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Annealing effect on I-V and C-V characteristics of Al/n-InP Schottky diodes at low temperatures

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ABSTRACT

In this study, Schottky contacts have been fabricated on n-InP (100) using an Al/n-InP/In configuration. The current voltage (I-V) and capacitance voltage (C-V) characteristics of Al/n-InP/In Schottky diodes were calculated from the liquid nitrogen temperature to the room temperature by steps of 10 K before annealing of this structure and after annealing at 400 °C for 3 min. The series resistance, ideality factor and barrier height values calculated using I-V characteristics, Cheung functions, Norde (F-V) functions, and C-V characteristics before and after annealing the contact and compared for each temperature. These measurements clearly showed that the Al/n-InP/In Schottky diode became extremely stable due to the annealing process and the mean barrier height value have been increased from 0,494 to 0,674 eV after thermal annealing at 400 °C. In addition, temperature dependent barrier height values of as-fab. and annealed (at 400 °C) Al/n-InP/InSchottky contacts are consistent with "the barrier inhomogeneous model" of Schottky diodes.
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1. Introduction

Schottky contacts are important for electronic circuit technology and increasing demand in the microelectronics industry for suitable optoelectronic and fast-switching devices has generated much interest in III-V semiconductors such as indium phosphide [1,2]. However, serious drawbacks of InP are the low Schottky-barrier height of metal contacts and the difficulty in surface quality control. This result in the degradation of the device performance and it is an important research area in InP device development [1,2]. Exposure of the semiconductor surface to different processes is experimentally found to cause the change of Shottky barrier height. One of these processes is the thermal annealing of the metal/semiconductor contact. Annealing tends to bring the system to thermal stability and leads to a more stable structure. Various works has been done to reduce the aforementioned disadvantage of InP in many previous studies. For example, Çakıcı et al. [3] studied the effects of thermal annealing on the electrical characteristics of Au/n–InP/In diode at temperatures 100 and 200 °C for 3 min in N_2 atmosphere and to observe the effect of the thermal annealing. They calculated the characteristic parameters such as leakage current, barrier height and ideality factor of this diode from the forward bias I-V and reverse bias C-V characteristics as a function of annealing temperature. Also they investigate that the rectifying ratio weakly increases for 100 °C annealing temperature but the rectifying ratio quite strongly increases for 200 °C annealing temperature. And they figured out that after thermal annealing the rectifying ratio increased thus the rectifying properties of the diode improved.

The electrical, structural and surface morphological properties of Yb/p-InP Schottky barrier diode (SBD) were investigated by Reddy et al. [4] at different annealing temperatures. They calculated the determined SBH of as-deposited Yb/p-InP SBD is 0,68 eV (I-V) and 0,81 eV (C-V). A maximum SBH is obtained on the Yb/p-InP SBD after annealing at 300 °C and the barrier heights values found to be 0,72 eV (I-V) and 0,88 eV (C-V) for this annealing structure and they indicated that the optimum annealing temperature for Yb/p-InP SBD is 300 °C. Orak et al. [5] fabricated the Co/n-GaP nano-Schottky diodes by DC Magnetron sputtering technique to investigate effect of annealing temperature on the characteristics of the Co metallic contact. The room temperature current–voltage (I-V) measurements showed that the ideality

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factor and series resistance decrease with the increasing annealing temperature. Thermal annealing effects on I-V-T characteristics of Cr/n-GaAs diodes are worked by Korkut et al. [6] at 200 and 400 °C annealing temperatures. The effect of thermal annealing on the temperature-dependent I-V characteristics of the diodes experimentally investigated and the ideality factor and barrier height values for 400 °C annealed diode approximately remain unchanged from 120 to 320 K, and those of the as-deposited sample from 160 to 320 K. The departures from ideality at low temperatures ascribed to the lateral fluctuations of the barrier height. The barrier height values for the as-deposited and 400 °C annealed diodes were obtained 0,61 and 0,74 eV at room temperature, respectively. In addition, T_0 anomaly values calculated as 15,52, 10,68 and 5,35 for the as-deposited and 200 and 400 °C annealed Cr/n-GaAs Schottky diodes from the nT-T graphs. And they observed that the interface structure and quality improved by the thermal annealing at 400 °C.

Experimental results, especially only at room temperature, do not give detailed information about the nature of barrier formation and the conduction mechanisms of the InP Schottky diodes. Therefore, the current–voltage (I-V) and the capacitance- voltage (C-V) characteristics of the Al/n-InP Schottky diodes have been studied as a function of temperature in the temperature range of 10 K-300 K, before and after annealing the diode at 400 °C. Since, the temperature dependence of the I-V and C-V characteristics allows us to understand different aspect of conduction mechanism. The aim of the present work is to analyze the effect of post annealing on the electrical parameters of Al/n-InP/In Schottky barrier diode such as barrier height, ideality factor and series resistance estimated from I to V, C-V, Cheung's and Norde's methods at low temperatures (10–300 K). We have calculated and discussed the electrical characteristics with and without annealing the contact at 400 °C.

