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Citation: [Journal of Applied Physics](#) **115**, 104502 (2014); doi: 10.1063/1.4868056

View online: <http://dx.doi.org/10.1063/1.4868056>

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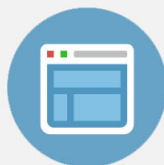
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## Structural and electrical characterizations of $\text{In}_x\text{Ga}_{1-x}\text{As}/\text{InP}$ structures for infrared photodetector applications

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(Received 24 December 2013; accepted 26 February 2014; published online 12 March 2014)

Three  $\text{InGaAs}/\text{InP}$  structures for photodetector applications were grown with different indium compositions by MBE technique. The structural properties of the samples have been obtained by means of high resolution X-ray diffraction and secondary ion mass spectrometry measurements. Three  $\text{InGaAs}/\text{InP}$  metal-semiconductor-metal devices were fabricated at room temperature. The experimental forward and reverse bias current–voltage characteristics of the devices such as ideality factor, barrier height, and saturation current were evaluated considering the structural properties of the grown structures. The carrier recombination lifetime and diffusion length in the devices were also calculated using carrier density and mobility data obtained with Hall effect measurement at room temperature. It was determined that all room temperature fabricated devices improved the Schottky barrier height. Especially, the device fabricated on the lower mismatched structure exhibited barrier height enhancement from 0.2 eV, which is the conventional barrier height to 0.642 eV. In addition, the obtained results show that the room temperature fabricated devices on  $\text{InGaAs}/\text{InP}$  structures can be convenient for infrared photodetector applications.

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### I. INTRODUCTION

III-V compound semiconductor  $\text{In}_x\text{Ga}_{1-x}\text{As}$  ternary alloys have been used in the development of novel optoelectronic device applications such as solar cells,<sup>1–3</sup> photoconductive switches,<sup>4</sup> transistors,<sup>5–7</sup> and photodetectors.<sup>8–13</sup> The  $\text{InGaAs}$  based semiconductor devices could be fabricated for any wavelength within a spectral range of 0.85–3.60  $\mu\text{m}$ .<sup>8</sup> Especially, the  $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$  ternary alloy which has a direct band gap with  $E_g = 0.75$  eV at room temperature has been grown with lattice matched on  $\text{InP}$ .<sup>8,14</sup> The  $\text{InGaAs}$  alloys can be grown on  $\text{GaAs}$  and  $\text{InP}$  substrate by epitaxial techniques such as metal organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE).<sup>15–17</sup> Atomic diffusion between the layers and atom exchange at the growing surface during the growth can cause some defects and non-abrupt interfaces.<sup>18,19</sup> Secondary ion mass spectroscopy gives excellent information about the alloy composition, atomic homogeneity, and interface characteristics of grown layers with its depth profile measurements capability in the ppm range.<sup>20–22</sup> As depending on the development of epitaxial growth technology, many semiconductor materials have been developed for improving of infrared devices for sensing or imaging systems. Among these materials, MCT alloys are important due to its narrow band gap. However, the lattice matched substrates with MCT as  $\text{ZnCdTe}$  are more expensive than III-V substrates and also the growing of MCT structures with low dislocation density on  $\text{Si}$  or  $\text{GaAs}$  as alternate substrates have some difficulties.<sup>23</sup>  $\text{InGaAs}$  along with  $\text{HgCdTe}$  (MCT) has also been extensively studied

