Electrical Characteristic of Au/Graphene/p-Si/Al Schottky Diode Depend on Annealing Temperature

Oğuzhan ÖZAKIN [1], Özkan BAYRAM [2], Cengiz AYKAÇ [3], Betül GÜZELDİR[4] and Mustafa SAĞLAM[5]

Abstract— In this work, graphene, growth with Chemıcal Vapour Deposıtıon was transferred on p-Si substrate. In order to get Au/graphene/p-Si/Al Schottky diode, firstly ohmic contact and then schottky contacts were obtained. To observe electrical charactersitic of Au/graphene/p-Si/Al structure was annealed from 150 to 300 °C by 50 °C steps. I-V characteristics of Au/graphene/p-Si/Al was investigated for each annealing temperature. Than the basic parameters of Au/graphene/p-Si/Al Schottky diode was calculated using the Norde and thermo ionic emission theory.

Index Terms— Anneal, Chemical Vapour Deposition, Graphene, Norde, Schottky diode, thermo ionic emission theory

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1 INTRODUCTION

ONE of the most interesting elements in the periodic table is the carbon atom. Along with the well-known allotropes of carbon such as graphite and diamonds, new synthesized forms such as nanotube and fullerene are also available.

Graphene, which has honeycomb crystal structure, was synthesized in 2004 and this work was awarded the Nobel Prize. In addition, metal semiconductor contacts are still among the most important devices in today's electronics industry. In order to realize high performance Schottky devices, a precise understanding of the electrical characteristics and conduction mechanisms for Schottky contacts is essential since the most important aspect of a metal–semiconductor junction is the process that determines the electron flow over the top of the barrier between the semiconductor and metal when a bias voltage is applied [1]. In recent years, graphene, which is of great importance due to its electronic and optical properties, is used as an interfacial layer for semiconductors such as Si[2], GaN[3] and GaAs[4]. Most studies so far have extracted the Schottky barrier height from room temperature I-V measurements. Temperature dependent I-V measurements, on the other hand, would enable the determination of barrier height without any assumptions of the electrically active area or the presence of any interfacial layer[5]. In this study, Au and Al metal were used as rectifier and ohmic contact respectively. Graphene which is interface layer was transferred on to Si substrate and the I-V characteristics were compared to see which diode was more stable due to annealing temperature.

2 EXPERIMENTAL

In this study, the firstly p type Si substrate, one side polished was chemically cleaned (i.e. 10 min boil in NH3 + H2O2 + 6H2O followed by HCl + H2O2 + 6H2O at 60 °C) to obtain Schottky contact structure. The native oxide on the polished surface of p type Si was extinguished in a HF:H2O (1:10) solution. Finally, the substrate was kept waiting in deionized water and the cleaning process was ended. Before transferring procces, the ohmic contact was made back surface of substrate using Al metal by evaporating system and annealed at 580o for 3 minutes. After the cleaning proccess. p-Si /Al structure was obtained after all process.

In the second stage of the experimental study, the transfer of graphene onto the P-Si semiconductor was performed. For the transfer process firstly supersaturated iron chloride solution was prepared and then the copper foils were placed into the iron chloride solution with the non-graphene coated surfaces at the bottom. Graphene thin film was obtained on the surface of the solution by etching from copper in about half an hour. Then the graphene film was removed on a glass cover glass and cleaned in deionized water for about 20 minutes. The thoroughly cleaned graphene was transferred onto the p-Si substrate to obtain a Schottky contact and graphene / P-Si / Al structure was obtained by drying in incubator. Because uncoated parts wanted to use as reference diode, all of the substrate was not coated with graphene.

At the last step of the of process the Au / Graphene / p-Si / Al structure was obtained by evaporating Au metal at 5x10-7 torr pressure using a mask with a contact area of 7,85x10-3. "KEİTLEY 2400 Picoammeter/Voltage Source was used to assign I-V changes depending on the annealing temperature of our device.

3 RESULTS AND DISCUSSION

The electrical properties of this structure, coated with thin layer graphene exhibit behavior similar to Schottky contacts. If a

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[1] *Oğuzhan ÖZAKIN· Horasan Vocational High School, Atatürk University, Erzurum, Turkey, oguzhanozakin@Atauni.Edu.tr*
[2] *Faculty of Engineering, Bayburt University, Bayburt, Turkey, obayram@bayburt.edu.tr*
[3,4,5] *Faculty of Sciences, Atatürk University, Erzurum, Turkey, cengiz35aykac@gmail.com, bgüzeldir@atauni.edu.tr, msaglam@atauni.edu.tr*

Schottky diode with a series resistance (Rs) is considered, it is assumed that the forward bias-thermionic emission current of the device can be expressed as[6].

$$I = I_0\left[\exp\left(\frac{qv}{nkT}\right)-1\right] \qquad (1)$$

I_0 is the Saturation current and is equal to

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

Where Φ_B is barrier height for zero bias, V is applied voltage, k is the Boltzman constant, T is absolute temperature, A is diode area, for effective Richardson constant and n is the ideality factor, is an important parameter that determines the quality of the diode and is expected to be 1 for an ideal diode. From the 2. equation n can be written

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

dV/dlnI is obtained from the forward bias of I-V graph. From the 2. equation we can find another parameter that is important for the diode, the barrier height.