2. Experimental procedure

The Schottky barrier diodes (SBDs) were prepared using n-type InP (100) wafer. The wafer was degreased consecutively in trichloroethylene, acetone, and methanol for 3 min. The degreased wafer was etched with H_2SO_4:H_2O_2:H_2O (5:1:1) for 1 min to remove the surface damages and undesirable impurities. The ohmic contact was made by evaporating In and annealing at 300 °C in N_2 atmosphere for 3 min. The Schottky contacts were formed on the other side of the semiconductor as 1,0 mm diameter dots by evaporation of Al, (diode area = 7,85 × 10^{-3} cm^2). All evaporation processes were carried out in a vacuum coating unit at about 10^{-6} mbar. The I-V characteristics of the devices were measured in the temperature range of 10–300 K using a temperature controlled ARS Closed Cycle 4 K He cryostat. Keithley 6514 electrometer and 2400 sourcemeter used for I-V measurements. The capacitance–voltage (C-V) characteristics of the Al/n type InP Schottky diodes have been measured between 300 and 10 K with 10 K steps at 1 MHz frequency by using Keithley 2400 sourcemeter and Boonton 72B capacitance meter used for C-V measurements. To analyze the effect of post annealing, the diodes have been annealed at 400 °C for three minutes in flowing N_2 and the I-V and C-V measurements against investigated. Depending on annealing temperature, the electrical performance of characteristic parameters of Al/n type InP Schottky diode has been experimentally examined.

3. Results and discussion

The current–voltage (I-V) and capacitance–voltage (C-V) characteristics of Al/n-InP/In Schottky diodes are measured between 300 and 10 K temperature range, before and after annealing the diode 400 °C. The temperature dependent semi log current–voltage (I-V) plots of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes are given in Fig. 1. The thermionic emission theory (TE) expresses the current in Schottky barrier diodes as Equation [1].

$$I = I_o \exp\left(\frac{qV}{nkT}\right)\left[1 - \exp\left(-\frac{qV}{kT}\right)\right] \quad (1)$$

$$I_o = A\ A^*\ T^2\ \exp\left(-\frac{q\Phi_b}{kT}\right) \quad (2)$$

is the saturation current derived from lnI-V plot, k is the Boltzmann constant, A* is the Richardson constant and 9,8 $Acm^{-2}\ K^{-2}$ for n-type InP [2],

$$n = \frac{q}{kT}\left(\frac{dV}{d\ln I}\right) \quad (3)$$

As shown in Fig. 1, the forward-voltage is linear across a wide range of lnI-V curves, but it deviates from linearity due to series resistance and interface layer effect at high voltages. Again from these graphs, I-V curves seem to be shifting towards higher voltages as the temperature drops. This behavior demonstrates that

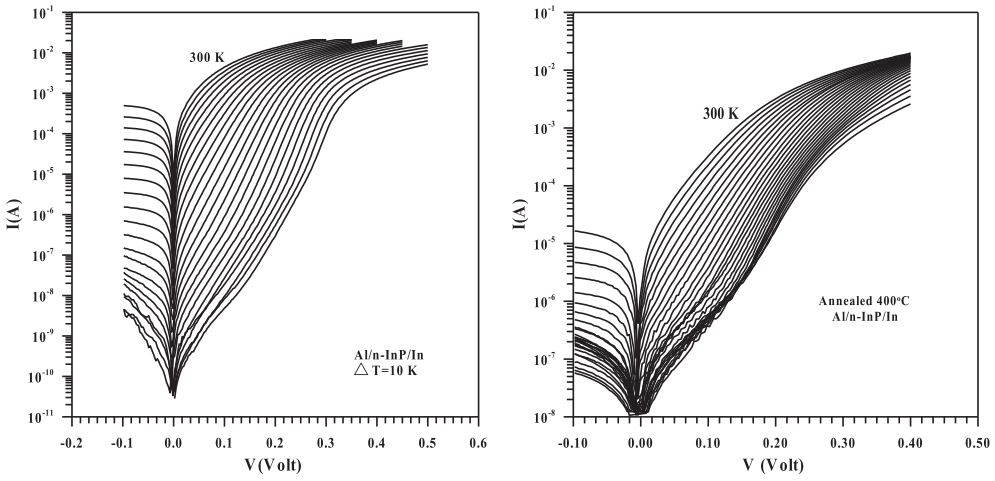


Fig. 1. The temperature dependent semi log current–voltage (I-V) plots of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes.

the current conduction of the Schottky diode structure is supported by the theory of thermionic emission (TE) in accordance with Equation (1).