with a great potential for the infrared detector applications<sup>24–32</sup> such as metal-semiconductor-metal (MSM) photodetectors.<sup>33–35</sup>  $\text{InGaAs}$  detector performance agrees with that of MCT in the 1.5–3.7  $\mu\text{m}$  wavelength range due to similar semiconductor band structures.<sup>36</sup> Nevertheless,  $\text{InGaAs}$  short wavelength infrared (SWIR) detectors are preferred due to having low dark current and noise and operating at room temperature.<sup>37,38</sup> In addition,  $\text{InGaAs}/\text{InP}$  MSM devices can operate for infrared imaging in the medium wavelength infrared (MWIR) and long wavelength infrared (LWIR) bands at room temperature.<sup>39</sup> In spite of having easy band gap tailoring, well developed theory and experiment,  $\text{InGaAs}$  detectors which have good materials, dopants, advanced technology, and possible monolithic integration have been preferred.<sup>36</sup> However, the low  $\Phi_B$  of n- $\text{InGaAs}$ , 0.2 eV (Refs. 40–44) leads to quite high leakage currents.<sup>45</sup> Because this low  $\Phi_B$  of n- $\text{InGaAs}$  is not sufficient for quality device applications.<sup>41</sup> There have been extensive studies conducted on its improvement.<sup>46–51</sup> For the enhancement of the barrier height ( $\Phi_B$ ) of n- $\text{InGaAs}$ , an important factor is the fabrication conditions of a Schottky contact, as well as the contact material and epilayer crystal quality for the design of 1.55  $\mu\text{m}$   $\text{InGaAs}/\text{InP}$  MSM photodetectors.<sup>52–54</sup> The previous works on the enhancement of the barrier height have adopted different approaches. One of these uses different metallization temperatures such as low temperature (LT = 77 K) (Ref. 14) and room temperature (RT = 300 K).<sup>40</sup> The other attempts employ a very thin cap layer above  $\text{InGaAs}$ ' active layer, such as  $\text{InP}$ ,  $\text{GaAs}$ ,  $\text{InAlAs}$ , and  $\text{AlGaAs}$  as a barrier-enhancement layer,<sup>44,54</sup> or a high-resistivity iron-doped  $\text{InP}$  layer after the  $\text{InGaAs}$  absorbing layer,<sup>45</sup> or a thin counter-doped  $p^+$ - $\text{InGaAs}$  surface layer on n- $\text{InGaAs}$ ,<sup>46–48</sup>

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or an interfacial oxide-like layer on the n-InGaAs.<sup>49-51</sup> In addition, recently, the effect of low dark current, high responsivity, growth temperature, and anodic oxide passivation layer on the InGaAs/InP photodetectors have been investigated for increasing the infrared photodetector performance.<sup>55-57</sup>

In this present work, the In<sub>x</sub>Ga<sub>1-x</sub>As/InP structures for photodetector applications were reported. The three In<sub>x</sub>Ga<sub>1-x</sub>As thin film layers were grown on n-type InP substrates by using a solid source MBE system. The structural parameters such as the crystal quality, indium alloy composition ( $x$ ), lattice parameter ( $a$ ), grain size ( $D$ ), dislocation density ( $\delta$ ), and strain ( $\epsilon$ ) were determined by High resolution X-Ray Diffraction (HRXRD) measurements. Interface abruptness and Indium homogeneity of the grown structures were analyzed by Secondary Ion Mass Spectrometry (SIMS) measurements. The fabrication of three Au/InGaAs/InP/Ni/Au:Ge MSM devices were produced at room temperature. Moreover, the forward and reverse bias experimental I–V measurements of devices were achieved at room temperature. The electrical parameters such as ideality factor ( $n$ ), barrier height ( $\Phi_B$ ), and saturation current ( $I_0$ ) were extracted from forward bias I–V characteristics. In addition, carrier lifetime ( $\tau$ ) and diffusion length ( $L$ ) in fabricated MSM devices were calculated using measured mobility ( $\mu$ ) and carrier density ( $N$ ) by Hall Effect at room temperature.

## II. EXPERIMENTAL

The three n-In<sub>x</sub>Ga<sub>1-x</sub>As thin film structures were grown on n-type InP substrates with changing In fraction by using a V80H solid source MBE system. Prior to the growth, InP substrates were chemically cleaned with a novel etching and cleaning process that was prepared by adding an alkaline (sodium hydroxide) solution to the standard acidic cleaning.<sup>58</sup> After loading in the MBE system, the substrate was degassed in a preparation chamber for 1 h at 350 °C in order to remove any residual organics. Then, the substrate was transferred to the deposition chamber and the oxide desorption was observed by RHEED. The n type (Si doped) epitaxial In<sub>x</sub>Ga<sub>1-x</sub>As layer with 850 nm thickness at the substrate temperature of 560 °C was grown on three n type InP substrates at different times. The In<sub>x</sub>Ga<sub>1-x</sub>As/InP structures were called PD1, PD2, and PD3. To obtain different indium contents in each structure, indium beam equivalent pressure (BEP) was changed while the gallium BEP was kept at a constant value during growth. All of the BEP values and Si cell temperatures are shown in Table I.

