

## Extraction of Diode's Electrical Parameters under Forward and Room Temperature Conditions in an InAsSb Based Device

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In semiconductor based components using  $p$ - $n$  junctions, simple heterojunctions or other different semiconducting systems, the current-voltage ( $I$ - $V$ ) characteristic is of great importance since it provides information about the device operation, performances and charge transport processes occurring in the structure of device. From a forward  $I$ - $V$  characteristic, key electrical parameters related to the device operation like series resistance ( $R_s$ ), saturation current ( $I_s$ ) and ideality factor ( $n$ ) can be derived. The extraction of correct values of these three parameters, which remains an open problem, is sometimes difficult and particularly when the device exhibits an important series resistance effect. This effect often causes a non-ideal or non-exponential  $I$ - $V$  behavior of the component. To extract accurate values of  $R_s$ ,  $n$  and  $I_s$  from a room temperature and forward  $I$ - $V$  curve measured on diodes based on the GaAlAsSb( $p$ )/GaAlAsSb( $n$ )/InAsSb( $n$ ) double interface, we used a technique encountered in the literature. This technique consists in using external resistors connected in series to the device during measurements. To derive the value  $R_s$  of the device and then to extract accurate values of  $n$  and  $I_s$ , a simple mathematical approach for the data treatment is adopted. This approach is first applied to simulated  $I$ - $V$  data, then to  $I$ - $V$  characteristics measured on our mesa diodes. The results obtained for both simulated and measured characteristics are compared to those obtained by using other approaches encountered in the literature. According to the values obtained for the electrical parameters of our device, the hole diffusion process from InAsSb towards the barrier GaAlAsSb seems to be responsible for the current flow in our structure. The latter result is in agreement with results published by other authors and which are related to semiconducting system similar to ours.

**Keywords:** InAsSb,  $I$ - $V$  characteristic, Series resistance, Ideality factor, Saturation current, Diffusion process.

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### 1. INTRODUCTION

For a semiconductor based device, the current-voltage ( $I$ - $V$ ) characteristic is very important since it contains information about charge transport processes and performances of the components. Important parameters related to the device operation and which can be derived from this characteristic are the ideality factor ( $n$ ), the saturation current ( $I_s$ ), the shunt resistance ( $R_{sh}$ ) and the series resistance ( $R_s$ ). For example, values of the ideality factor close to 1 or 2 indicate that the current flow is due to minority carrier diffusion or generation-recombination processes, respectively [1, 2]. Excess currents due to bulk or surface defects present in the structure of the device, are generally modeled by a shunt resistance [3]. In ideal junction diodes and under forward polarizations, the semi-logarithmic plot of the current-voltage characteristic is linear. In the real case, the  $\log(I)$ - $V$  plot deviates from linearity due to the series resistance effect. The series resistance, which originates from neutral regions of the junction or non-ohmic contacts [4], makes the extraction of the electrical parameters of the diode quite difficult. Several methods have been proposed to extract the parameters described above from experimental  $I$ - $V$  curves. The well-known conventional method uses the  $\log(I)$  versus  $V$  plot [5]. Some suggested methods use auxiliary or artificial functions deduced by transformations of the Shockley formulation of the  $I$ - $V$  characteristic [5-7]. Other methods

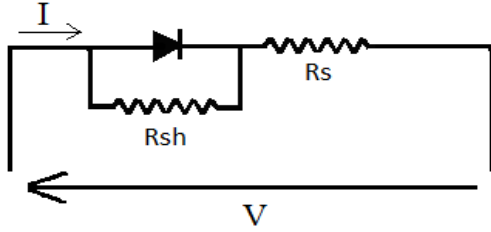
use numerical algorithms to treat the experimental  $I$ - $V$  data [3, 8-10]. More simple techniques are based on the application of derivation [11] or integration [12] procedures to the measured data. These methods do not always give accurate results for  $n$  and  $I_s$ . For example, the classical method needs a large linear part of the  $\log(I)$  versus  $V$  plot for the extraction of accurate values of the ideality factor and the saturation current. This simple technique fails when the device presents leakage or high series resistance. The proposed techniques, which use derivation or integration procedures, suffer from numerical errors and are very sensitive to noise present in measurement and to the step of the applied voltage. In this work, we used the experimental methods proposed by Lyakas et al. [13] and Banwell et al. [14] to extract  $R_s$ ,  $n$  and  $I_s$  of a double junction based device. These methods use external resistances connected in series with the diode when performing the  $I$ - $V$  measurements. For the measured data treatment we use a simple mathematical procedure based on a simple logarithmic transformation of the experimental ( $I$ ,  $V$ ) data. First, the series resistance and the ideality factor are determined at high forward bias. Before extracting the saturation current, the value obtained for  $R_s$  is then used to correct the  $I$ - $V$  curve. Only two measured ( $I$ - $V$ ) data points taken from the  $I$ - $V$  curve at high forward bias and only one resistor connected in series with the diode are needed. The use of external resistor is first described in the beginning of section 2. The method was applied successfully to an experimental current-