Ideality factor is one of the characteristic parameter of Schottky diodes which shows the ideality of the diode. The ideality factors obtained from the slopes of the linear region of the lnI-V curves were calculated as 1,01 (300 K) and 9,42 (10 K) for as-fab. Al /n-InP and 1,04 (300 K) and 13,52 (10 K) for annealed at 400 °C Al/n-InP diodes. At room temperature both diodes are ideal and after annealing the ideality of the diode increased. Both graphs show that the ideality factor increases with decreasing temperature. This abnormal increase behavior in the ideality factor observed especially at low temperatures can be regarded as a deviation behavior from the classical TE theory which is valid in both diode structures. This apparent increase in the ideality factor at low temperatures can be due to some factors such as the diversity of the interface charges, the inhomogeneity of the interface layer and the barrier height. In addition, I_o values obtained from these graphs are used in Equation (2) and the barrier heights found to be 0,410 eV (300 K), 0,038 eV (10 K) and 0,479 eV (300 K), 0,056 (10 K) for as-fabricated and annealed at 400 °C Al/n-InP diodes, respectively (Table 1). Fig. 2 shows the barrier heights obtained from the the I-V curves for as-fabricated and annealed at 400 °C Al/n-InP diodes between 300 and 10 K temperature range. According to these values, there is an inverse relationship between the experimental effective barrier heights and the ideality factors of the diodes. That is, as the ideality factors increase, the barrier heights decrease. This relationship can be explained by the spatial inhomogeneity of the barrier height of Schottky diodes [7,8].

Effective barrier height can be calculated with the help of conventional Richardson curves or, alternatively, activation energy curves. Accordingly, the current in Equation (2) can be edited and rewritten as:

$$\ln\left(\frac{I_0}{T^2}\right) = \ln(AA^*) - \frac{e\Phi_b}{kT} \tag{4}$$

According to Equation (4), the change of ln (I_0/T^2)-1/kT or 1/nkT should be linear and from these equations, if graphs ofln (I_0/T^2)/-1/kT or 1/nkT are plotted, zero bias barrier height and Richardson constant can be calculated from these graphs. The deviation in the Richardson curves may be due to the presence of spatial barrier heights, that is, the potential fluctuations at the interface due to the fact that high and low barrier areas are present [9]. Similarly, the lateral distribution of the barrier height may be due to the local increase in the electric field causing the local elevation of the barrier height [10].

For the as-fabricated and annealed Al/n-InP/In Schottky diodes, the ln (I_0/T^2)-1/kT or 1/nKT curve is given in Fig. 3.a and b. The barrier height values for the as-fabricated and annealed Al/n-InP/In structures were calculated as 0,340 eV and 0,426 eV, respectively, from the slopes of the ln(I_0/T^2)-1/nkT activation energy graphs in Fig. 3. At the same time, the Richardson constant (A*) values were calculated from the cut-off points of the fit line as 6,67 $Acm^{-2}K^{-2}$ and 6,64 $Acm^{-2}K^{-2}$, respectively. The calculated Richardson constant values are closer to the known theoretical Richardson constant value (≈ 9.8 $Acm^{-2}K^{-2}$) for n type InP. In conclusion, the current passing through the diodes will prefer to flow from these low impedances at low temperatures, which will lead to an increase in current and hence an increase in the ideality factor. And it is determined that the effective barrier height value increased when the Al/n-InP/In structure is annealed.

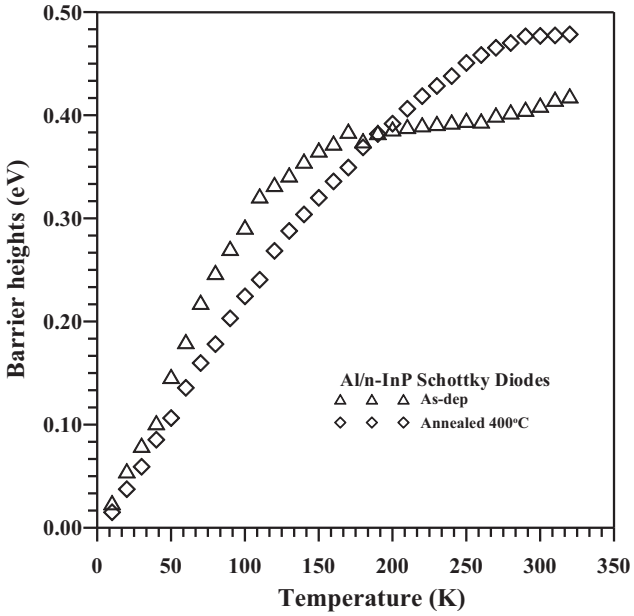


Fig. 2. The barrier heights obtained from the I-V curves for as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes between 300 and 10 K temperature ranges.