HRXRD measurements were carried out on a D-8 Bruker high-resolution diffractometer by using CuK $\alpha$ 1 (1.540 Å) radiation, a prodded mirror, and a 4-bounce Ge (220) symmetric monochromator. The angular resolution of the diffractometer was 0.004° with the Si calibration sample.

In order to understand and compare the In composition profile changes after each In<sub>x</sub>Ga<sub>1-x</sub>As/InP sample was grown, a SIMS, Hiden system was used for the depth profile of the samples. Information about the In composition and depth profiles of In, Ga, As, P, and Si atoms was obtained. A 5 keV

TABLE I. Si temperatures and BEPs for the In<sub>x</sub>Ga<sub>1-x</sub>As/InP structures.

Structure	BEP of Ga (mbar)	BEP of In (mbar)	Temp. of Si Cell (°C)
PD1	$3.5 \times 10^{-7}$	$7.4 \times 10^{-7}$	1050
PD2	$3.5 \times 10^{-7}$	$7.5 \times 10^{-7}$	1100
PD3	$3.5 \times 10^{-7}$	$7.8 \times 10^{-7}$	1100

O<sub>2</sub> gas source was used as a sputtered gun. The sputtering beam was steered over and the analysis signal was taken in an area of 0.5 mm  $\times$  0.5 mm at the center of the irradiated spots. The average sputtering rate was kept at 25 nm/min and the sputtered crater depths were determined by a stylus type profilometer (Veeco, Dektak 150).

For the electrical characterizations, all the samples were divided in square parts of 10  $\times$  10 mm<sup>2</sup> for diode fabrications. The diode fabrication included an ohmic back contact, native oxide removal, and Schottky contact steps. Contacts were obtained by a thermal evaporation system with  $1.0 \times 10^{-8}$  mbar base pressure. First, the samples were cleaned with acetone, methanol, and de-ionized (DI) water, respectively, and dried with nitrogen gas. The ohmic contacts were formed on InP substrates by the deposition of high purity (99.999%) Ni and Au:Ge at room temperature with 200 Å, 2000 Å thicknesses, respectively. Then, the samples were annealed at 360 °C for 3 min under  $5.41 \times 10^{-6}$  mbar vacuum to achieve good ohmic contact behavior. Then, the native oxide on the InGaAs surfaces were removed by 1H<sub>2</sub>SO<sub>4</sub>:1H<sub>2</sub>O<sub>2</sub>:80DI-H<sub>2</sub>O wet chemical etch solution in 1 min. The samples were rinsed in DI-H<sub>2</sub>O and dried with nitrogen gas. Finally, dot shaped Schottky contacts with 1200 Å thickness were formed by the deposition of high purity Au (99.999%) at room temperature under  $3.73 \times 10^{-6}$  mbar vacuum. These InGaAs/InP MSM devices were called MSM1 (Au/In<sub>0.5410</sub>Ga<sub>0.4590</sub>As/InP/Ni/Au:Ge), MSM2 (Au/In<sub>0.5430</sub>Ga<sub>0.4570</sub>As/InP/Ni/Au:Ge) and MSM3 (Au/In<sub>0.5575</sub>Ga<sub>0.4425</sub>As/InP/Ni/Au:Ge). Schematic representation of fabricated MSM device and corresponding energy band diagram are given in Figs. 1(a) and 1(b), respectively. In a MSM detector, the IR radiation as depend on  $\Phi_B$  barrier height is absorbed within the material by interaction with electrons. The detection of the IR light is achieved by measuring electrical output signal produced with changing of the electronic energy distribution in the material. After the fabrication of devices, I–V characteristics were performed using a Keithley 4200 semiconductor parameter analyzer system. In addition, to calculate the carrier lifetime and diffusion length in the MSM devices, mobility and carrier density of the devices were measured by Lake Shore Hall Effect system at room temperature.

