Time-Based Analysis of the Characteristic Parameters of AuAgCu(2:1:1)/n-Si, AuAgCu(1:2:1)/n-Si and AuAgCu(1:1:2)/n-Si Junctions

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Abstract— AuAgCu (2: 1: 1), AuAgCu (1: 2: 1) and AuAgCu (1: 1: 2) alloys were prepared using Au, Ag and Cu metals by thermal evaporation technique. n-Si semiconductor wafer was used as base material in the fabrication of junctions. The one side of the chemically cleaned n-Si semiconductor wafer, ohmic contact was made with Ti metal. Then the semiconductor was divided into three parts. On the other side of the n-Si semiconductor substrates, these alloys were evaporated and AuAgCu(2:1:1)/n-Si/Ti, AuAgCu(1:2:1)/n-Si/Ti and AuAgCu(1:1:2)/n-Si/Ti junctions were obtained, respectively. These three samples were placed in the sample holders to determine the characteristic parameters as a function of aging time, and the current voltage (I-V) measurements at room temperature and in the dark were performed at certain time periods (immediate, 1st, 7th, 15th, 30th, 90th, 180th and 365th day). The characteristic parameters such as ideality factor (n), barrier height (Φ_b), series resistance (R_s) and leakage current (I_0) of these junctions were examined by time with the help of thermionic emission theory.

Index Terms— Aging time, Alloy-Semicomducto r junctions, barrier height, ideality factor, leakage current, series resistance, thermionic. emission theory.

1 Introduction

It is well-known that the rectifying metal-semiconductor or Schottky contacts are ideal for microwave, switching, gating and clamping applications in the semiconductor device technology[1,2].

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. To date, the I–V characteristics of Schottky contacts to Si have been extensively investigated by many researchers [3].

The electrical properties of these Schottky contacts are found to depend on various factors such as work function of metal and semiconductor, type of semiconductor (n- or p-type), interface chemistry, processing methodology, presence of defect states and doping concentration of thesemiconductor [4].

The stability of the electrical characteristics of the metal / semiconductor contacts has great importance in the circuit technology. As an alternative to metal / semiconductor contacts, with the emergence of alloy / semiconductor contacts with more stable interfaces, interest in alloys has begun. Alloy aims to change some properties of metal and even to give it new properties. Pure metals have certain properties. Therefore, it has limited usage areas. Alloys are needed to provide numerous properties required by the industry (strength, elongation, forming, surface gloss, electrical and thermal conductivity, etc.).

In this paper, AuAgCu alloys were prepared in different ratios by using Au, Ag and Cu metals. Alloy / semiconductor diodes were prepared from these alloys and their electrical characteristics were investigated according to time.

2 Experimental

The one-side polished n-Si semiconductor used in this study was first subjected to a chemical cleaning procedure. During the cleaning process, the n-Si semiconductor was first ultrasonic washed for 10 minutes in Acetone and Methanol and thoroughly rinsed with deionized water. After this stage, known as organic RCA1: (H2O: H2O2: NH3; 6:1:1) was subjected to a treatment to stand for 10 minutes at 60 °C in the chemical cleaning process. P-Si semiconductor maintained for 30 seconds in dilute HF: (H2O: HF; 10: 1) after RCA1 procedure and than second cleaning procedure was called RCA2: (H2O: H2O2: HCl; 6:1:1) and was processed a treatment known as metallic cleaning. The samples were kept at 60 °C for 10 minutes at RCA2. After the RCA2 treatment, the p-Si semiconductor was washed thoroughly with deionized water for 30 seconds in diluted HF and then passed through a deionized water for 15-20 min. Finally, the chemical cleaning process was completed by drying with pure nitrogen gas.