The formation mechanism of Schottky barrier height (SBH) in metal-semiconductors is still not fully understood despite years of intense work. The presence of inhomogeneities at the Schottky barrier heights leads to significant explanations for many of the anomalies in experimental results. These results suggest that the Schottky barrier formation mechanism is not homogeneous or uniform locally at the metal–semiconductor interface. Especially at low temperatures the decrease in barrier height and the increase in the ideality factor are probably due to inhomogeneous barrier height. It is known that one of the models explaining deviations from the ideal situation in Schottky diodes is the "model of barrier inhomogeneity". Behaviors in this situation can be explained using Gaussian distribution. In Gaussian distribution for a Schottky diode, the parameters of mean barrier height and standard deviation are linearly dependent on the supply voltage.

In Fig. 4, the experimental barrier heights versus 1/2kT graphs are used to show a Gaussian distribution (GD) of barrier heights. This graph gives a linear line. The y-axis intercept of this linear line

Table 1
The temperature dependent barrier height values of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes.

Methods	I-V		Cheung		C-V		F-V	
T (K)	As-dep	400 °C	As-dep	400 °C	As-dep	400 °C	As-dep	400 °C
300	0.410	0.479	0.436	0.509	0.383	0.790	0.397	0.512
250	0.395	0.451	0.426	0.441	0.356	0.738	0.395	0.473
200	0.387	0.392	0.414	0.344	0.344	0.697	0.393	0.438
150	0.367	0.320	0.385	0.333	0.278	0.677	0.394	0.383
100	0.291	0.224	0.320	0.235	0.239	0.626	0.233	0.207
50	0.147	0.107	0.161	0.112	0.201	0.583	0.241	0.298
10	0.038	0.056	0.267	0.039	0.177	0.331	0.208	0.225

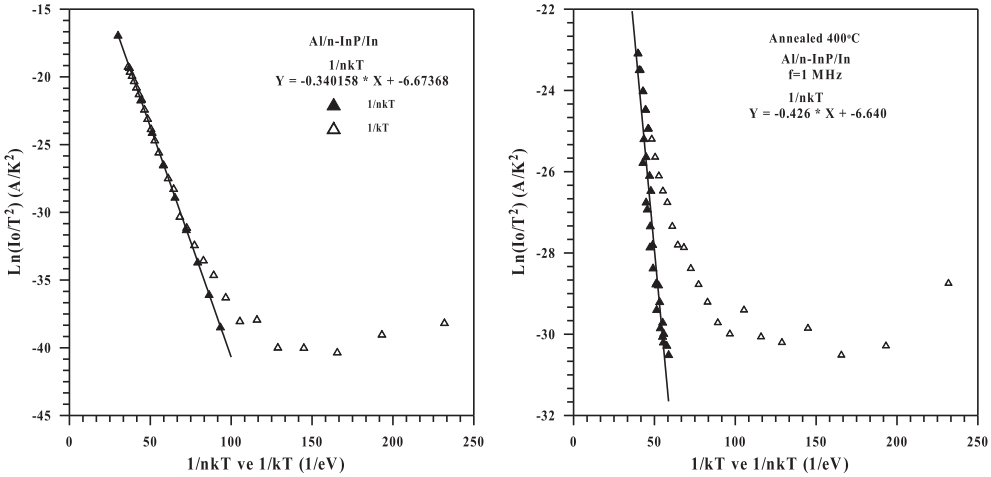


Fig. 3. The Richardson plots of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes.

shows zero bias mean barrier height and the standard deviation is found from the slope of the line [11]. The mean barrier heights are found to be 0,494 eV and 0,674 eV respectively by means of linear fit on graph 4 for the as-fabricated and annealed Al/n-InP/In Schottky diodes (Table 1). The standard deviations are also determined as σ1 = −11,392 eV, σ2 = −0,011 eV (Fig. 4). Already the Al/n-InP/In Schottky diode have a high diode quality before annealing, it has shown better improvement after annealing as expected. The mean barrier height value shows a great increase after annealing and this indicates that annealing improves the homogeneity of the interface structure or the homogeneity of the barrier height. Other calculations and evaluations are also compatible with this result.