## III. RESULTS AND DISCUSSION

The indium alloy composition ( $x$ ) of the grown structures was determined by HRXRD measurements. Fig. 2 shows the recorded  $\omega$ -2 $\theta$  X-ray diffraction spectra of the three In<sub>x</sub>Ga<sub>1-x</sub>As/InP structures. In the figure, it is clear that the high-intense peaks were derived from InP substrates and the other peaks from In<sub>x</sub>Ga<sub>1-x</sub>As layers. The peaks belonged

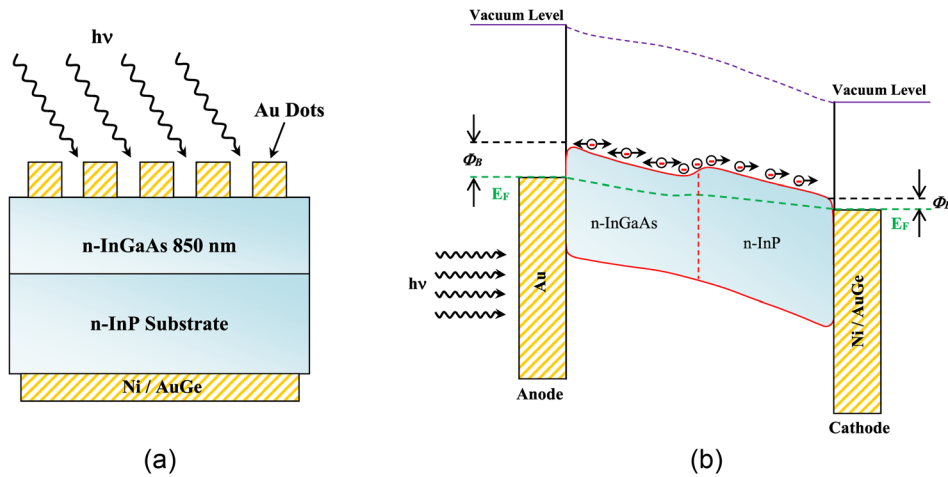


FIG. 1. (a) Schematic representation of the cross section and (b) energy band diagram of the MSM device.  $\Phi_B$  denotes Schottky barrier height of the device and  $\Phi_B'$  have to be almost zero for good ohmic contact behavior.

to the  $\text{In}_x\text{Ga}_{1-x}\text{As}$  layers were further separated from the InP substrate peaks due to the increase of the Indium alloy composition in the layer. The peak separation angle can be used to determine the In composition in the alloy. Thus, the  $x$  values were found as 54.10%, 54.30%, and 55.75% for PD1, PD2, and PD3 structures, respectively, by using commercial LEPTOS software.<sup>59</sup>

In addition, the full width at half maximum (FWHM) values of XRD peaks for the PD1, PD2, and PD3 structures were determined as  $0.014^\circ$ ,  $0.020^\circ$ , and  $0.015^\circ$ , respectively. These values indicate that the grown structures are of good crystal quality. The PD1 structure, which has the lowest FWHM value ( $0.014^\circ$ ), is the closest one to the lattice-match InGaAs/InP structure.

As seen in Table II, the crystal structural parameters of the three structures such as the lattice parameter ( $a$ ), grain size ( $D$ ), dislocation density ( $\delta$ ), and strain ( $\varepsilon$ ) were calculated. They were obtained from the equations given by  $a = (\lambda/2 \sin \theta) \cdot (\sqrt{h^2 + k^2 + l^2})$ ,  $D = (0, 9\lambda)/(\beta \cos \theta)$ ,  $\delta = 1/(D^2)$  and  $\varepsilon = ((\lambda/D \cos \theta) - \beta) \cdot (1/\tan \theta)$ , where  $\lambda$  is the X-Ray wavelength,  $\theta$  is the peak angle value in the  $\omega$ - $2\theta$  scans,  $hkl$  are the Miller indices, and  $\beta$  is the FWHM value of the  $\text{In}_x\text{Ga}_{1-x}\text{As}$  peaks.

In Table II, the dislocation density and strain values of the PD1 are lower than the others. The good crystallinity of

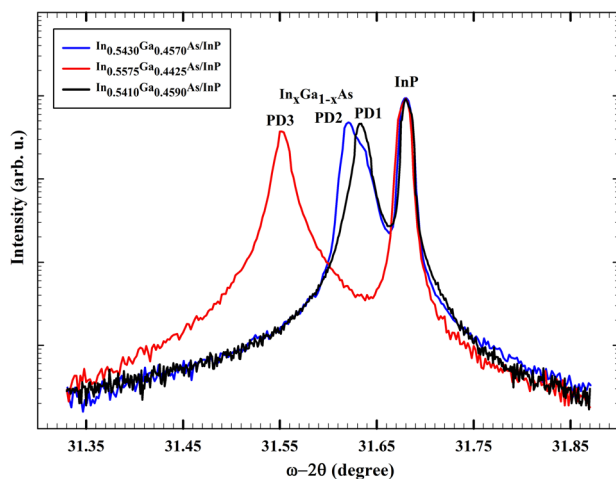


FIG. 2.  $\omega$ - $2\theta$  curves of (004) symmetric planes of the  $\text{In}_x\text{Ga}_{1-x}\text{As}/\text{InP}$  structures.

the PD1 structure with respect to the other grown structures is also evidenced by these results.

