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Investigation Of GaAs MIS Deposited By PECVD Method

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Abstract- Plasma-enhanced chemical vapor deposition of silicon nitride Si3N4 is commonly used to passivate surface states and to encapsulate III-V devices and circuits; this method has been used for Metal-oxide-semiconductor (MIS) capacitors in the GaAs semiconductor to improve the device. In this work, measurements are performed to obtain capacitance voltage (C–V) and conductance (G–V), measurements have been carried out in the frequency range of 10 kHz–1MHz and bias voltage range of (−6V) to (14V) at room temperature. Using the Terman method, the interface trap density is extracted from C–V curves. The Dit is responsible for the non-ideal behavior of C-Vg and G-Vg leading to the breakdown of such device.

Keywords: MIS ; Gallium arsenide; silicon nitride; capacitance–voltage; interface state ; PECVD; Terman method.

I. INTRODUCTION

Al/Si_3N_4/n-GaAs metal-insulator-semiconductor (MIS) capacitors deposited at low frequency PECVD is a type of device used in electronic circuits for various applications, such as in high-speed digital electronics and wireless communication systems. The device consists of a layer of silicon nitride (Si_3N_4) deposited on an n-type Gallium Arsenide (n-GaAs) substrate, which is then covered with a layer of aluminum (Al).Al/Si3N4/n-GaAs MIS capacitors have several advantages, including high capacitance, low leakage current, and excellent frequency response. These properties make them ideal for use in high-frequency applications, such as radio frequency (RF) circuits and microwave systems. Additionally, the use of GaAs allows for better device performance compared to silicon-based devices, due to GaAs's higher electron mobility[1].Overall, GaAs offers improved performance, efficiency, and reliability over silicon in certain applications, making it a preferred choice for high-frequency and high-speed applications[2].

II. EXPERIMENTAL

Silicon nitride (Si_3N_4) thin film has been prepared on n-type GaAs single crystal wafer to fabricate an Al/Si3N4/n-GaAs (MIS) capacitor using low frequency PECVD. In our article [3], more information on fabrication processes was given. The Si_3N_4 films deposited had thicknesses of 72 nm, Aluminum circular contacts was estimated to be about 1.92 cm^2 from the oxide capacitance (Cox) in the strong accumulation. Samples received sulfur passivation by soaking

them in $(NH_4)_2S$.The C-V and G-V measurements, were carried out in the frequency range of 10 kHz–1MHz and bias voltage range of (−6V) to (14V) at room temperature.

III. RESULTS AND DISCUSSION

To investigate the electrical instability and potential use of Si_3N_4 in MIS-based technology, capacitance voltage (C-V) and conductance voltage (G-V) measurements were conducted at room temperature for frequencies ranging from 10 kHz to 1 MHz. The C-V characteristics of Al/Si3N4/n-GaAs capacitors at different frequencies were plotted in Figure 1,2, showing three regions of accumulation, depletion, and inversion. The C-V curves were found to be a function of frequency and bias voltage, with flat band voltages (Vfb) exhibiting sensitivity to the applied frequency and consistently shifting to higher values as the frequency increased. This behavior can be attributed to frequency-dependent interface states and border traps located near the interface between Si_3N_4/GaAs, which exchange mobile carriers with GaAs[4].

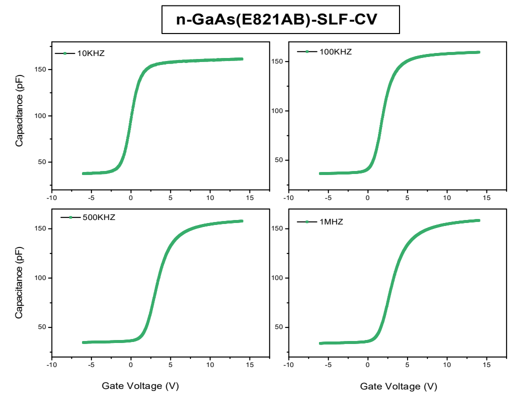

Fig 1: C–V characteristics of Al/Si3N4/n-GaAs (MIS) capacitor in various frequencies range from 10 kHz to 1MHz

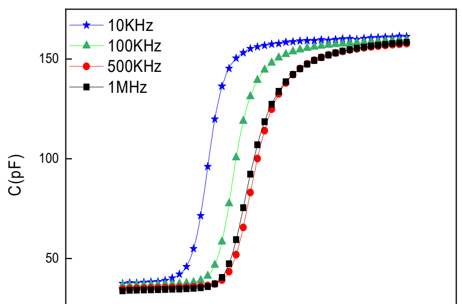

Fig. 2: Comparison between the capacitance–voltage (C–V) curves for the different frequencies

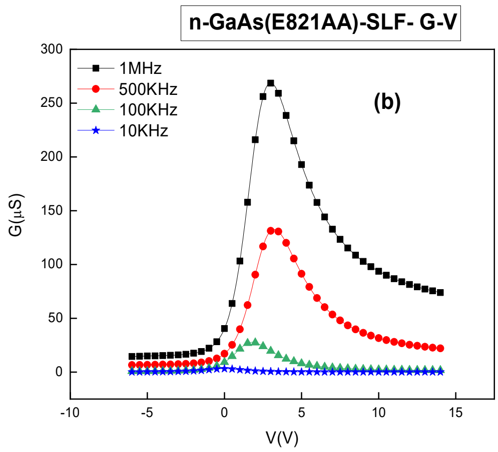

Fig3 Conductance–voltage curves Al/Si3N4/n-GaAs MIS capacitor for the different frequencies

In Figure 3, it can be observed that the conductance curves showed a peak for each frequency in the depletion region due to interface traps. The maximum value of these peaks increases and moves towards more positive voltages at frequency, this peaks that are directly related to the AC response of interface states.

To determine the interface state density, the Terman method was employed in which a high

frequency C-V curve was compared to an ideal calculated C-V curve. This allowed the generation of an interface trap density distribution over the bandgap. The ideal C-V curve was calculated numerically using MATLAB. The interface trap density can be determined from the stretch out of the measured curves by [5]:

$$C_{it}(V_S) = C_{ox}\left[\left(\frac{dV_S}{dV_G}\right)^{-1} - 1\right] - C_{SC}(V_S) \quad \text{(Eq1)}$$

$$D_{it}(V_S) = \frac{C_{it}}{q} \quad \text{(Eq2)}$$

where Vs is surface potential and Csc is semiconductor capacitance. The Dit extracted from Terman method for sample SLF at 1Mhz is 4.96 10^{13} eV^{-1} cm^{-2} at 1.25 ev below conduction band.

IV. CONCLUSION

In this study, The PECVD method allows depositing conformal Si_3N_4 dielectric films for Al/Si3N4/n-GaAs passivation,the electrical characteristics of the Al/Si3N4/n-GaAs MIS capacitor were analyzed at room temperature for various voltage frequencies. The results indicate that both capacitance and conductance are influenced by the applied voltage frequency due to frequency dependent charges, interface states, and border traps. The determined values of Dit were in the range of is 4.96 10^{13} eV^{-1} cm^{-2}.

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