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voltage characteristic measured on a mesa diode using the  $\text{GaAl}_{0.4}\text{As}_{0.034}\text{Sb}(p)/\text{GaAl}_{0.4}\text{As}_{0.034}\text{Sb}(n)/\text{InAs}_{0.9}\text{Sb}(n)$  semi-conducting double junction, dedicated for the fabrication of a mid-infrared detector and for room temperature operation [15, 16]. The diffusion transport process could be identified.

## 2. DESCRIPTION OF THE METHOD

The current-voltage ( $I$ - $V$ ) characteristic of a  $p$ - $n$  junction based device is generally described by an exponential expression where the effects of a parasitic series resistance  $R_s$  and a parasitic shunt resistance  $R_{sh}$  are taken into account. At high forward bias,  $R_s$  causes a deviation of the  $\log(I)$ - $V$  curve from the linear behavior. A parallel or shunt resistance  $R_{sh}$  is used to model the excess current which appears at low reverse or forward polarizations. The equivalent circuit corresponding to a real diode can be represented by the figure below.



**Fig. 1** – Equivalent circuit of a real diode with series and shunt resistances

According to the circuit above, the relation between the current and the external applied voltage is given by the well-known empirical formula:

$$I = I_s \left( \exp\left(\frac{q}{nkT}(V - R_s I)\right) - 1 \right) + \frac{(V - R_s I)}{R_{sh}}. \quad (2.1)$$

In equation (2.1),  $I$  is the measured current,  $V$  the measured voltage,  $I_s$  the saturation current and  $n$  the ideality factor.  $q/kT$  represents the thermal voltage. For sufficiently high forward polarizations, the effect of  $R_{sh}$  can be neglected and the  $I$ - $V$  characteristic can be modeled by the following expression:

$$I = I_s \exp\left(\frac{q}{nkT}[V - (R_s + R) I]\right). \quad (2.2)$$

In equation (2.2), if  $R_s$  is the series resistance of the diode, then  $R$  represents the external resistor connected in series to the device [13]. To extract  $R_s$  and  $n$  from the measured data, we used the following procedure.

For a given value of the applied voltage  $V_i$ , in the range where  $R_s$  acts, we consider two values of the measured currents  $I_i$  and  $I_{iR}$ . These currents correspond to the currents without and in the presence of the external resistor, respectively.  $I_i$  and  $I_{iR}$  can be written as:

$$I_i = I_s \exp\left(\frac{q}{nkT}(V_i - R_s I_i)\right), \quad (2.3)$$

$$I_{iR} = I_s \exp\left(\frac{q}{nkT}[V_i - (R_s + R) I_{iR}]\right). \quad (2.4)$$

Dividing equation (2.3) by equation (2.4) and using

a simple logarithmic transformation of this ratio, we obtain the following equation:

$$RI_{iR} = \frac{nkT}{q} \log \frac{I_i}{I_{iR}} + R_s \cdot (I_i - I_{iR}). \quad (2.5)$$

From equation (2.5), a quantity  $\alpha$ , which corresponds to a resistance, can be obtained by dividing equation (2.5) by the difference  $(I_i - I_{iR})$ :

$$\alpha = \frac{RI_{iR}}{I_i - I_{iR}} = \frac{nkT}{q} \cdot \left\{ \frac{\log \frac{I_i}{I_{iR}}}{I_i - I_{iR}} \right\} + R_s. \quad (2.6)$$