Atomic distributions and interface characteristics of the PD1, PD2, and PD3 structures were analyzed by SIMS depth profile measurements. The SIMS depth profile of the As, Ga, In, and Si atoms in the grown three InGaAs layers on InP are given in Figs. 3–5. It is shown in the SIMS depth profile in the figures that there is no interdiffusion in the layers of all the samples. The samples have excellent abruptness of P distribution on the interface between the layer and substrate and P outdiffusion into the InGaAs layer is a negligible amount. In the interface between the InGaAs layer and InP substrate for all the grown structures, the amount of P is sharply increased while the amount of Ga is sharply decreased. It resulted in the formation of a sharp interface. This result is also an indication of the good quality of the grown InGaAs layer on an InP substrate. In addition, Si doping distribution in the layer has shown similar behavior in all the layers.

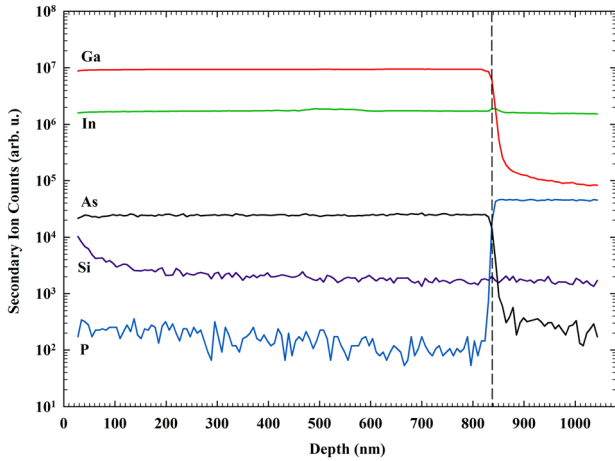
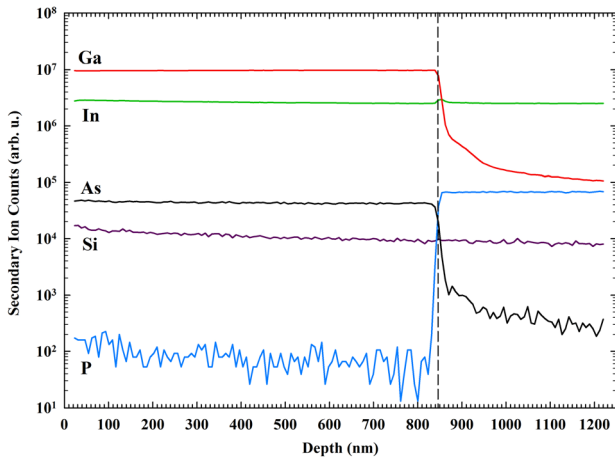
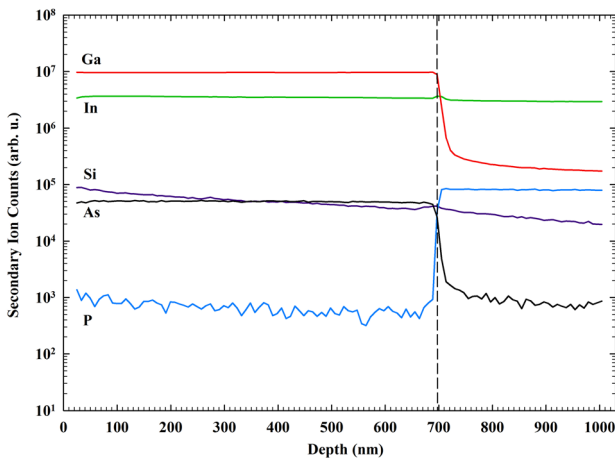
As seen in Figure 5, the Ga amounts are approximately the same in the PD1-PD3 structures while the In amounts increased, respectively. These results are in agreement with the Ga and In BEPs, as seen in Table I, indium BEP was increased while the gallium BEP was kept at a constant value for the three structures during the growth. The depth profile analysis of the samples show that In alloy composition ( $x$ ) was increased with the increasing of In BEP, as expected.