Today, many methods have been developed to determine some characteristic parameters of metal–semiconductor structures. In our study, we used the method developed by Cheung [12] to determine barrier height. In this method, the dV/dln(I)-I and H(I)-I functions derived from I to V characteristics are used. From these graphs, the fundamental factors of the diode such as the ideality factor, the barrier height and the series resistance values are calculated. Using the fundamental current equation given by Eq. (1),

$$\frac{dV}{d(\ln I)} = \frac{nkT}{e} + IR_s \tag{5}$$

$$H(I) = n\Phi b + IRs \tag{6}$$

Cheung functions can be obtained. The dV/d(lnI)-I graph of the Cheung functions should be linear and the slope of this graph gives the series resistance and the value of ideality factor can be obtained from y-axis intercept. The ideality factors calculated from the dV/d(lnI)-I graph are 1,04 (300 K)-9,16 (10 K) and 1,04 (300 K)-13,60 (10 K) for as-fab.and annealed at 400 °C Al/n-InP/In Schottky diodes, respectively. In addition, the series resistances are in the range between values 7,37 Ω (300 K) −711,81 Ω (10 K) for the as-fab. Al/n-InP/In Schottky diode and between 4,27 Ω (300 K) to 90,75 Ω (10 K) for annealed at 400 °C Al/n-InP/In Schottky diode. The graph of the H(I) against I given in Equation 6 should be linear and by using the ideality factor values obtained from Equation (5), the barrier height values of the diodes can be obtained from the y-axis intercept and the series resistance values from the slope of H (I)-I graphs. For the as-fab. and annealed at 400 °C Al/n-InP/In Schottky diodes, the series resistance obtained from the H(I)-I graphs is changed from 7,88 Ω (300 K) to 713,30 Ω (10 K) and from 4,28 Ω (300 K) to 91,89 Ω (10 K) respectively. The series resistance values obtained from the dV/d(lnI)-I and H(I)-I graphs are close to each other. The barrier heights changed from 0,436 eV (300 K) and 0,267 eV (10 K) for as-fab. Al/n-InP/In Schottky diode while 0,509 eV (300 K) and 0,039 eV (10 K) for annealed diode (Table 1). The series resistance values obtained from the dV/d(lnI)-I and H(I)-I graphs are almost the same for both diodes at all temperatures. As given at Table 1, the barrier height values of the Al/n-InP/In structure obtained from Cheung functions increased by annealing

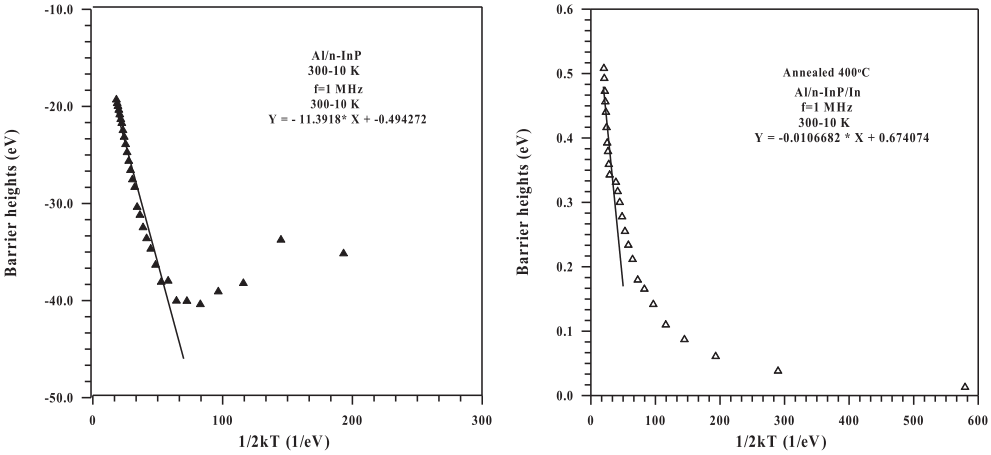


Fig. 4. Barrier heights versus 1/2kT plots and their linear fits for as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes according to Gaussian distribution of the barrier heights.

process especially at high temperatures. Another method used for calculating the diode parameters is Norde method [13]. Using the modified Norde functions, the series resistance and barrier height values can be calculated by Equations (7), 8 and 9 for both structures [14].

$$F(V) = \frac{V}{\gamma} - \frac{kT}{q}\ln\left(\frac{I(V)}{AA^{*}T^{2}}\right) \tag{7}$$

where γ is dimensionless and its value is bigger than n.