Then, titanium is evaporated onto the matt surface of the n-Si at vacuum 10^{-6} Torr and Ti/n-Si contact is thermally an-

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nealed at 420 °C in nitrogen atmosphere. Thus, n-Si / Ti ohmic contact is obtained. The ohmic contacted n-Si is divided into three parts. Later, to make the rectifier contacts of the diodes, The AuAgCu (2: 1: 1), AuAgCu (1: 2: 1) and AuAgCu (1: 1: 2) alloys is evaporated onto the polished surface of each of the silicon parts at vacuum 10^{-6} Torr using 1 mm diameter circular mask, respectively. Thus, AuAgCu(2:1:1)/n-Si/Ti, AuAgCu(1:2:1)/n-Si/Ti and AuAgCu(1:1:2)/n-Si/Ti diodes were successfully obtained. The I-V measurements of the fabricated diodes were immediately taken at room temperature in dark conditions. To investigate the effects of aging time, the I-V measurements of the diodes have been also repeated after 1, 7, 15, 30, 90, 180 and 365 days. The electrical measurements of diodes were taken using a HP 4140B picoammeter.

3 Results and Discussion

The forward and reverse bias ln (I)-V characteristics of the AuAgCu (2: 1: 1) / n-Si / Ti, AuAgCu 1: 2: 1) / n-Si / Ti and AuAgCu (1: 1: 2) / n-Si / Ti alloy-semiconductor diodes are shown in Figure 1 and at room temperature, as a function of increasing aging time (immediate, 1st, 7th, 15th, 30th, 90th, 180th and 365th day) .

The most useful method for characterizing the electrical parameters of Schottky diodes is based on I-V measurement. The thermionic I-V properties of Schottky diodes (if series and shunt resistance are omitted) are expressed by the following equation[5];

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

where I0 is the leakage current is written as follows

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

A is effective area of the Schottky contact, A* is the Richardson constant (for n-Si, A* =112 A.cm−2 K−2), q is charge of the electron, ΦB is Schottky barrier height, k is Boltzmann constant and T is absolute temperature.

From equation 2, the barrier height of the Schottky type diode can be obtained as follows:

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

The n ideal factor is defined as the deviation of experimental I-V data in Schottky diodes and represents a dimensionless constant. The ideality factor can be calculated using the following relation;

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

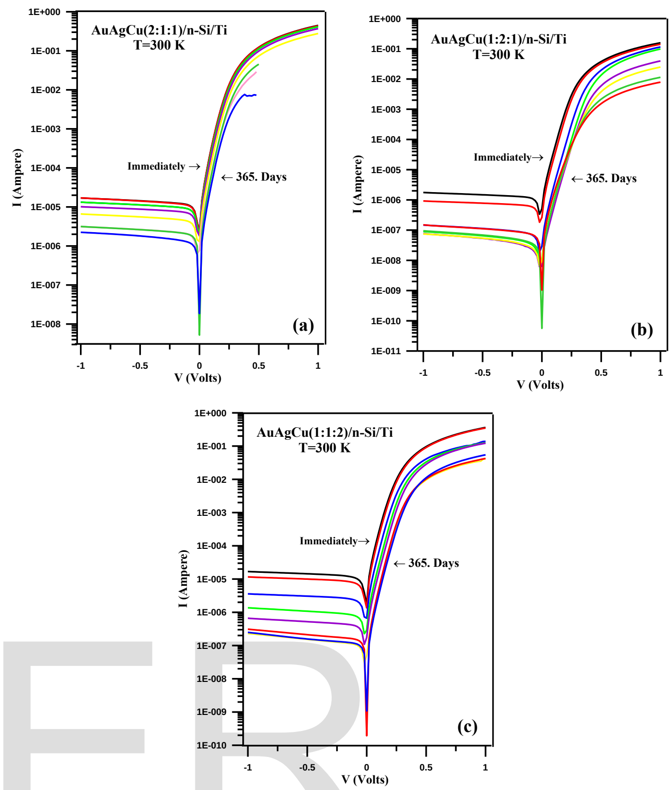

Fig. 1. The forward and reverse bias ln (I)-V characteristics of the AuAgCu (2: 1: 1) / n-Si / Ti, AuAgCu 1: 2: 1) / n-Si / Ti and AuAgCu (1: 1: 2) / n-Si / Ti.