Another quantity  $\beta$ , corresponding to a voltage, is obtained by dividing the same equation (2.5) by  $\log(I_i/I_{iR})$ :

$$\beta = \frac{RI_{iR}}{\log \frac{I_i}{I_{iR}}} = R_s \cdot \left\{ \frac{I_i - I_{iR}}{\log \frac{I_i}{I_{iR}}} \right\} + \frac{nkT}{q}. \quad (2.7)$$

It is clear from equations (2.6) and (2.7) that the plot of  $\alpha$  versus  $\log(I_i/I_{iR})/(I_i - I_{iR})$  and the plot of  $\beta$  versus  $(I_i - I_{iR})/\log(I_i/I_{iR})$  should produce straight lines. From the plot of  $\alpha$ , the ideality factor and the series resistance can be extracted from the slope and the intercept of the line with the  $\alpha$  axis, respectively. In the case of plot  $\beta$ ,  $R_s$  corresponds to the slope of the line and the ideality factor is obtained from the intercept of the line with the  $\beta$  axis. Once  $R_s$  is known, the voltage axis can be corrected by subtracting the quantity  $R_s I$  from the measured voltages [13]. For voltages satisfying the condition  $V \gg kT/q$ , the corrected  $\log(I)$  versus  $V$  curve will exhibit a larger linear part. The parameters extracted from the corrected curve by using the conventional technique will be more accurate.

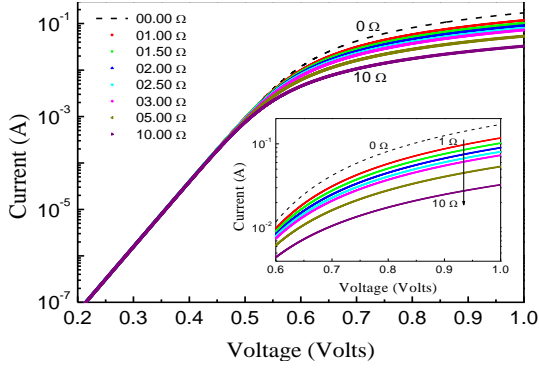
As mentioned in the introduction, the method necessitates only one resistor and two measured ( $I$ ,  $V$ ) data points which can be taken from the  $I$ - $V$  curve at high forward bias, where the series resistances acts. Instead of two data points, some ( $I_i$ ,  $I_{iR}$ ) data can be used and several  $\alpha_i$  and  $\beta_i$  values can be calculated. ( $I_i$ ,  $I_{iR}$ ) data points can be taken at equally spaced voltages  $V_i$ , with a constant voltage step ( $\Delta V$ ). This is what we did for the analysis of a simulated and the measured  $I$ - $V$  characteristics.

Two questions arise. The first one is: how can the external resistor be chosen? The second one is, when using more than two data points, how does the chosen step voltage ( $\Delta V$ ) affect the extracted values of  $R_s$  and  $n$ ? For this, and for both simulated and measured  $I$ - $V$  characteristics; we used different values of  $R$  and several data points for two different voltage steps.

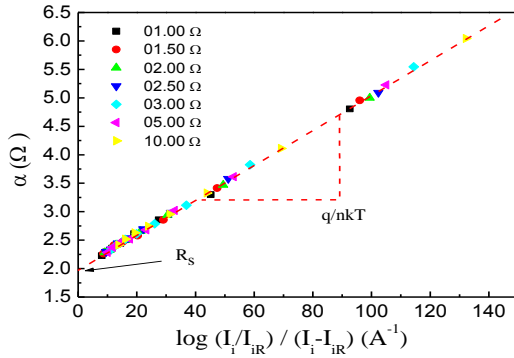
## 3. VALIDATION OF THE MATHEMATICAL DATA TREATMENT

The simple treatment of the data described in section 2 is first applied to a simulated forward  $I$ - $V$  curve, for the sake of validity. Values used for  $I_s$ ,  $n$  and  $R_s$  are  $10^{-10}$  A, 1.2 and  $2 \Omega$ , respectively. For the external resistors, we used values between  $1 \Omega$  and  $10 \Omega$ . The calculated  $I$ - $V$  curves are represented in Fig. 2.

