INVESTIGATION OF POTENTIAL BARRIER HEIGHT OF SCHOTTKY DIODE Al-TiCu/n-Si

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Al-TiCu/*n*-Si diodes with polycrystalline metallic film obtained by the method of magnetron sputtering and satisfying to demands of diode theory, have been investigated in temperature interval 298-458K. Diode matrix has 14 diodes the dimensions of which change from $1\cdot10^{-6}$cm^2 up to $14\cdot10^{-6}$cm^2. In spite of current change on several orders at voltage change in range (0,1- 0,5)V, the VAC deflection on electron emission theory is observed. The barrier height is defined by several methods. The dependence of barrier height on temperature and diode geometrical sizes has been revealed. The heterogeneity on barrier height is investigated with application of Gaussian distribution. The values of potential barrier height $\overline{\Phi}_{bo}$ = 0,59 eV and deflection parameter σ_0 =0,088V have been defined on the base of dependence of barrier height Φ_{B0} at zero correction.

INTRODUCTION

The semiconductor diodes on the base of Schottky barrier because of its many advantages [1-3] are used in integrated circuits last years. Meanwhile, the tracing technology of single crystalline metal films is connected with carrying out of many complex operations [4]. The polycrystalline metal films are characterized by grain small dimension and consequently, by large length of grain boundary because of which they have the set of physical-mechanical properties [5-7]. The cheapness and easy accessibility of technological process and also interesting electro-physical properties caused by metal structure present the interest for formation of new instruments and elements of electronic circuits of low dimensions working in narrow range of contributor change [7-8].

The goal of present paper is to define the “real” value of barrier height of Schottky barrier Al-TiCu/n-Si. The diodes are obtained by methods of alloy magnetron sputtering on semiconductor substrate (Si(111), ρ=0,7Omcm) [8]. The diode matrix has 14 diodes the areas of which vary from $1\cdot10^{-6}$см^2 up to $14\cdot10^{-6}$см^2. In the present paper the investigation results of diodes №1, №3 и №13 are presented.

RESULTS AND DISCUSSION

According to theory of thermal electron emission (TEE), the current dependence on voltage for CMS is described by expression [1-5, 9-11]:

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

where I_0 is saturation current obtained from obtained from characteristic cutoff *ln I-V* at *V=0*:

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

A is diode area, A^* is Richardson constant (264 A cm^{-2} K^{-2} for n-Si (111)), Φ_{B0} is barrier height at zero shift. The idealness index *n* is defined by expression (1), as:

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

We obtain VAC of Schottky diodes Al-TiCu/n-Si for all samples in temperature interval (298-458)K at direct (0,1-0,5)V and reversal (0,1-15)V shift correspondingly (fig.1).

As a result of carried investigations it is observed the VAC deviation from characteristics inherent in “ideal” CMS that is obviously caused by interface heterogeneity [6]. The step dependence lnI-V doesn’t allow us determinating of barrier height for whole range of applied voltage. The height of potential barrier and idealness index are defined from dependence linear part. The dependence of obtained values Φ_{B0} and *n* on temperature and contact geometric sizes has been revealed. Temperature dependence of electric characteristics of many CMS described in [9,12], deviation of barrier height and idealness index on TEE especially at low temperatures show that standard TEE can’t totally explain the given phenomena [13].

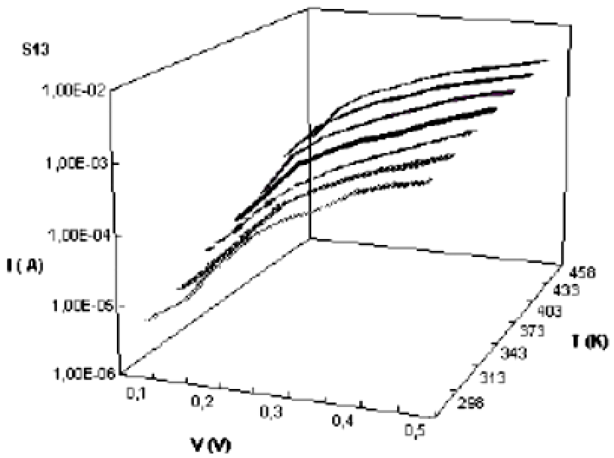


Fig.1. VAC of Al-TiCu/n-Si diode (№13) at direct shift.