$$\phi_b = F(V_0) + \frac{V_0}{\gamma} - \frac{kT}{q} \tag{8}$$

Here $F(V_0)$ is the minimum value of F(V) and the series resistance is given by

$$R_s = \left(\frac{kT(\gamma - n)}{qI_0}\right) \tag{9}$$

Fig. 5 shows the Norde function F(V) against V plots of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes. The values of Schottky barrier heights of the as-fab. Al/n-InP/In Schottky diode changes between 0,397 eV (300 K)-0,208 eV (10 K) and 0,512 eV (300 K)-0,241 eV (10 K) for annealed Al/n-InP/In Schottky diode (Table 1). Also the series resistance values are calculated as 14,70 Ω (300 K)-428,82 Ω (10 K) for as fab. Al/n-InP/In Schottky diode and 7,36 Ω (300 K)-105,70 Ω (10 K) for annealed Al/n-InP/In Schottky diode. These barrier height and series resistance values are agree with those calculated from Cheung functions and lnI-V methods [15]. According to these results, Norde and Cheung functions were found to be quite good methods to find barrier height and series resistance. It has been found in the literature [16] that the Cheung function is applied to the nonlinear region (high voltage region) of the forward-bias lnI-V graph and the Norde function to the whole region of the forward-bias lnI-V graph. In addition, the ideality factor and barrier height values obtained from the thermionic emission theory depends on the annealing process.

As can be clearly seen from these values, the oxide layer and undesirable impurities in the metal semiconductor interface which cause series resistance in the diode are removed depending on the annealing process and the series resistance of the diode Al/n-InP/In Schottky is considerably reduced. Thus, the annealing effect has brought a highly desirable effect on diode stability.

The capacitance of the space charge region in Schottky diodes gives important information about the formation of the metal–semiconductor interface. From reverse bias of capacitance- voltage (C-V) plots, characteristic parameters of Schottky rectifiers such as barrier height, carrier concentration, diffusion potential and Fermi energy level can be calculated [17]. The C-V measurements for as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes were carried out at 1 MHz frequency, from −1 V to 0 V, in the temperature range 10 K-300 K by 10 K steps. Fig. 6 shows the C-V change (300 K, 200 K, 100 K, 60 K) of the reverse bias at 1 MHz for the four different temperatures of the as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes. Fig. 6 reveals that as the reverse bias voltage increases, the capacitance rapidly decreases. This can be attributed to the increase of the depletion layer by increasing reverse bias voltage and to the reduction of the displacement capacity by Equation (10). Fig. 7 shows the $1/C^2$-V variation (300 K, 200 K, 100 K, 60 K) obtained by using the reverse bias C-V graphs for the four different temperatures of the as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes. It can be seen from the $1/C^2$-V graphs that the application voltage decreases while $1/C^2$ decreases for the reverse bias region.

The C-V measurements are evaluated by arranging Equation (10) for the diode capacitance as given below.

$$C = A\left(\frac{\varepsilon_s\varepsilon_0 eN_d}{2}\right)^{\frac{1}{2}}\left(V_d - \frac{kT}{e}\right)^{\frac{1}{2}} \tag{10}$$

where εs is the dielectric constant of the semiconductor (ε_s = 12,4 for InP), $\varepsilon_0 = 8{,}85\text{x}10^{-14}$F/m of the dielectric constant of the cavity, e, electron charge, V_d, diffusion potential, k = $8{,}625\text{x}10^{-5}$ eV/K (Boltzman constant), N_d is the ionized donor concentration and T is the temperature in Kelvin. The C^{-2}-V plot has linear curves when obtained using equation (11).

$$C^{-2} = \frac{2(V_d + V)}{\varepsilon_s\varepsilon_0 eA^2N_d} \tag{11}$$

where V is the applied voltage and A is the area of the contact. With the appropriate linear fit to C^{-2}-V when the C^{-2} = 0, V_d is equal to $V_d = -V$. Thus diffusion potential is obtained. Using these graphs, diffusion potentials at different temperatures were calculated for as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes. The slope of the linear part of the C^{-2}-V curves gives $d(C^{-2})/dV$ and after slope values were found, the N_d carrier concentrations for each temperature were obtained by substituting in the expression (11). These values of N_d varied from 1,515 1014 cm^{-3} (300 K) and 3,286 1014 cm^{-3} (10 K) for the as-fabricated and 7,348 1013 cm^{-3} (300 K) and 1,750 1014 cm^{-3} (10 K) annealed at 400 °C Al/n-InP/In Schottky diodes.