In addition, the homogeneity of the In distribution along the growth direction in the grown layer on InP may be important for device application. As seen in Fig. 6, the In contents have increased along the growth direction for PD2 and PD3 structures. Although the growth temperature is the same for the different structure, this type In content variation can be observed due to the kinetics of the In during epitaxial growth. The variation of the In along the growth direction for the PD2 sample is higher than the PD3. This behavior may cause a shoulder in the HRXRD peak of the InGaAs layer in the PD2 as seen in Fig. 2. The In distribution in the PD1 has good homogeneity with growth direction in the InGaAs layer.

As a result of the analyses of the HRXRD and SIMS measurements, it can be said that factors such as the homogeneity of the In, low dislocation density and strain, sharp

TABLE II. The lattice parameter, grain size, dislocation density, and strain values of the  $\text{In}_x\text{Ga}_{1-x}\text{As}/\text{InP}$  structures.

Structure	$2\theta$ (deg)	$\beta$ (deg)	$a$ (Å)	$D$ (nm)	$\delta$ ( $\times 10^{11} \text{ cm}^{-2}$ )	$\epsilon$ ( $\times 10^{-4}$ )
PD1	31.633	0.014	11.3047627	589.7777333	0.0028749	0.9583918
PD2	31.621	0.020	11.3089433	412.8321688	0.0058675	1.3696781
PD3	31.551	0.015	11.3333943	550.3477962	0.0033016	1.0296575

FIG. 3. SIMS profiles of the PD1 ( $\text{In}_{0.541}\text{Ga}_{0.459}\text{As}/\text{InP}$ ) structure.FIG. 4. SIMS profiles of the PD2 ( $\text{In}_{0.543}\text{Ga}_{0.457}\text{As}/\text{InP}$ ) structure.FIG. 5. SIMS profiles of the PD3 ( $\text{In}_{0.5575}\text{Ga}_{0.4425}\text{As}/\text{InP}$ ) structure.

interface of the layer/substrate and FWHM of the HRXRD peak have significant effects on the growth of the  $\text{In}_{0.543}\text{Ga}_{0.457}\text{As}/\text{InP}$  structure, which is the one that fits best to the lattice matched  $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}/\text{InP}$  structure.

The forward and reverse-bias  $I-V$  characteristics of  $\text{InGaAs}/\text{InP}$  MSM devices were measured to investigate certain electrical properties of structures such as the ideality factor ( $n$ ), barrier height ( $\Phi_B$ ), and saturation current ( $I_0$ ). Fig. 7 shows the semi-logarithmic  $I-V$  characteristics of the MSM1, MSM2, and MSM3 structures at room temperature. According to the thermionic emission theory, the relationship between the applied forward voltage ( $V \geq kT/q$ ) and the current can be expressed as shown below<sup>60</sup>

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

where  $V$  is the forward bias voltage,  $n$  the ideality factor,  $k$  is the Boltzmann constant,  $T$  is the temperature in K, and the term  $IR_s$  is the voltage drop across the series resistance of the device. The voltage  $V_d = V - IR_s$  across the diode can be expressed in terms of the total voltage drop  $V$  across the series combination of the device and the series resistance.

In Fig. 7, the saturation current  $I_0$  is derived from the straight-line intercept of  $\ln I$  at zero bias and is

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

where  $A$ ,  $A^*$ ,  $q$ , and  $\Phi_B$  are the diode area, the effective Richardson constant (for  $n$ -type  $\text{InP}$   $9.4 \text{ A cm}^{-2} \text{ K}^{-2}$ ),<sup>61</sup> the electronic charge, and the zero-bias barrier height, respectively. From Eq. (1), the ideality factor can be written as