According to Schottky theory in ideal contact metal-semiconductor, the potential barrier height is defined by difference of metal work functions of contacting materials [1-5]. From papers it is known that metal work function depends on its nature, structure and surface contamination factor

[7,14]. Moreover, the work function of polycrystalline film depends on surface coordinate and is expressed by formula:

$$\Phi_{aver.} = \frac{1}{S}\int_s \Phi(y,z)dydz \qquad (4)$$

In such case we can say that CMS barrier height with polycrystalline metallic film changes from point to point along whole contact area. The deviations from classic theory of thermo-electronic emission are investigated by different authors [3,5,10-13]. In Tung's article for explanation of usually observable deviations [15,16], the heterogeneous interface is considered as system of discrete regions or "ways" of low barriers introduced in regions of more high barriers. Song and other authors [17] have introduced the analytical model of potential fluctuations. Schmitsdorf and others [18,19] have used Tung theoretical approach and found the linear correlation between experimental BH value and idealness index. The BH dependence on idealness index for Al-TiCu/n-Si diodes obtained by experiment is shown on fig.2. The extrapolation of dependence to n=1 gives the height of homogeneous barrier 0.54eV, 0.5368eV and 0.535eV correspondingly for diodes №1, №3 and №13. However, as it is seen from fig.2 there is no correlation between obtained values.

Considering the contact as many parallel diodes with different BH which independently promote to current transfer, the total current through Schottky diode with heterogeneity on BH can be expressed in following form [3]:

$$I(V) = \int_{-\infty}^{+\infty} I(\Phi_b, V)P(\Phi_b)d\Phi \qquad (5)$$

where $I(\Phi_b, V)$ current at V shift for SchD, based on ideal TEE and $P(\Phi_b)$ (normalized distribution function giving the accuracy probability for barrier height).

The contact characteristics presenting itself the system of discrete regions with different barrier heights is obtained on the base of potential fluctuation model [3,9,17,19] after average of spatially heterogeneous on interface parameters. For this usually one can use the general rule of finding of average value if distribution function of P value on surface is given, and the supposition that BH is satisfied to normal distribution law (Gauss distribution):

$$P(\Phi_b) = \frac{1}{\sigma_0\sqrt{2\pi}}\exp\left(-\frac{(\Phi_b - \bar{\Phi}_b)^2}{2\sigma_0^2}\right) \qquad (6)$$

where $\frac{1}{\sigma_0\sqrt{2\pi}}$ is normalization constant of Gauss distribution of BH. Φ_{B0} is barrier height, σ_0 is deviation parameter. The total current $I(V)$ through Schottky barrier at V shift is defined by the following expression [3,9,19]:

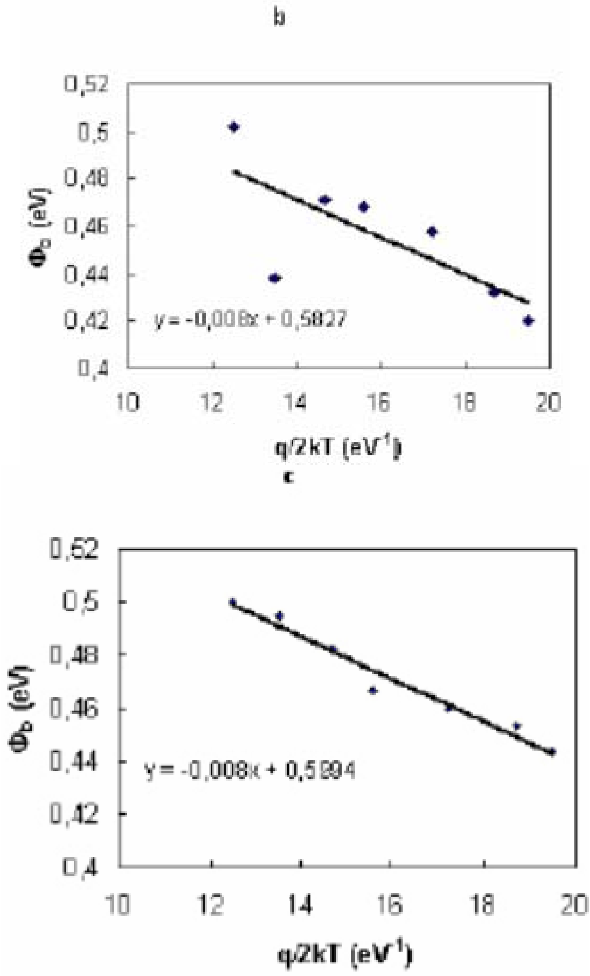


Fig.2. Linear dependence of BH on idealness index at different temperatures (a is №1, b is №3, c is №13).

$$I(V) = AA^*T^2\exp\left[-\frac{q}{kT}\left(\bar{\Phi} - \frac{q\sigma_0^2}{2kT}\right)\right]\exp\left(\frac{qV}{nkT} - 1\right) \qquad (7)$$

The supposition on Gauss distribution of BH values leads to the following expression for barrier height [3,9,19]:

$$\Phi_b = \overline{\Phi}_{bo} - \frac{q\sigma_o^2}{2kT} \qquad (8)$$

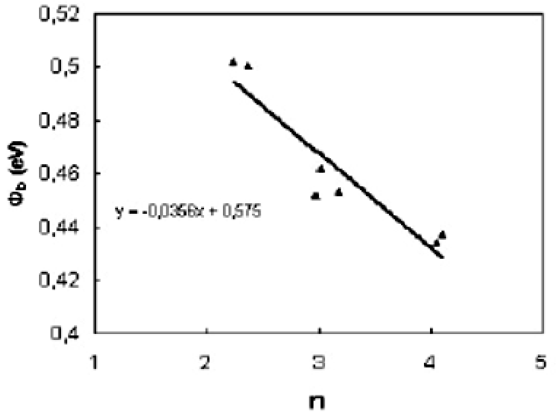
where $\overline{\Phi}_{bo}$ is average barrier height at zero shift, σ_0 is standard deviation at zero shift.

On the fig.2 BH dependence Φ_b on $q/2kT$ at zero shift is defined by direct line the extrapolation of which has the following values $\overline{\Phi}_{bo}(T=0)$ and σ_0.

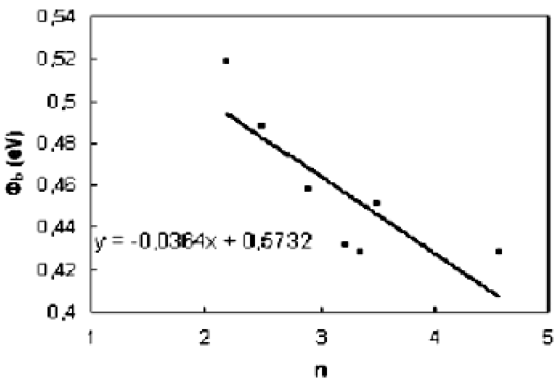
The values $\overline{\Phi}_{bo}$ and σ_0 are equal to 0.59eV, 0.58eV, 0.599eV and 0,088V, 0,089V, 0,089V correspondingly. The barrier height values obtained by Gauss method exceed the values obtained by other calculation methods. The deviation parameter σ_0 testifies on heterogeneous barrier. As it is seen from carried out investigations it is impossible to define the barrier height of Al-TiCu/n-Si diode uniquely.

