



## Comparison of daylight and dark characteristics parameters of Au/n-type GaAs Schottky barrier diodes

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This work measures the current-voltage (I-V) properties of the Au/n-GaAs/Au Schottky barrier diode in both daylight and dark conditions. The measured current-voltage characteristics show good diode behavior with a high rectification ratio. The values of the rectifying ratio (RR), ideality factor ( $n$ ) and barrier height ( $\phi_b$ ) were obtained as 1098, 1.230, and 0.672 eV for dark and 1652, 1.167, and 0.688 eV for daylight, respectively. According to Ohm's law, the values of series resistance ( $R_s$ ) and shunt resistance ( $R_{sh}$ ) were found as 1.94  $\Omega$ , and 643  $\Omega$  for dark and 1.11  $\Omega$ , and 837  $\Omega$  for daylight, respectively. Additionally, by accounting for the bias dependency of the effective barrier height, the forward bias I-V characteristics were used to derive the energy distribution of the interface state density. The findings demonstrate that there is a thin interfacial layer between the semiconductor and the metal.

**Keywords:** n-GaAs, Schottky diode, barrier height, ideality factor, interface state density, series resistance

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### 1. Introduction

Because of its potential uses, Schottky barrier diodes (SBDs) have been the subject of extensive research recently [1-3]. In electrical circuits, metal/semiconductor (M/S) connections allow semiconductor-based devices to communicate with one another [4-5]. One significant direct bandgap semiconductor is gallium arsenide (GaAs). These days, it finds usage in a wide range of applications, including microwave sources, optical fiber sources and detectors, and solar cells in space [4-6]. The material is well suited for the creation of high frequency and low power devices due to its strong electron mobility and high carrier saturation velocity [6]. To date, many opto-electronic devices have been installed on it.

Determining how contact characteristics alter in both daylight and dark situations is crucial. Production of optoelectronic devices depends on an understanding of how devices behave under various operating conditions, particularly those with highly doped semiconductors like GaAs that are expected to function both in the dark and in

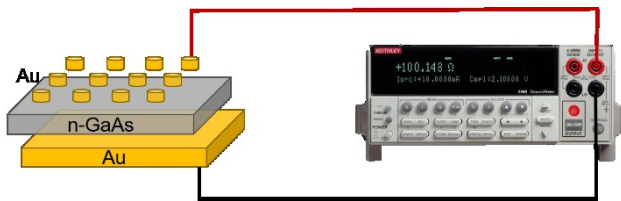
the light. Because of the high electron mobility in GaAs, devices based on this semiconductor have some benefits over Si-based devices in high-speed and high-power applications.

To explain the reported observations, many attempts have been made to understand the electrical behavior across Schottky diodes. [6]. The M/S Schottky diode parameters have been reported by researchers [7-10]. Karabulut et al. [7] have produced Au/n-GaAs diode and its Schottky barrier height value was calculated at 0.77 eV. Bobby et al. prepared Au/n-GaAs/In diode [8]. They reported using electrical properties of the device by using the current-voltage characteristics. They have calculated the values of barrier height and ideality factor as 0.69 eV and 2.50, respectively. A Gaussian distribution of the Schottky barrier height was used by Örzeli et al. [9] to explain the temperature dependence of the I-V measurements at high temperatures (280–415 K) of Au/n-GaAs Schottky. Using a semi-analytical model, Kim et al. [10] investigated the temperature dependency of Au/n-GaAs I-V characteristics in between 83 and 323 K. They stated that the features' temperature-dependent fluctuations were in line with the energy band gap's characteristics.

To compare the change of diode parameters in daylight and darkness environments, we prepared the Au/n-GaAs/Au Schottky barrier diodes. We discussed the diode's current-voltage ( $I-V$ ) properties in both daylight and darkness conditions. The barrier height ( $\Phi_b$ ), ideality factor ( $n$ ), series resistance ( $R_s$ ), shunt resistance ( $R_{sh}$ ), interface state density ( $N_{ss}$ ) parameters of the Au/n-GaAs type Schottky diode were determined in this study using the Norde function and thermionic emission (TE) separately, based on  $I-V$  measurements of the sample that were made in both daylight and dark conditions. The goal is to compare the outcomes for various approaches and to establish accurate and trustworthy metrics.

## 2. Experimental

In this study, the n-GaAs wafer has silicon doped, fabrication of VGF method, (1 0 0) surface orientation, and 350  $\mu\text{m}$  thickness. The n-GaAs wafer purchased from University Wafer was chemically cleaned by RCA cleaning method. Gold metal was deposited in a vacuum environment by thermal evaporation technique to create both ohmic and rectifying contact. Metal thicknesses were approximately 150 nm. In a result, an Au/n-GaAs/Au Schottky barrier diode was prepared. Figure 1 shows the 3D presentation of Au/ n-GaAs/Au Schottky barrier diode. To compare the parameters such as ideality factor, barrier height and series resistance of the diode produced both in the darkness and in daylight, current-voltage ( $I-V$ ) measurement was taken, varying between -1 V and +1 V, at room temperature. Using a Keithley 2400 Sourcemeater, the  $I-V$  measurement of the Au/n-GaAs/Au Schottky barrier diode was performed.