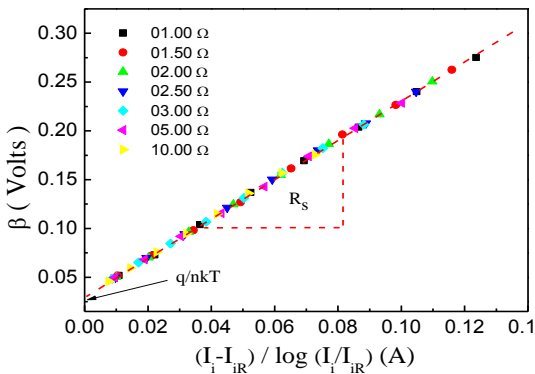
From data of Fig. 2 and for polarizations up to 0.6 V, the results for the two quantities  $\alpha$  and  $\beta$  are perfectly linear. We precise that for simplicity, all data points obtained for the different values of  $R$  are regrouped into one graph; Fig. 3 for the plot  $\alpha$  and Fig. 4 for the plot  $\beta$ . This result confirms the fact that two data points are sufficient for the extraction of  $n$  and  $R_s$ .



**Fig. 2** – Simulated forward  $I$ - $V$  characteristics ( $I_s = 10^{-10}$  A,  $n = 1.2$ ,  $R_s = 2 \Omega$ ) for different values of the external resistor between  $0 \Omega$  and  $10 \Omega$



**Fig. 3** – Plot of  $\alpha$  versus  $\log(I_i/I_{IR})/(I_i - I_{IR})$  extracted from the simulated data of Fig. 2 for values of the external resistance  $R$  between  $1 \Omega$  and  $10 \Omega$



**Fig. 4** – Plot of  $\beta$  versus  $(I_i - I_{IR}) \log(I_i/I_{IR})$  extracted from the simulated data of Fig. 2 for values of the external resistance  $R$  between  $1 \Omega$  and  $10 \Omega$

The values of  $n$  and  $R_s$  extracted separately from plots of  $\alpha$  and  $\beta$  and which correspond to the different values used for  $R$  are given in Table 1. All results are in agreement with values of  $n$  and  $R_s$  used initially for the simulation of the  $I$ - $V$  characteristics. In addition,  $n$  and  $R_s$  do not rely on the value of  $R$ . Good results are obtained for  $R$  smaller, higher or close to  $2 \Omega$ .

**Table 1** – Parameters extracted from Fig. 3 and Fig. 4 for different values of the external resistor

Resistor $R(\Omega)$	Plots of $\alpha$		Plots of $\beta$	
	$n$	$R_s (\Omega)$	$n$	$R_s (\Omega)$
01.0	1.198	2.005	1.192	1.992
01.5	1.186	1.991	1.189	2.012
02.0	1.189	2.014	1.195	2.012
02.5	1.193	2.003	1.193	2.005
03.0	1.198	1.993	1.189	1.995
05.0	1.199	1.996	1.187	2.005
10.0	1.187	2.013	1.196	2.016

To deduce mean values of  $n$  and  $R_s$  as well as errors on these quantities, we used a simple descriptive analysis of the data given in Table 1. The plot  $\alpha$  gives 1.193 and  $2.002 \Omega$  for  $n$  and  $R_s$  with low relative errors of about 0.6 % and 0.9 %, respectively. From plot  $\beta$ , mean values of 1.191 for  $n$  and  $2.005 \Omega$  for  $R_s$  are obtained with errors of about 0.3 % and 0.9 %, respectively.

To examine the effect of the step voltage ( $\Delta V$ ) on the extracted electrical parameters when using multiple ( $I_i$ ,  $I_{IR}$ ) data points, we used two voltage steps. The  $I$ - $V$  characteristics were also analyzed using the methods proposed by Kaminski et al. [12] and the so-called plot A proposed by Werner et al. [11]. These methods use integration and derivation procedures, respectively. In Table 2, the results obtained by these two methods are compared to those obtained by using equations (2.6) and (2.7).