The diode parameters calculated from the thermionic emission method based on time using these characteristics Table 1 is given in the table. As seen in Table 1, the ideality factor in all diodes, ideal value was found to be very close to 1. In addition, it has been found that the saturation currents do not change with increasing reverse bias voltage in reverse bias conditions of diodes, that is, they are almost constant. Also, It is seen that the barrier height values change slightly depending on the alloy ratios.

TABLE 1.

THE DIODE PARAMETERS CALCULATED BY THE THERMIONIC EMISSION METHOD OF AUAGCU (2: 1: 1) / N-SI / TI, AUAGCU 1: 2: 1) / N-SI / TI AND AUAGCU (1: 1: 2)/N-SI/TI DIODES WITH RESPECT TO INCREASING AGING TIME.

Thermionic Emission Method									
	AuAgCu (2:1:1)/n-Si/Ti			AuAgCu (1:2:1)/n-Si/Ti			AuAgCu (1:1:2)/n-Si/Ti		
Time (Day)	I_0 (A)	n	Φ_B (eV)	I_0 (A)	n	Φ_B (eV)	I_0 (A)	n	Φ_B (eV)
immediately	8,47E-06	1,033	0,526	1,15E-06	1,053	0,578	6,27E-06	1,030	0,534
1	8,20E-06	1,034	0,527	6,08E-07	1,060	0,594	4,51E-06	1,029	0,543
7	6,89E-06	1,041	0,532	6,97E-08	1,062	0,650	1,67E-06	1,053	0,568
15	5,66E-06	1,052	0,537	2,59E-08	1,071	0,676	7,52E-07	1,082	0,589
30	3,49E-06	1,061	0,549	1,48E-08	1,074	0,690	3,98E-07	1,080	0,605
90	1,86E-06	1,068	0,565	2,40E-08	1,082	0,678	1,36E-07	1,101	0,633
180	1,61E-06	1,068	0,569	2,39E-08	1,088	0,678	1,33E-07	1,094	0,634
365	1,74E-06	1,082	0,567	4,46E-08	1,115	0,662	9,01E-08	1,107	0,644

It is also important to examine the effect of series resistance on diode characteristics in device physics. The series resistances of the diodes can be examined with different methods [6]. The Norde method was used in this study

Norde proposed a method to determine value of the series resistance. The following function has been defined in the modified Norde's Method [7].

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

where γ is an arbitrary constant greater than the ideality factor and I(V) is current obtained from the I–V curve and the other parameters are described above. From Norde's functions, the effective barrier height and Rs value can be determined as

$$\varphi_B = F_m + \left[\frac{(\gamma - n)}{n} \right] \left[\frac{V_m}{\gamma} - \frac{kT}{q} \right] \tag{6}$$

$$R_s = (\gamma - n) \frac{kT}{qI_m} \tag{7}$$

where F_m is the minimum value of F(V) and V_m is the corresponding voltage. Im is the value of the forward current at the voltage V_m where the function F(V) exhibits a minimum.