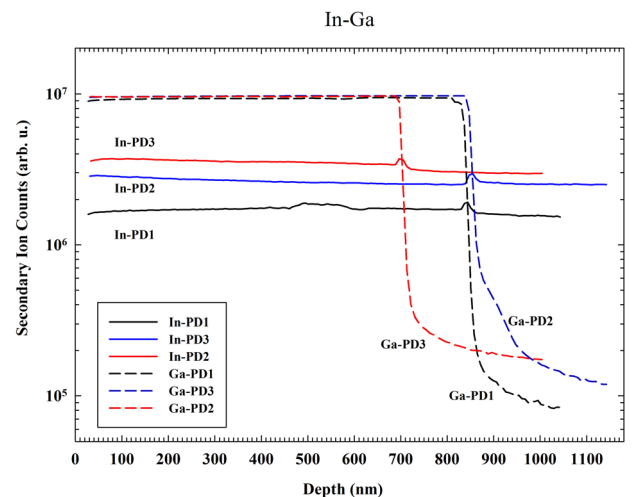


FIG. 6. In and Ga SIMS profiles of the structures.

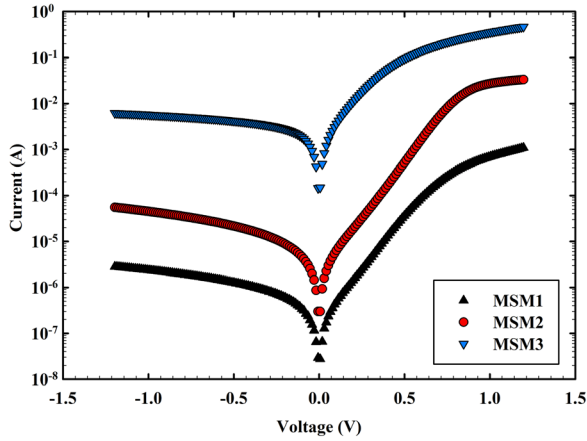


FIG. 7. The semi-logarithmic forward and reverse bias current-voltage characteristics of the MSM devices at room temperature.

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

$n$  is used to calculate the deviation from the ideal thermionic model.  $\Phi_B$  was calculated using the theoretical value of  $A^*$  and extrapolated  $I_0$  at room temperature according to

$$\Phi_B = \frac{kT}{q} \ln \left( \frac{AA^*T^2}{I_0} \right). \quad (4)$$

The calculated values of  $n$  and  $\Phi_B$  obtained from Eqs. (3) and (4) are shown in Table III.

As seen from the Table III, the  $\Phi_B$  values were calculated as 0.642 eV for MSM1, 0.582 eV for MSM2 and 0.382 eV for MSM3. These values correspond the wavelengths of 1.931  $\mu\text{m}$ , 2.130  $\mu\text{m}$ , and 3.246  $\mu\text{m}$  and they can be deemed suitable for infrared photodetector applications. This study has achieved the same result with the above-mentioned literature, which has used fabrication processes such as low temperature fabrication and additional layer growth in the structure, by only fabricating diodes at room temperature. The enhancement of the Schottky barrier height with this study can be attributed to the crystal quality of the structure.

In addition, the performance of optoelectronic devices include InGaAs/InP infrared photodetector is critically dependent on some important parameters such as mobility, carrier density, recombination lifetime, and diffusion length.<sup>62</sup> Recombination lifetime ( $\tau$ ) and diffusion length ( $L$ ) for InGaAs/InP MSM devices were calculated with obtained the carrier density ( $N$ ) and mobility ( $\mu$ ) data by Hall Effect measurements at room temperature.

The total recombination lifetime is given by<sup>63</sup>

$$\frac{1}{\tau} = \frac{1}{\tau_{SRH}} + \frac{1}{\tau_R} + \frac{1}{\tau_A}. \quad (5)$$

TABLE III. Electrical parameters for the InGaAs/InP MSM devices.

Device	$n$	$\Phi_B$ (eV)	$I_0$ (A)
MSM1	3.59	0.642	$1.78 \times 10^{-7}$
MSM2	3.76	0.582	$1.97 \times 10^{-6}$
MSM3	4.07	0.382	$1.46 \times 10^{-3}$

TABLE IV. Carrier density, mobility, diffusion coefficient, carrier lifetime, and diffusion length of the MSM devices.