Fermi energy level values (Ef) of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes determined from C-V measurements. In addition, barrier heights from the C-V graph calculated

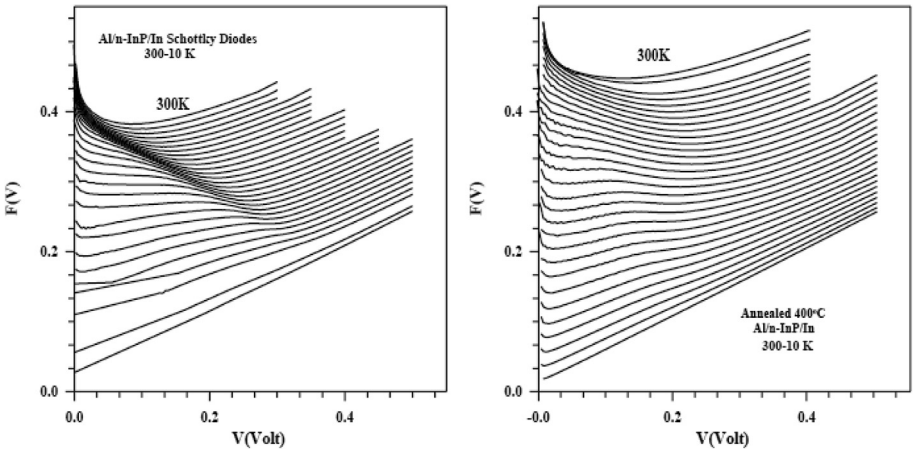


Fig. 5. The Norde function F(V) against V plots of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes.

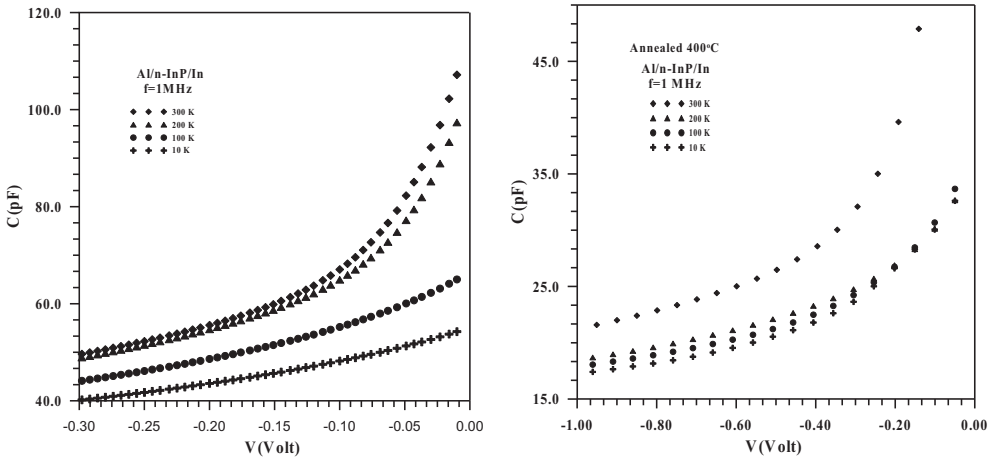


Fig. 6. The temperature dependent reverse bias C-V characteristics (300, 200, 100, 60 K) of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes (f = 1 MHz).

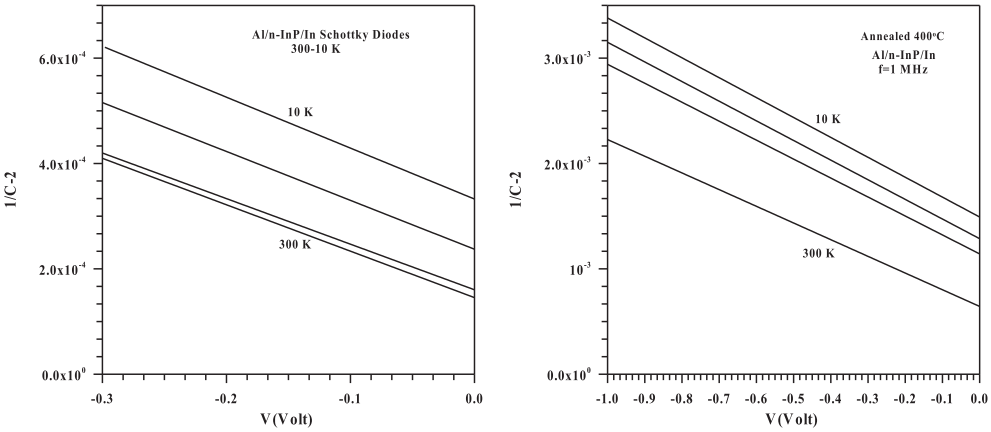


Fig. 7. The temperature dependent $1/C^{-2}$ versus V for as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes (300, 200, 100, 60 K).

by the difference between the conductivity band and the Fermi level and using the donor density obtained from the slope. The temperature-dependent barrier heights values obtained from C-V characteristics are between 0,383 eV (300 K) and 0,177 eV (10 K) for as-fabricated and 0,790 eV (300 K) and 0,332 eV (10 K) for annealed at 400 °C Al/n-InP/In Schottky diodes (Table 1). In addition, the temperature dependent barrier heights obtained from C-V measurements are shown in Fig. 8. These graphs are lineer as seen in Fig. 8 and the weighted arithmetic average of the Schottky barrier heights were obtained from the linear fit of this plots as 0,405 eV for as-fab. and 0,801 eV for annealed at 400 °C Al/n-InP/In Schottky diodes, respectively. These values indicate that there is an obvious increase between the average barrier heights after thermal annealing.