It is clear from Table 2 that  $n$  and  $R_s$  extracted by integration and derivation schemes are close to those obtained by using equations (2.6) and (2.7), particularly for the low voltage step equal to 5 mV.

**Table 2** – Parameters extracted from the simulated  $I$ - $V$  characteristic for two different step voltages

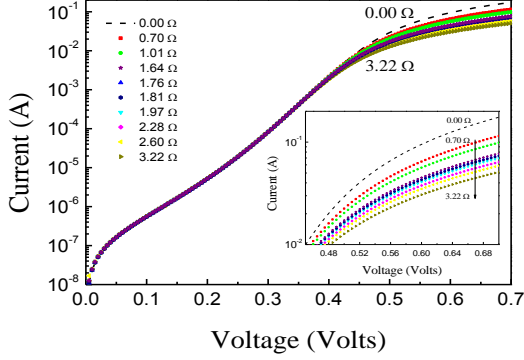
$\Delta V$ (mV)	Parameter	Eqs.(2.6) and (2.7)	Ref. [12]	Ref. [11]
5	$n$	1.19	1.19	1.19
	$R_s (\Omega)$	2.00	2.01	2.01
50	$n$	1.20	1.43	0.99
	$R_s (\Omega)$	2.01	1.89	2.22

#### 4. ANALYSIS OF THE FORWARD $I$ - $V$ CHARACTERISTIC OF A $\text{GaAl}_{0.4}\text{As}_{0.034}\text{Sb}(p)/\text{GaAl}_{0.4}\text{As}_{0.034}\text{Sb}(n)/\text{InAs}_{0.9}\text{Sb}(n)$ BASED DOUBLE JUNCTION

In this section, the room temperature (300 K) forward  $I$ - $V$  characteristic measured on a  $\text{GaAl}_{0.4}\text{As}_{0.034}\text{Sb}(p)/\text{GaAl}_{0.4}\text{As}_{0.034}\text{Sb}(n)/\text{InAs}_{0.9}\text{Sb}(n)$  double junction based mesa diode with a diameter of about  $500 \mu\text{m}$  is analyzed. The structure was fabricated by molecular beam epitaxy on an  $n$ -type (100) oriented GaSb substrate and on a Varian Gen II solid-source machine. Details concerning the epitaxy of the complete structure, dopings and thicknesses of the different layers as well as the mesa device fabrication were reported in Refs. [15, 16].

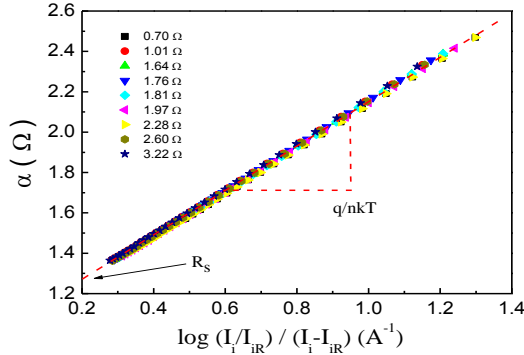
The structure is characterized by a strong energy band offset ( $\Delta E_c$ ) in the conduction band and a low energy band offset ( $\Delta E_v$ ) in the valence band [16]. In this structure, the charge flow and transport processes are governed by the  $\Delta E_c$  and  $\Delta E_v$  at the  $\text{GaAlAsSb}(n)/$

InAsSb(*n*) interface. The charge transport mechanism is mainly due to minority carriers (holes) diffusion from the quaternary layer. The room temperature forward *I-V* characteristics measured on the mesa device with and without external resistors between 0.7 Ω and 3.22 Ω are represented in Fig. 5.



