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The interface states and series resistance analyzing of Au/SiO_2/n-GaAs at high temperatures

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ABSTRACT

The current–voltage (*I–V*) characteristics of Au/SiO_2/n-GaAs metal-oxide-semiconductor (MOS) type Schottky barrier diodes (SBDs) have been measured in the temperature range of 300–400 K with 25 K steps. From the *I–V* characteristics of SBDs, the zero-bias barrier height ϕ_{Bo} and ideality factor (n) assuming the thermionic emission (TE) mechanism show strong temperature dependence. While n decreases, ϕ_{Bo} increases with increasing temperature. The obtained values of ϕ_{Bo} and n varied from 0.81 eV and 1.33 at 300 K and 0.93 eV and 1.12 at 400 K, respectively. In addition, the interface states distribution profile (N_{ss}) as a function of temperature was extracted from the forward-bias *I–V* measurements by taking into account the bias dependence of the effective barrier height ϕ_e and series resistance (R_s) for the SBDs. The values of R_s were performed using the Cheung's method. Thus, important electrical parameters as a function of temperature were analyzed by using the *I–V* measurements.

1. Introduction

Metal-oxide-semiconductor (MOS) type Schottky barrier diodes (SBDs) are very attractive devices for high frequency switching and low power applications. As a gate dielectric, silicon dioxide (SiO_2) material has played an important role in development of fundamental devices for microelectronics and semiconductor industries. Also SiO_2 dielectric material will continue to be an important part of new-generation gate stacks as an intermediate layer between silicon and high permittivity (high-*k*) dielectrics [1]. Electronic properties of a Schottky diode are characterized by its main electrical parameters such as barrier height, ideality factor, series resistance, and interface state density. An oxide layer between metal and semiconductor can have strong influence the device properties as well as interface state density (N_{ss}), Schottky barrier heights (SBHs), ideality factor (n), and leakage current level [2–8]. Especially, series resistance (R_s) and surface states (N_{ss}) are crucial important parameters that affect the device properties of the SBDs. But the analysis of current–voltage (*I–V*) characteristics of the SBDs at room temperature does not give detailed information about their current conduction mechanisms. So that, obtaining ideality factor, barrier height, series resistance, and surface state density parameters as a function of temperature give to us more detailed information about the SBDs.

In this study, the forward and reverse bias *I–V* characteristics of Au/SiO_2/n-GaAs SBDs were carried out in the temperature range of 300–400 K with 25 K steps. The temperature dependent of ideality factor, barrier height, and series resistance were obtained from *I–V* measurements. In addition, the density of interface states as a function of E_c–E_{ss} was extracted from *I–V* characteristics. The results show that all device parameters depend on temperature very strongly.

2. Experimental method

Au/SiO_2/n-GaAs SBDs were fabricated on quarter of the 5.08 cm diameter float zone (100) n-GaAs wafer having thickness of about 350 μm with 2-3 × 10^{18} cm^{-3} dopant concentrations. For the fabrication process, the firstly GaAs wafers were dipped in ammonium peroxide for 40 s to remove native oxide layer on the surface. Au/Ge/Ni alloy was evaporated onto the whole back side of the wafer at a pressure about 10^{-7} Torr in a vacuum system. In order to perform the ohmic contact, wafer was sintered at 430 °C for 40 s. Oxide layer (SiO_2) was coated on the upper surface of the GaAs by using plasma enhanced chemical vapor deposition (PECVD) technique. In PECVD system, SiH_4 gas was used for Si source and O_2 gas used for oxygen source. The wafer was placed in the vacuum system after SiO_2 coated and high purity gold (Au) front/Scottky contacts with a thickness of 1500 Å were evaporated at a rate of on the ~2 Å/s through a metal shadow masks with circular dots of 1 mm diameter. The metal layer thickness and the deposition rates were monitored with the help of quartz crystal thickness monitor. Before the SiO_2 coating, we checked the native-GaAs substrate surface by atomic force microscopy (AFM) and was given in detail [9].