**Figure 1:** 3D view of Au/n-GaAs/Au Schottky diode structure

## 3. Results

Fig. 2 depicts the experimental semi-logarithmic current-voltage ( $I-V$ ) characteristics of the Au/n-GaAs Schottky barrier diode under forward and reverse bias in both daylight and dark environments. To calculate Schottky barrier height, ideality factor and saturation current of the device, the relationship between the applied bias voltage  $V$  and the current  $I$  for thermionic emission is provided by [1,11-13]:

$$I = I_0 \left[ \exp\left(\frac{q(V-IR_s)}{nkT}\right) - 1 \right] \quad (1)$$

where  $T$  is the temperature in K,  $q$  is the electron charge,  $R_s$  is the series resistance,  $k$  is Boltzmann's constant and  $I_0$  is the saturation.

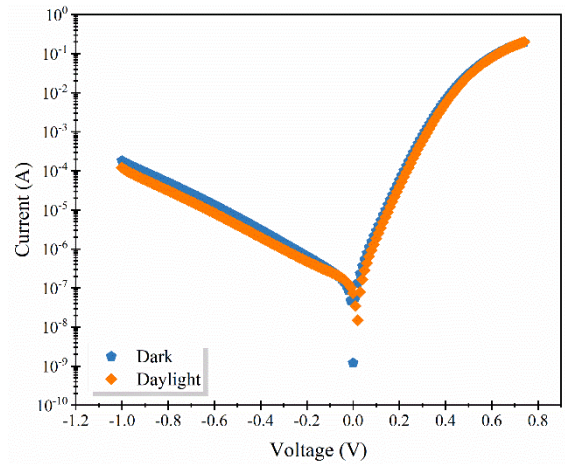
$$I_0 = AA^*T^2 \exp\left[\frac{-q\Phi_b}{kT}\right] \quad (2)$$

Where  $A$  is the diode area and  $A^*$  is Richardson constant for n-GaAs ( $8,16 \text{ Acm}^{-2} \text{ K}^{-2}$ ). The barrier height ( $\Phi_b$ ) and ideality factor ( $n$ ) values are obtained from the intercept and slope of the  $V$  vs  $\ln I$  plot.  $\Phi_b$  and  $n$  are determined using [11-13]:

$$\Phi_b = \frac{kT}{q} \ln\left(\frac{AA^*T^2}{I_0}\right) \quad (3)$$

$$n = \frac{q}{kT} \frac{dV}{d(\ln I)} \quad (4)$$

According to Fig. 2, in both daylight and dark environments, it exhibits good rectifying behavior with soft reverse features. The series resistance effect causes the features to depart from linearity at increased bias. The determined  $I_0$ ,  $\Phi_b$  and  $n$  parameters are illustrated in Table 1. The rectification ratio (RR) for dark and daylight from Fig. 2 is calculated as 1098 and 1652, respectively. The fact that Table 1's  $n$  is more than 1 indicates that the manufactured diode is of non-ideal. Among the possible causes of this are interfacial states, leakage current, and series resistance [14].

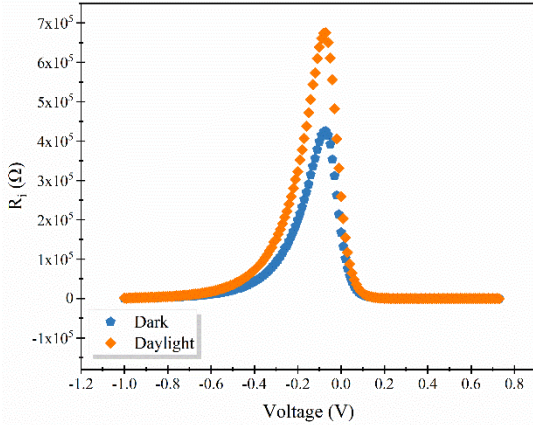


**Figure 2:** Graph of  $\ln I - V$  of the Au/n-GaAs/Au Schottky barrier diode in dark and daylight environments.

**Table 1.** The values of  $I_0$ ,  $\Phi_b$  and  $n$  obtained from  $\ln I - V$  plots of Au/n-GaAs/Au Schottky barrier diode at dark and daylight environments.

	$n$	$I_0$ (A)	$\Phi_b$ (eV)
dark	1.23	$1.24 \times 10^{-7}$	0.672
daylight	1.17	$6.59 \times 10^{-8}$	0.688

As can be seen in Table 1, in daylight, the  $\Phi_b$  value increases and the  $n$  value drops when the diode parameters estimated in the dark are compared to the parameters obtained in the light. It is commonly recognized that at high forward bias voltage, the diode's minimum  $R_i = dV_i/dI_i$  value is represented by the  $R_s$  value, and at high reverse bias voltage, the highest  $R_i$  value is represented by the  $R_{sh}$  value. Fig. 3 depicts the  $R_i-V$  characteristics of the Au/n-GaAs Schottky barrier diode in both daylight and dark environments. The values of  $R_s$  and  $R_{sh}$  for dark and daylight from Fig. 3 are calculated as 1.94-693  $\Omega$  and 1.11-837  $\Omega$ , respectively.



