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The effect of frequency and temperature on capacitance/conductance–voltage (*C*/*G*–*V*) characteristics of Au/n-GaAs Schottky barrier diodes (SBDs)

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ABSTRACT

The capacitance–voltage (C–V) and conductance–voltage (G/ω–V) characteristics of the Au/n-GaAs Schottky barrier diodes (SBDs) have been investigated for 10, 100 and 500 kHz at 80 and 280 K. To evaluate the reason of non-ideal behavior in C–V and G/ω–V plots, the measured C and G/ω values were corrected by taking into accounts series resistance effect. Experimental results show that the values of C and G/ω were found to be a strong function of interface states (N_{ss}) at inverse and depletion regions especially at low frequencies, but R_s is effective only at the accumulation region especially at high frequencies. Such behavior of the C and G/ω values may be attributed to an increase in polarization especially at low frequencies and the existence of N_{ss} or dislocations between metal and semiconductor. It can be concluded that the increase in C and G/ω at low frequencies especially at weak and depletion regions results from the existence of N_{ss}. The values of doping concentration (N_d) and barrier height (BH) between metal and semiconductor were also obtained from the linear part of high frequency (500 kHz) C^{-2} vs. V plots at 80 and 280 K, respectively.

1. Introduction

Gallium arsenide (GaAs) is quite a versatile semiconductor and the subject of many experimental and theoretical studies which has considerable electrical properties such as direct forbidden band gap, high electron mobility, a high breakdown voltage, mechanical stability and lower power dissipation. Therefore, GaAs based structures are widely used as a basic component for high speed electronic, optoelectronic and high-speed microelectronic applications in different fields of technology [1–6]. The conduction mechanisms become more complex especially under room temperature or at low temperatures in GaAs based structures. The change in main diode parameters also becomes important especially at low and intermediate frequencies due to charges at interface states/traps and surface polarization. Thus, the analysis of the electrical characteristics of the diode only at room temperature and at one frequency by using admittance spectroscopy (C–V and G/ω–V) measurements cannot give detailed information on the conduction mechanisms and the formation of barrier height at the M/S interface. Therefore, the investigation of these measurements especially at low temperatures and frequencies can supply more information both on conduction mechanism and formation of barrier height at the M/S interface. Although, many works have been carried out in the literature on n-GaAs Schottky diodes using capacitance/conductance–voltage measurements [3,7–12]. However, the detail information on main electrical parameters/characteristics of n-GaAs Schottky diodes has not been clarified yet. The electrical characteristics are dependent

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on various parameters such as the process of surface preparation, BH inhomogeneity at the M/S interface, impurity concentration of a semiconductor, density distribution of interface states or dislocations, R_s of device, device temperature, and frequency and applied bias voltage. For example, while tunneling (thermionic field emission (TFE) and field emission (FE)), generation-recombination mechanisms became dominant at low temperatures, thermionic emission (TE) theory becomes effectives only at room or above room temperatures.

In the ideal situation, specially at high frequencies, the C–V and G/w–V characteristics of MS and MIS structures are usually frequency independent, and exhibit an increase in capacitance with increasing forward bias voltage. On the other hand, the situation is different especially at low and moderate frequencies and temperatures in the depletion and accumulation regions due to the contribution of carriers at interface states (N_{ss}), interfacial insulator layer and series resistance (R_s) of device. It is well known, the semiconductor crystal surface is usually covered with a layer of native oxides and organic contaminants in the laboratory environment. The existence such an insulator layer at the M/S interface, R_s and N_{ss} significantly alters the devices C–V and G/ω characteristics [5–14]. Therefore, the effect of this interfacial layer deposited or native, N_{ss}, and R_s of the diode have been investigated by many workers [7–20].