The current–voltage (*I–V*) characteristics of the Au/SiO_2/n-GaAs SBDs were measured in the temperature range of 300–400 K using a temperature controlled Janes vpf-475 cryostat, which enables us to make measurements in the temperature range of 77–450 K, and a Keithley 220 programmable constant current source and Keithley 614 electrometer in dark conditions. The sample temperature was always

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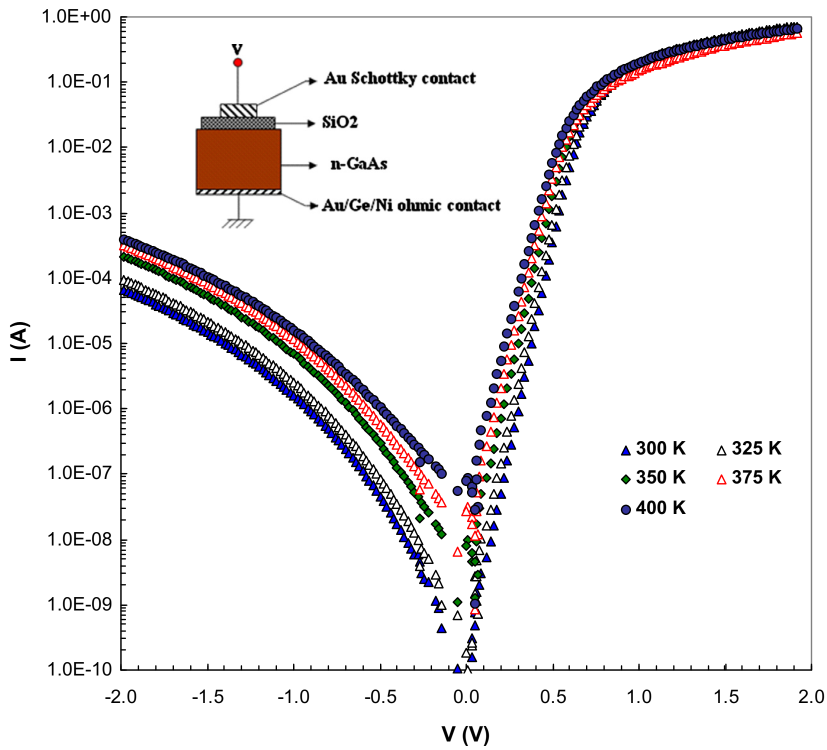

Fig. 1. The semi-logarithmic forward and reverse bias current–voltage characteristics of the Au/SiO_2/n-GaAs (MOS) Schottky diode at various temperatures. (Inset figure shows the structure of the SBD).

Table 1
Temperature dependence of basic parameters obtained from forward bias I-V characteristics.

Temperature (K)	n	ϕ_{Bo} (eV)	R_s ($H(I)$) (Ω)	R_s ($dV/d\ln(I)$) (Ω)	N_{ss} (eV^{-1} cm^{-2})
300	1.33	0.81	1.56	1.65	2.75×10^{12}
325	1.27	0.84	1.47	1.72	2.05×10^{12}
350	1.20	0.87	1.39	1.81	1.64×10^{12}
375	1.15	0.91	1.71	2.05	1.52×10^{12}
400	1.12	0.93	1.32	1.96	1.34×10^{12}

monitored by using a copper-constant thermocouple and Lakeshore 321 auto-tuning temperature controller with sensitivity better than ±0.1 K. All measurements were carried out with the help of a microcomputer through an IEEE-488 ac/dc converter card.

3. Results and discussion

The current according to thermionic emission (TE) theory for a SBD with series resistance (R_s) is given by [7,10,11]:

$$I = I_o\left[\exp\frac{q}{nkT}(V - IR_s)\right] \tag{1}$$

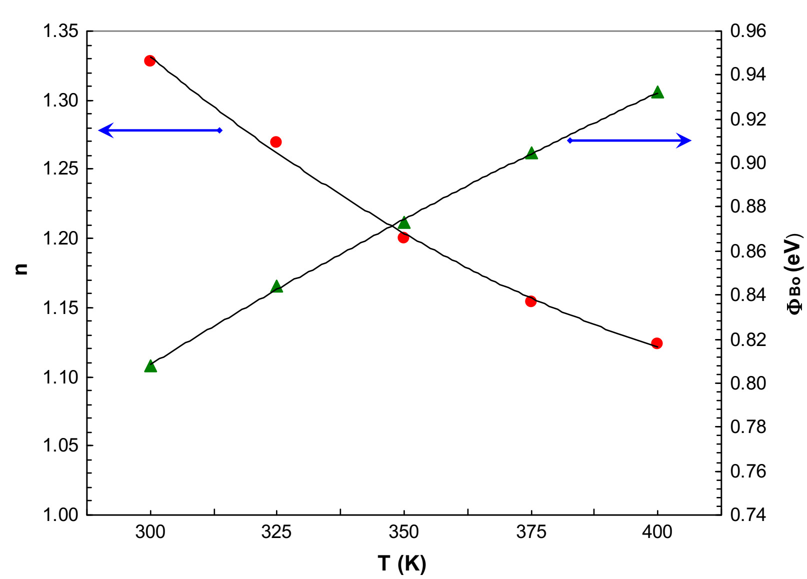

Fig. 2. The variation in the ideality factors and zero-bias barrier heights with temperature for SBDs.