Device	T (K)	$N$ ( $1/\text{cm}^3$ )	$\mu$ ( $\text{cm}^2/\text{V}\cdot\text{s}$ )	$D$ ( $\text{cm}^2/\text{s}$ )	$\tau$ (ns)	$L$ ( $\mu\text{m}$ )
MSM1	299.839	$3.818 \times 10^{17}$	4553.1	116.519	20.040	15.281
MSM2	296.972	$3.490 \times 10^{17}$	3563.3	92.069	18.314	12.985
MSM3	296.336	$3.891 \times 10^{17}$	3659.6	93.453	17.973	12.960

In terms of doping concentrations  $N$ , the Eq. (5) can be rewritten as

$$\tau = [\tau_{SRH}^{-1} + BN + CN^2]^{-1}. \quad (6)$$

As seen from the equations, the total recombination lifetime depends upon the  $N$  separate into the three parts as Shockley–Read–Hall (SRH), Auger and radiative recombination. From  $10^{16}$  to  $10^{18} \text{ cm}^{-3}$  doping range, radiative recombination is dominant and the total lifetime varies as  $1/N$ .<sup>64</sup> Then, the total lifetime can be given by

$$\tau = [BN]^{-1}. \quad (7)$$

Here, the radiative recombination coefficient  $B$  is  $2 \times 10^{-11} \text{ cm}^{-3} \text{ s}^{-1}$  for InP and  $1.43 \times 10^{-10} \text{ cm}^{-3} \text{ s}^{-1}$  for InGaAs.<sup>25,64</sup>

The diffusion length ( $L$ ) can be calculated by Eq. (8).  $L$  leads the distribution of carrier in devices depend on minority carrier injection and diffusion.

The diffusion length can be derived from the carrier lifetime  $\tau$  by

$$L_{n,p} = \sqrt{\tau \cdot D_{n,p}}, \quad (8)$$

where the diffusion coefficient  $D_{n,p}$  is given by the Einstein relation,

$$D_{n,p} = \mu_{n,p} \frac{kT}{q}. \quad (9)$$

Here,  $\mu_{n,p}$  is the carrier mobility,  $k$  is the Boltzmann's constant, and  $q$  is the electrical charge on electron.<sup>65</sup>

Consequent of the theoretical modelling, as seen the Table IV, the carrier lifetime and diffusion length can be derived from the mobility and carrier density, which were obtained from the Hall measurements at room temperature.

## IV. CONCLUSIONS

We have presented experimental and theoretical evidences that the room temperature metallization process in this work can be used for InGaAs/InP MSM photodetector by engineering the Schottky barrier height. For this purpose, the indium alloy composition ( $x$ ) and room temperature metallization effect have been investigated on the structural and electrical properties of MBE grown InGaAs/InP structures. Structural parameters such as alloy composition, lattice parameter, grain size, dislocation density, and strain of the structures have been obtained by HRXRD measurements.

Indium homogeneity and abruptness in the interface of the grown  $\text{In}_x\text{Ga}_{1-x}\text{As}$  layers on InP substrates are identified by SIMS depth profile measurements. It was seen that there was a good agreement between the change of the  $x$  values obtained from the HRXRD and SIMS measurements. In the SIMS measurements, the great steepness of As and P distributions across the interface between InGaAs and InP was obtained in all the structures. Important device parameters such as ideality factor, Schottky barrier height and saturation current of room temperature fabricated MSM devices were obtained by current-voltage measurements. In addition, the carrier lifetime and diffusion length in the MSM devices were calculated using the mobility and carrier density data obtained from Hall Effect measurements. The values of  $\Phi_B$  were calculated 0.642 eV for MSM1, 0.582 eV for MSM2, and 0.382 eV for MSM3 from room temperature forward-bias  $I$ - $V$  measurements. It was seen that the Schottky barrier height  $\Phi_B$  was increased from the conventional barrier height 0.2 eV to 0.642 eV. These results show that an important improvement of the barrier height is obtained by the fabrication of the diode at room temperature process. Improvement on the barrier height of MSM devices can be attributed to the bigger grain size, lower FWHM, lower dislocation density, lower strain, and great steepness of As and P distributions of the grown samples. Besides these parameters, Indium homogeneity in the epilayer may affect the electrical parameters of the devices. In addition, it can be said that these types of structures can be more convenient for photodetector applications especially due to fabricating at room temperature.

## ACKNOWLEDGMENTS

This work was supported by the Ministry of Development of Turkey under project number: 2011K120290.

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