In the light of above instructions, in this study, we have investigated the analysis in a certain range of frequency and two different temperatures (80 and 280 K) and three different frequencies (10, 100 and 500 kHz) to understand a detail information on the electrical parameters of Au/n-GaAs SBD. For this purpose, the frequency dependence of C–V and G/ω–V characteristics of Au/n-GaAs SBD have been carried out in the wide range of applied bias voltage −4 V to +4 V. The voltage dependent N_{ss} profile was obtained from the high-low frequencies (C_{LF}–C_{HF}) C–V plots at 80 and 280 K. In addition the values of doping concentration (N_d), Fermi energy level (E_F) and barrier height (BH) between metal and semiconductor were obtained from the linear part of high frequency (500 kHz) C^{-2} vs. V plots at 80 and 280 K, respectively.

2. Experimental method

Au/n-GaAs SBDs were fabricated on n-GaAs semiconductor with 5.08 cm diameter and (1 0 0) orientation, 350 μm thickness and $\sim 2 \times 10^{18}$ cm^{-3} dopant concentrations and 2.14 Ω cm resistivity. The structure of Au/n-GaAs and details its fabrication processes have be given in previous study [3].

The C–V and G/ω–V measurements were performed at various frequencies (10, 100, 500 kHz) at 80 and 280 K temperatures by using an HP 4192A LF impedance analyzer (5 Hz–13 MHz) and test signal of 40 m V_{rms}. All of the measurements were carried out in the temperature controlled Janes vpf-75 cryostat and the temperature was monitored by Lake Shore model 321 auto-tuning temperature controller. In addition, all of measurements were carried out with the help of a microcomputer through an IEEE-488 AC/DC converter card. The schematic diagram of the Au/n-GaAs SBDs and measurement system are given in Fig. 1.

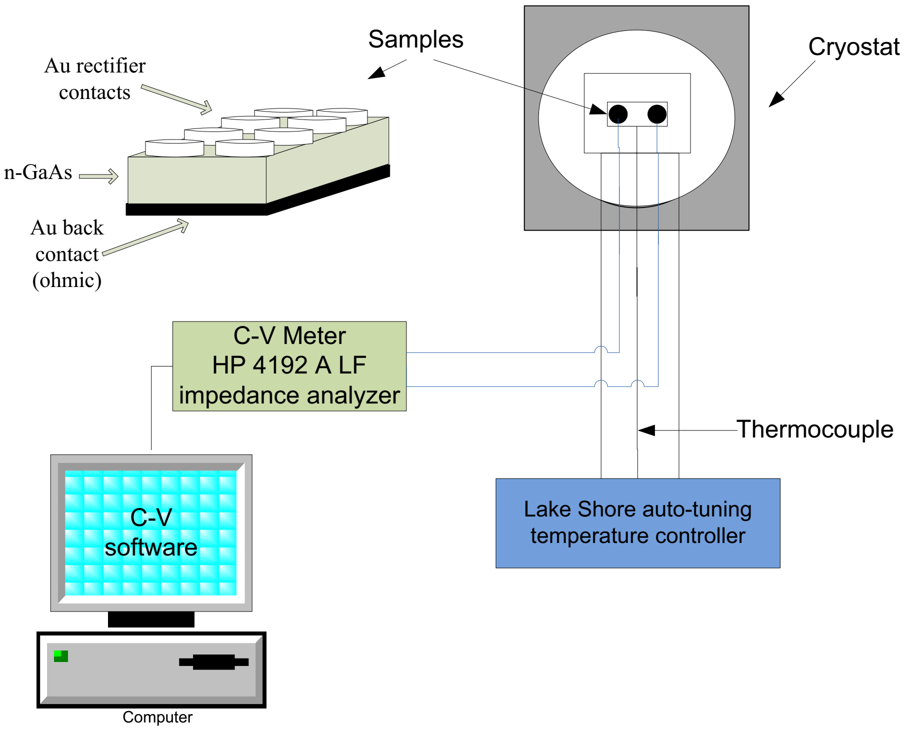

Fig. 1. Schematic diagram of the Au/n-GaAs SBD and measurement system.