frequency.

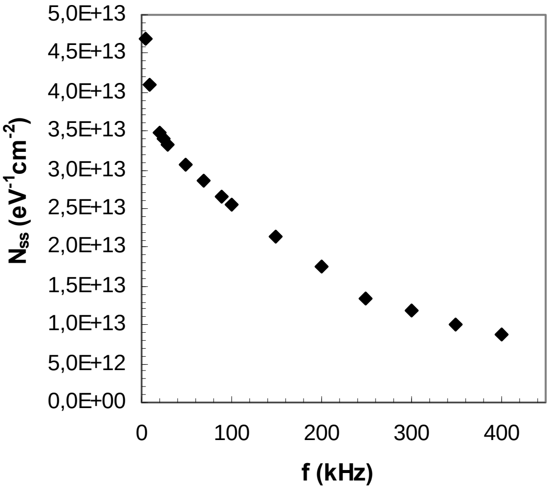

Fig. 4. Interface state density vs. frequency at room temperature.

Frequency dependent series resistance and interface state density have investigated by using the capacitance and conductance characteristics. Measurements and calculated results show that both the series resistance and interface state density depend on frequency and decreases with increasing frequency.

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