**Fig. 5** – Semi-logarithmic plots of the forward *I-V* characteristic measured on a GaAl<sub>0.4</sub>As<sub>0.034</sub>Sb(*p*)/GaAl<sub>0.4</sub>As<sub>0.034</sub>Sb(*n*)/InAs<sub>0.9</sub>Sb(*n*) based mesa diode at 300 K

The curves above exhibit three regions. At low polarizations below 150 mV, the currents, which are relatively important, are generally attributed to leakage or recombination process in the depletion region of the InAsSb layer. The second region, in the narrow voltage range between 250 mV and 400 mV is perfectly linear and corresponds to an exponential behavior of the current. The last parts of the curves are non-exponential and the deviation from linearity is due to the resistances connected in series to the device. When no resistance (*R*) is connected to the sample, the characteristic deviates from linearity for an applied voltage around 450 mV. This voltage limit is lowered and the deviation appears earlier, around 400 mV for *R* equal to 3.22 Ω. The results for plots of  $\alpha$  and  $\beta$ , corresponding to data of Fig. 5, are given in Fig. 6 and Fig. 7, respectively.

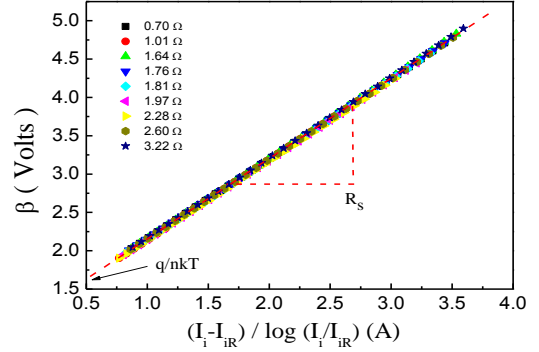


**Fig. 6** – Plot of  $\alpha$  versus  $\log(I/I_{IR})/(I - I_{IR})$  extracted from the measured data of Fig. 5 for values of the external resistance *R* between 0.7 Ω and 3.22 Ω

As predicted by equations (2.6) and (2.7), the plots  $\alpha = f(\log(I/I_{IR})/(I - I_{IR}))$  and  $\beta = f((I - I_{IR})/\log(I/I_{IR}))$  are perfectly linear, for all external resistors used. The values of *n* and *R<sub>s</sub>* extracted from these two plots are regrouped in Table 3.

From data of Table 3 and by the same descriptive analysis (section 3), the experimental mean values of *n*

and *R<sub>s</sub>* obtained from plot  $\alpha$  are 1.09 and 1.05, respectively. The relative error is around 0.2 % for both parameters. The same results with the same relative error are obtained from plot  $\beta$ . Our extracted parameters are also compared to those obtained by the two other techniques in Table 4. Series resistance and ideality factor extracted by using equations (2.6) and (2.7) are the same for the two chosen step voltages and the results are in good agreement with those obtained by using the other methods for the step voltage of about 5 mV.



**Fig. 7** – Plot of  $\beta$  versus  $(I - I_{IR})/\log(I/I_{IR})$  extracted from the measured data of Fig. 5 for values of the external resistance *R* between 0.7 Ω and 3.22 Ω

**Table 3** – Parameters extracted from Fig. 6 and Fig. 7 for the different values of the external resistor

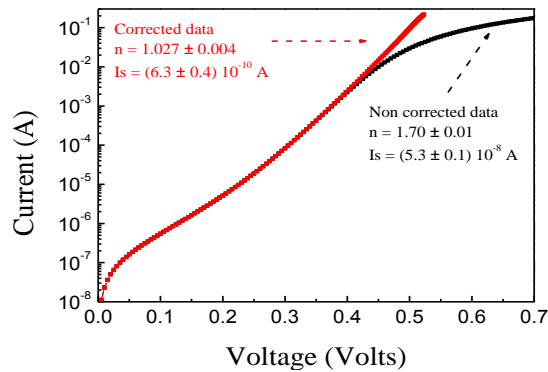
Resistor <i>R</i> (Ω)	Plots of $\alpha$		Plots of $\beta$	
	<i>n</i>	<i>R<sub>s</sub></i> (Ω)	<i>n</i>	<i>R<sub>s</sub></i> (Ω)
0.70	1.089	1.051	1.089	1.049
1.01	1.091	1.045	1.088	1.048
1.64	1.092	1.052	1.092	1.052
1.76	1.088	1.048	1.091	1.051
1.81	1.090	1.047	1.091	1.049
1.97	1.089	1.052	1.089	1.048
2.28	1.092	1.049	1.091	1.048
2.60	1.091	1.051	1.088	1.051
3.22	1.091	1.049	1.091	1.051