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

Figure 1and 2 show that I-V graphs of the reference and Au/Graphene/P-Si/Al structure depending on the annealing temperature respectively. The barrier height, saturation current and ideality factor were calculated by thermionic emission theory, to determinate the characteristic parameters of the diodes using I-V measurements.

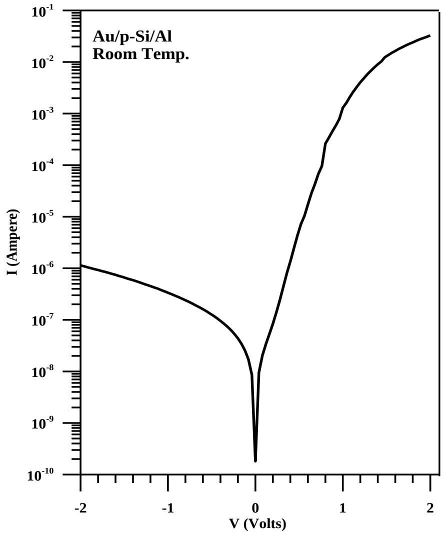

Figure 1 The forward and reverse bias ln (I)-V characteristics of reference diode

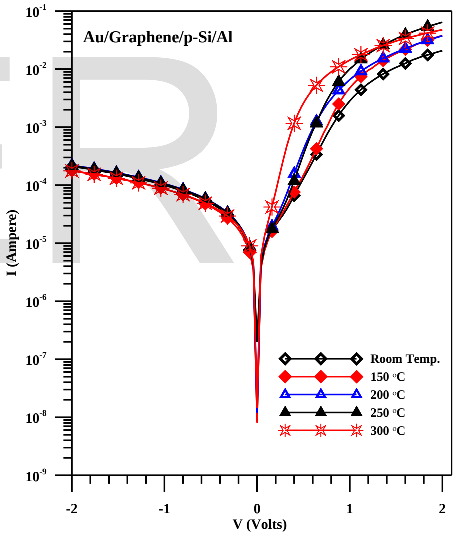

Figure 2 The forward and reverse bias ln (I)-V characteristics of Au/Graphene/p-Si/Al diode

Another approach used to calculate parameters such as barrier height and series resistance of a metal semiconductor contact are Norde functions. Figure 3 shows that F (V) -V graphs of Au/Graphene/p-Si/Al Schottky diode depending annealing temperature. Using these graphs, some diode parameters such as Φ_B and Rs of Au/Graphene/p-Si/Al Schottky diode are calculated. The values calculated from the F (V) -V graphs are given in Tables 1. It is seen that the values of the series resistance have increased and barrieer height has decreased with annealing temperature.

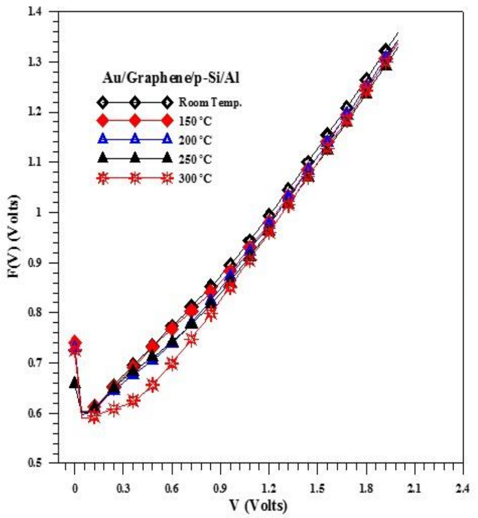

Figure 3 F (V) -V graphs of Au/Graphene/p-Si/Al Schottky diode depending annealing temperature.

TABLE 1
THE DIODE PARAMETERS, WAS OBTAINED USING THERMIONIC EMISSION THEORY AND NORDE FUNCTIONS.

	Thermionic Emission Method			**Norde Method**	
	I_0	**n**	**Φ_B (eV)**	**Φ_B (eV)**	**R_s (Ω)**
Reference	4.42E-09	2.689	0.757	0.758	39617
Room Temp	4.33E-06	5.675	0.579	0.600	2125
150 °C	3.18E-06	5.040	0.587	0.608	1774
200 °C	3.28E-06	3.999	0.586	0.598	1743
250 °C	1.95E-06	3.749	0.600	0.600	1607
300 °C	3.56E-06	2.511	0.584	0.590	948

4 CONCLUSION

In this study, the effects of annealing temperature on the characteristic parameters such as ideality factor, barrier height and series resistance of Au/Graphene/p-Si/Al Schottky type diode was investigated. Au/Graphene/p-Si/Al diode exhibited stable diode characteristics up to 300 oC, while the Au/Graphene/p-Si/Al diodes began to deteriorate after 300 oC. These results showed that the Au/Graphene/p-Si/Al Schottky diodes could not maintain their stability over high annealing temperature. In the light of the results, it has been seen that graphene can be used as an interface in metal semiconductor contacts and can be used safely in device construction.

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