Taking into consideration the polycrystalline structure of metal film CMS Al-TiCu/n-Si we can conclude that contact heterogeneity is caused by granular structure of metal film.

a



b



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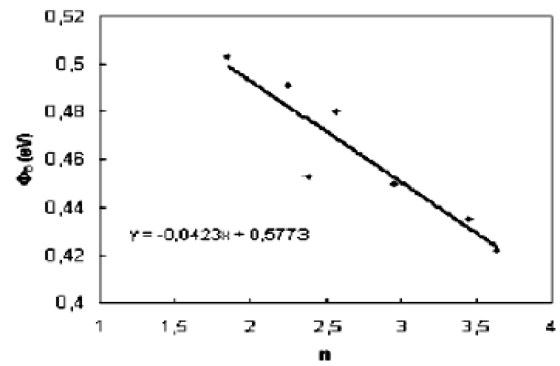

Fig.3. The dependence BH at zero shift Φ_b on $q / 2kT$ for SchD Al-TiCu/n-Si according to Gauss distribution (a is №1, b is №3, c is №13).

CONCLUSION

The parameter analysis SchD Al-TiCu/n-Si reveals the temperature dependence of barrier height and idealness index that testifies about heterogeneity of interface. The fluctuations of barrier height in these SchD are explained to some extent by supposition of BH Gauss distribution. Obtained by given investigations the BH values $\overline{\Phi}_{bo}(T = 0)$ and parameter of standard deviation σ_o change in the following region (0.58-0,59)eV and (0.088 - 0,089)V correspondingly. The parameter dependence on contact geometric sizes is observed. The parameter fluctuations are most probably caused by the polycrystalline structure of metallic film.

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Al-TiCu/n-Si ŞOTTKİ DİODU POTENSİAL BARYERİN HÜNDÜRLÜYÜNÜN TƏDQİQİ

Maqnetron tozlanma üsulu ilə alınmış diod nəzəriyyəsinin tələblərini ödəyən polikristal metal təbəqəli Al-TiCu/*n*-Si diodları (298-458)K temperatur oblastında tədqiq edilmişdirlər**.** Diod matrisi sahələri $1\cdot10^{-6}$sm^2 -$14\cdot10^{-6}$sm^2 intervalında dəyişən 14 dioddan ibarətdir. Gərginlik (0,1 -0,5)V diapazonunda dəyişdikdə cərəyanın qiyməti bir neçə tərtib dəyişməsinə baxmayaraq volt-amper xarakteristikalarının termoelektron emissiya nəzəriyyəsindən kənara çıxması müşahidə olunur. Baryerin hündürlüyü bir neçə metodla hesablanmışdır. Baryer hündürlüyünün temperaturdan və diodun həndəsi ölçülərindən asılılığı aşkar edilmişdir. Baryer hündürlüyünün qeyri-bircinsliyi Hauss normal paylanmasının tətbiq edilməsilə hesablanmışdır. Potensial baryer hündürlüyü Φ_{B0} -nin $1/2kT$ -dan asılılığı əsasında potensial baryerin hündürlüyü ($\overline{\Phi}_{bo}$ = 0,59eV) və kənaraçıxma parametri hesablanmışdır σ_0 =0,088V.

И.М. Эфендиева

ИССЛЕДОВАНИЕ ВЫСОТЫ ПОТЕНЦИАЛЬНОГО БАРЬЕРА ДИОДА ШОТТКИ Al-TiCu/n-Si

Диоды Al-TiCu/*n*-Si с поликристаллической металлической пленкой, полученные методом магнетронного распыления и удовлетворяющие требованиям диодной теории, были исследованы в области температур 298-458K. Диодная матрица содержит 14 диодов, размеры которых изменяются от $1x10^{-6}$см^2 до $14x10^{-6}$см^2. Несмотря на изменение тока на несколько порядков, при изменении напряжения в диапазоне (0,1- 0,5)В наблюдается отклонение ВАХ от теории термоэлектронной эмиссии. Высота барьера определена несколькими методами. Выявлена зависимость высоты барьера и коэффициента отклонения от температуры и геометрических размеров диодов. Неоднородность по высоте барьера исследована с применением нормального распределения Гаусса. На основе зависимости высоты барьера Φ_{B0} при нулевом смещении от $1/2kT$ определены значения высоты потенциального барьера $\overline{\Phi}_{bo}$ = 0,59 эВ и параметра отклонения σ_0 =0,088В.

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