**Figure 3:** Graph of  $R_i-V$  of the Au/n-GaAs Schottky barrier diode in dark and daylight environments.

In this study, the Norde method [15] is the second technique used to calculate diode properties. Using this method barrier height and series resistance values can be calculated as following equations [15]:

$$F(V) = \frac{V}{\gamma} - \frac{kT}{q} \ln\left(\frac{I(V)}{AA^*T^2}\right) \quad (5)$$

$$\Phi_b = F(V_{min}) + \frac{V_{min}}{\gamma} - \frac{kT}{q} \quad (6)$$

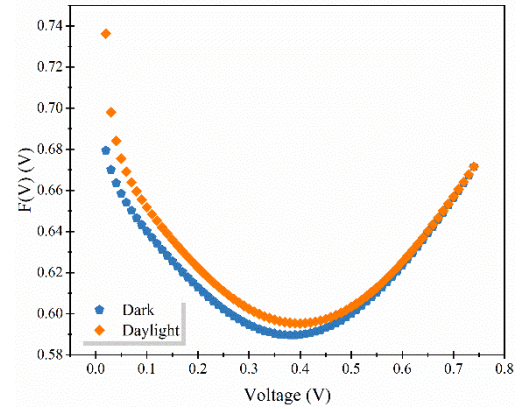
$$R_s = \frac{kT(\gamma-n)}{qI_{min}} \quad (7)$$

where  $I_{min}$  and  $V_{min}$  are the minimum current and voltage and The comparable minimal value of  $F(V)$  is  $F(V_{min})$ .  $\gamma$  is the first integer number greater than  $n$  of Au/n-GaAs Schottky barrier diode.  $F(V) - V$  graphs of the Au/n-GaAs Schottky barrier diode are illustrated in Fig. 4. The diode parameters obtained from this graphs are illustrated in Table 3.

**Table 3.** The values of  $R_s$  and  $\Phi_b$  obtained from Norde plots of Au/n-GaAs/Au Schottky barrier diode.

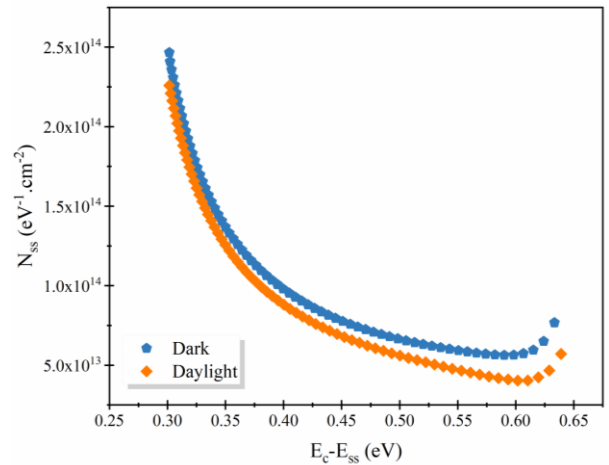
	$F(V_{min})$ (V)	$V_{min}$ (V)	$I_{min}$ (mA)	$\Phi_b$ (eV)	$R_s$ ( $\Omega$ )
dark	0.599	0.40	6.61	0.699	3.02

daylight	0.595	0.40	5.34	0.720	4.03
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**Figure 4:**  $F(V)-V$  plot of the Au/n-GaAs/Au Schottky diode.

The semiconductor surface defects such as structural rearrangements, oxygen vacancies, and doping bonds carried on by metallization, doping concentration atoms, and native or deposited interfacial layer are often the source of the interface state density ( $N_{ss}$ ) at the M/S interface. These states have a significant impact on the produced M/S type Schottky diodes' I-V properties. As a function of  $E_c - E_{ss}$ , the energy dispersion of  $N_{ss}$  obtained from forward bias I-V measurements is displayed in Fig. 5. It is evident that an exponential behavior is observed from the conduction band's bottom edge toward the mid-gap. Donor type dopants are often considered to be dominating.



**Figure 5:**  $N_{ss}-(E_c - E_{ss})$  plot of the Au/n-GaAs/Au Schottky diode.

#### 4. Conclusion

Current-voltage (I-V) characteristics of the fabricated of Au/n-GaAs/Au Schottky barrier diode were measured in dark and daylight environments. Ohm's law, thermionic emission (TE), and the Norde function were used to independently determine some of the sample's fundamental

diode properties, such as  $n$ ,  $\Phi_b$ , and  $R_s$ . The findings were then compared. The series resistance impact was found to be minimal. It was found that the barrier height increased and the ideality factor and interface state density decreased during the daylight. This study reports improved parameters for daylight utilization of Au/n-GaAs/Au Schottky structure for use in electronic applications.

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