**Table 4** – Parameters extracted by using Eqs. (2.6) and (2.7) and by the methods proposed by Kaminski et al. [12] and Werner et al. [11]

$\Delta V$ (mV)	Parameter	Eqs. (2.6) and (2.7)	Ref. [12]	Ref. [11]
5	<i>n</i>	1.09	1.13	1.08
	<i>R<sub>s</sub></i> (Ω)	1.05	1.04	1.03
50	<i>n</i>	1.09	1.87	0.88
	<i>R<sub>s</sub></i> (Ω)	1.05	0.98	1.44

The value of 1.05 Ω for *R<sub>s</sub>* was used to correct the measured *I-V* characteristic. The corrected and non-corrected curves are given in Fig. 8.

The fit of the linear part of the non-corrected curve gives 1.7 for *n* and 53 nA for *I<sub>s</sub>*. These results are different from those obtained when fitting the larger linear portion of the corrected curve. Indeed, the saturation current *I<sub>s</sub>* equal to 0.63 nA is nearly about two orders of magnitude lower. The value of *n*, equal to 1.027, is very close to that obtained by using both plots  $\alpha$  and  $\beta$ .



**Fig. 8** – Corrected and non-corrected forward  $I$ - $V$  characteristics of the GaAlAsSb(p)/GaAlAsSb(n)/InAsSb(n) based mesa diode at 300 K

As far as we know, few results related to the analysis of the current-voltage behavior under direct polarizations and for devices using the InAsSb material have been reported. For a photovoltaic component using the InAs<sub>0.91</sub>Sb<sub>0.91</sub> alloy as an active material and the In<sub>0.88</sub>Al<sub>0.12</sub>As<sub>0.80</sub>Sb<sub>0.20</sub> quaternary alloy as a barrier, a value of the ideality factor equal to 1.32 has been reported [17]. This value extracted from the forward  $I$ - $V$  characteristic at room temperature (300 K) and which is in a reasonable agreement with our result was attributed to the diffusion transport process [17]. In the case of a photovoltaic detector using the same active InAs<sub>0.91</sub>Sb<sub>0.91</sub> material and the Al<sub>0.15</sub>In<sub>0.95</sub>As<sub>0.9</sub>Sb<sub>0.1</sub> alloy as a barrier, an ideality factor of 1.2 has been extracted from direct  $I$ - $V$  measurements at 291 K [18]. The authors' conclusion was that the current flow in their device is due to diffusion of holes from the active layer through the barrier at near room temperature. Another value of  $n$ , in agreement with our result and equal to 1.03, has been extracted from direct  $I$ - $V$  characteristic measured on an InAs/InAs<sub>0.7</sub>Sb<sub>0.1</sub>P<sub>0.2</sub> heterojunction based photodiode [19]. This result corresponding to a temperature range between 230 K and 340 K was also explained by the diffusion mechanism.