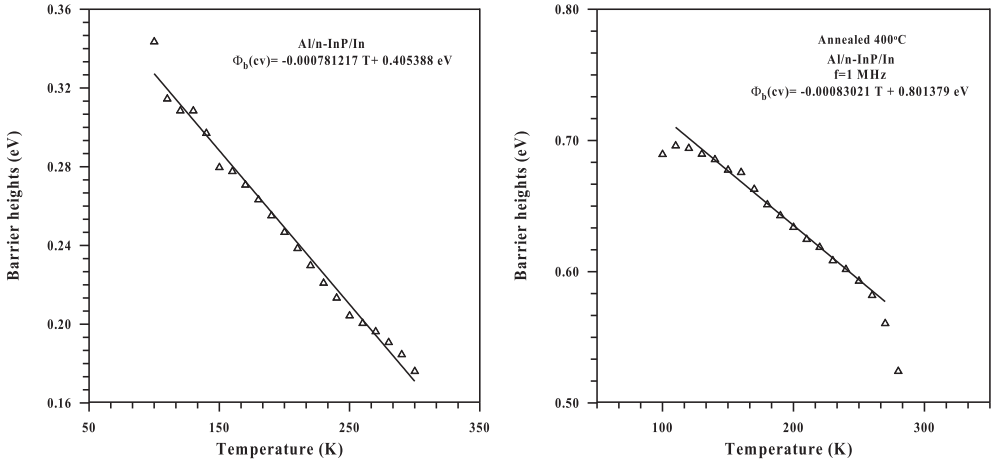


Fig. 8. The temperature dependent barrier height values of as-fabricated and annealed at 400 °C Al/n-InP/In Schottky diodes obtained from C-V characteristics.

At the same time, the measured I-V barrier heights are much smaller than the weighted arithmetic average of the Schottky barrier heights, since current conduction in I-V measurements is dominated by current passing through the low Schottky barrier height region. The measured C-V barrier height is affected by the load distribution at the boundary of the depletion region.

The load distribution at the boundary of the depletion region follows the weighted arithmetic average of the Schottky barrier height homogeneity. For these reasons, the barrier height values obtained from the C-V measurements are closer to the weighted arithmetic mean of the Schottky barrier height. Since the I-V method involves the electron flow towards the semiconductor to the metal, any damage at the interface affects the I-V behavior because defects can act as recombination centers or as trap-assisted tunnel currents. It increases the value of these mechanisms and reduces the value of barrier height. However, C-V measurements are less affected by the presence of such imperfections [18]. Also, even if the width of the depletion region varies with the interface defects located deep within the space charge region, the barrier height values obtained from the C-V measurements will be more reliable since the C-V measurements are less influenced by potential fluctuations, dislocations (defects) and vacancies at the metal/n-InP interface.

In both diodes, the barrier height decreases with decreasing temperature due to the strong dependence of the barrier height values on the temperature. Since the current conduction through the metal/semiconductor interface is a process that is active with temperature, at low temperatures, electrons can overcome lower impedances, so that current conduction becomes dominant with the current flowing through the patches of the lower Schottky barrier [9]. When the temperature increases, too much electrons will have enough energy to overcome the barrier. As a result, the dominant barrier height increases with temperature and voltage. Thus, the current flowing through the lower barrier height reveals higher ideality factor values. A visible increase in the ideality factor at low temperatures and a decrease in the barrier height may result from other possible effects such as inhomogeneity of the thicknesses and inhomogeneity of the interface charges [19]. These results are consistent with the literature [20].

4. Conclusion

The positive effect of annealing on Al/n-InP/In Schottky diode was investigated according to the results obtained from the temperature-dependent changes of the current–voltage (I-V) and capacitance-voltage (C-V) characteristics.

As can be seen from these values, the effect of the oxide layer and undesirable impurities in the metal semiconductor-interface, which causes series resistance in the diode, has been removed due to the annealing process and so, series resistance of the Al/n-InP/In Schottky diode has been reduced considerably and the barrier height increased. Thus, the annealing effect brings a highly desired effect on the diode stability.

The series resistance, ideality factor and barrier height values calculated using I-V characteristics, Cheung functions, Norde (F-V) functions, and C-V characteristics clearly showed that the Al/n-InP/In Schottky diode, which had high diode quality before annealing, became extremely stable due to the annealing process after annealing at 400 °C. This indicates that the annealing process increases the homogeneity of the interface structure or the homogeneity of the barrier height.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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