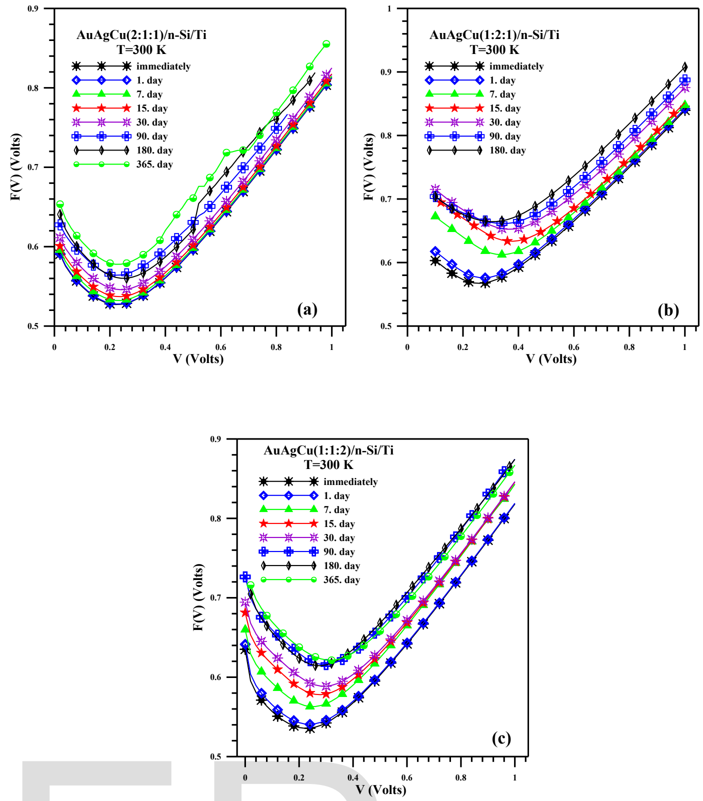

Fig. 2. The F(V)-V plots of the (a) AuAgCu (2:1:1)/n-Si/Ti b) AuAgCu (1:2:1)/n-Si/Ti and c) AuAgCu (1:1:2)/n-Si/Ti diodes at room temperature as a function of aging time.

Figure 2 shows the F(V)–V plots of the AuAgCu (2:1:1)/n-Si/Ti, AuAgCu (1:2:1)/n-Si/Ti and AuAgCu (1:1:2)/n-Si/Ti diodes as a function of ageing time. From the F(V)–V plots, some parameters of the AuAgCu (2:1:1)/n-Si/Ti, AuAgCu (1:2:1)/n-Si/Ti and AuAgCu (1:1:2)/n-Si/Ti diodes, (Φb, Rs) have been determined. These parameters calculated from Norde functions are given in Table 2 for all three diodes.

TABLE 2.

THE PARAMETERS CALCULATED FROM NORDE METHODS OF THE AUAGCU (2:1:1)/N-SI/TI, AUAGCU (1:2:1)/N-SI/TI AND AUAGCU (1:1:2)/N-SI/TI DIODES WITH RESPECT TO INCREASING AGING TIME.

Norde methods						
	AuAgCu(2:1:1)/nSi/Ti		AuAgCu(1:2:1)/nSi/Ti		AuAgCu (1:1:2)/nSi/Ti	
Time (day)	Φ_B (eV)	R_s (Ω)	Φ_B (eV)	R_s (Ω)	Φ_B (eV)	R_s (Ω)
immediately	0,606	3,174	0,661	6,767	0,615	4,414
1	0,606	3,247	0,677	6,406	0,621	5,470
7	0,610	3,837	0,740	8,135	0,657	5,749
15	0,613	4,614	0,776	8,431	0,675	6,751
30	0,621	6,468	0,785	25,614	0,695	6,913
90	0,647	8,737	0,792	36,221	0,717	19,456
180	0,635	11,499	0,797	45,452	0,709	27,298
365	0,649	21,296	0,796	54,675	0,715	37,513

The series resistances of the AuAgCu (2:1:1)/n-Si/Ti, AuAgCu (1:2:1)/n-Si/Ti and AuAgCu (1:1:2)/n-Si/Ti diodes increase with increasing aging time. These changes can also be attributed to new formations in the interfaces.

4 Conclusions

Alloys of different proportions (2: 1: 1, 1: 2: 1, 1: 1: 2) were obtained from Au, Ag and Cu metals. Using these alloys, AuAgCu (2:1:1)/n-Si/Ti, AuAgCu (1:2:1)/n-Si/Ti and AuAgCu (1:1:2)/n-Si/Ti alloy / semiconductor diodes were obtained. Diode parameters were calculated from current voltage measurements of these diodes and their changes due to aging were examined.

As a result, changes in diode parameters were observed in alloy / semiconductor diodes due to differences in metal ratios in alloys. In addition, alloy / semiconductor diodes exhibited stable structures for 365 days. Alloy / semiconductor diodes can be used safely as an alternative to metal / semiconductor diodes.

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