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## 5. CONCLUSIONS

The analysis of room temperature (300 K) and forward current-voltage ( $I$ - $V$ ) characteristic measured on the GaAl<sub>0.4</sub>As<sub>0.034</sub>Sb(p)/GaAl<sub>0.4</sub>As<sub>0.034</sub>Sb(n)/InAs<sub>0.9</sub>Sb(n) double junction based mesa diode is presented. The objective was to extract the electrical parameters of the diode, which relate to the device operation, performances as well as charge transport process occurring in such semiconductor system. These electrical parameters are the series resistance ( $R_s$ ), the ideality factor ( $n$ ) and the saturation current ( $I_s$ ). To extract these quantities from our forward  $I$ - $V$  curves, we used a method encountered in the literature. In this technique and as a first step,  $I$ - $V$  measurements are performed by connecting external resistors ( $R$ ) in series with the device. This allows the extraction of the real series resistance of the device and a first value of the ideality factor of a diode. For our device,  $R_s$  was found around 1.05  $\Omega$  and  $n$  is close to 1.1. As a second step, the value of  $R_s$  was used to correct the  $I$ - $V$  data measured without  $R$  and values of  $n$  and  $I_s$  were extracted from the corrected  $I$ - $V$  curve by using the standard  $\log(I)$ - $V$  plot. To compare and from the non-corrected  $I$ - $V$  curve, the results obtained for  $n$  and  $I_s$  were 1.70  $\pm$  0.01 and 53.0  $\pm$  0.1 nA, respectively. From the corrected  $I$ - $V$  data, the final value obtained for  $n$  was 1.027  $\pm$  0.004, and for the saturation current the value extracted was 0.63  $\pm$  0.04 nA which is nearly two orders of magnitude lower than the initial value. Our measured curve was also treated by using techniques where the mathematical treatment of the measured data is based on integration and derivation schemes. The results obtained are in good agreement with ours when the used  $I$ - $V$  data were taken with a low voltage step. For the GaAlAsSb(p)/GaAlAsSb(n)/InAsSb(n) semiconductor system with InAsSb as an active material and GaAlAsSb as a barrier, the extracted values for  $n$  and  $I_s$  at room temperature (300 K) suggest a minority carrier transport mechanism. This means the diffusion of holes from InAsSb towards the barrier. Such a process has been identified by other authors for other InAsSb based systems like InAs<sub>0.91</sub>Sb<sub>0.91</sub>In<sub>0.88</sub>/Al<sub>0.12</sub>As<sub>0.80</sub>Sb<sub>0.20</sub> and InAs<sub>0.91</sub>Sb<sub>0.91</sub>/Al<sub>0.15</sub>In<sub>0.95</sub>As<sub>0.9</sub>Sb<sub>0.1</sub>. Similar conclusions were made for InAs/In-As<sub>0.7</sub>Sb<sub>0.1</sub>P<sub>0.2</sub> heterojunction.

## Отримання електричних параметрів діода в умовах кімнатної температури в пристрої на основі InAsSb

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У компонентах на основі напівпровідників з використанням  $p$ - $n$ -переходів, простих гетеро-переходів або в інших різних напівпровідникових системах велике значення має вольт-амперна характеристика ( $I$ - $V$ ), оскільки вона надає інформацію про роботу пристрою, характеристики і процеси перенесення заряду, що відбуваються в структурі пристрою. З прямої  $I$ - $V$  характеристики можна отримати ключові електричні параметри, пов'язані з роботою пристрою, наприклад, послідовний опір ( $R_s$ ), струм насичення ( $I_s$ ) і коефіцієнт ідеальності ( $n$ ). Отримання правильних значень цих трьох параметрів, що залишається відкритою проблемою, іноді є складним завданням, особливо коли пристрій демонструє важливий вплив послідовного опору. Цей ефект часто викликає неідеальну або неекспоненційну  $I$ - $V$  поведінку компоненти. Для отримання точних значень  $R_s$ ,  $n$  і  $I_s$  за умови кімнатної температури і прямої  $I$ - $V$  характеристики, виміряної на діодах на основі подвійної межі поділу GaAlAsSb( $p$ )/GaAlAsSb( $n$ )/InAsSb( $n$ ), ми застосовували метод, який полягає у використанні зовнішніх резисторів, з'єднаних послідовно з пристроєм під час вимірювань. Для отримання величини  $R_s$  пристрою, а потім для знаходження точних значень  $n$  і  $I_s$  був використаний простий математичний підхід для обробки даних. Цей підхід вперше застосовується до модельованих  $I$ - $V$  даних, а потім до  $I$ - $V$  характеристик, виміряних на наших мезо-діодах. Результати, отримані як для модельованих, так і для виміряних характеристик, порівнюються з результатами, отриманими при використанні інших підходів, що зустрічаються в літературі. Відповідно до значень, отриманих для електричних параметрів нашого пристрою, процес дифузії дірок від InAsSb до бар'єру GaAlAsSb, здається, відповідає за електричний потік у нашій структурі. Останній результат узгоджується з результатами, опублікованими іншими авторами і пов'язаними з подібною до нашої напівпровідниковою системою.

**Ключові слова:** InAsSb,  $I$ - $V$  характеристика, Послідовний опір, Коефіцієнт ідеальності, Струм насичення, Процес дифузії.