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Electrical, structural and morphological properties of Ni/n-Si contacts

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This paper presents structural, morphological and electrical properties of Ni/n-Si contacts formed by electro-deposition technique. Ni film is deposited on n-type Si (100) substrate using 2 mol/L Nickel Sulphamate, 0.5 mol/L Boric Acid solutions. The morphological properties are investigated by using energy dispersive X-Ray analysis and scanning electron microscopy imaging to perform local distribution of Ni. Electrical measurements have been done at room temperature to investigate the Schottky barrier height.

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1. Introduction

Schottky barrier diodes (SBDs) are widely used in semiconductor technology such as electronic and optoelectronic applications [1-5]. The most important aspect characterizing the SBD is its barrier height (BH).

In the recent years, different methods, vacuum deposition and electro-deposition, for metallization of silicon surfaces are utilized. Electro-deposition method is more suitable than vacuum evaporation due to its valuable advantages, e.g. low costs and low temperatures. Properties of an electro-deposited film may be affected by many parameters, such as bath type and deposition potential [6].

Some researchers have been applied electro-deposition to produce SBDs [7,8]. Guler et al. concluded that electro-deposited Ni/n-Si samples allowed meaningful extra-polation to n=1 to determine the laterally homogeneous BH. They also obtained laterally homogeneous BH value of approximately 0.69 eV. Ahmetoglu et al., investigated electrical properties of Cu/n-Si formed by electro-deposition. They measured the ideality factor *(n)* and zero bias barrier height (ϕ_{B0}) 1.62 and 0.59 eV respectively.

The aim of the present investigation is to determine structural, morphological and electrical properties (*I-V* measurement, BH and rectification coefficient) of electro-deposited Ni/n-Si SBDs.

2. Experimental

One-sided polished n-Si (100) samples, phosphorus-doped, 1-20 Ω-cm ($N_D = 10^{15}$cm^{-3}) are used as substrate [8].

Ni film is deposited on n-type Si (100) substrate using 2 mol/L Nickel Sulphamate (99.0% purity), 0.5 mol/L Boric Acid (99.5-100.5% purity) solutions.

The current-voltage (*I-V*) measurements are performed using a KEITHLEY 2400 voltage source at room temperature. All measurements are controlled by a computer via an IEEE-488 standard interface so that the data collecting, processing and plotting can be accomplished automatically.

Ni electro-deposited Si surfaces observation are performed using Carl Zeiss EVO 40 type SEM operated at 10 kV. Structural investigation is achieved Bruker AXS Microanalysis energy disperse X-ray (EDX) analysis operated at 10 keV with XFlash 4010 detector.

3. Results and discussion

3.1. I-V Measurements

The electrical characterizations of the device are achieved through *I-V* measurement at room temperature. The formation of a Schottky barrier between a Ni layer and n-doped Si (100) at room temperature is shown in Fig. 1.

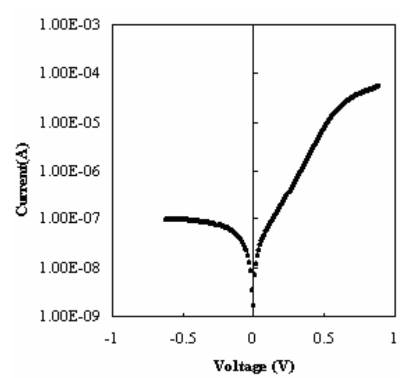

Fig.1. The experimental forward and reverse bias current vs. voltage characteristics in a semilog scale of Ni/ n-Si SBDs at room temperature.

The reverse and forward currents of diodes demonstrate that the rectifying properties and the rectification coefficient are 101.2. The current through a Schottky barrier diode at a forward bias V, based on the thermionic emission theory, is given by the relation [9]:

$$J = J_0 \exp\left(\frac{qV}{nkT}\right)\left[1-\exp\left(\frac{qV}{kT}\right)\right] \tag{1}$$

here, J_0 is the saturation current density is given by

$$J_0 = A^*T^2 \exp\left(-\frac{q\phi_{B0}}{kT}\right) \tag{2}$$

where q, V , k, T and A are the electron charge, forward bias voltage, Boltzmann constant, absolute temperature, effective diode area respectively. $A^*=4\pi qm^*k^2 / h^3$ is the effective Richardson constant of 110 A/cm^2K^2 for n-type Si, ϕ_{B0} is the zero bias apparent BH and n is the ideality factor. The ideality factor is calculated from slope of the linear region of the forward bias ln J -V plot and can be written from Eq. (1) as:

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

The zero-bias barrier height ϕ_{B0} is given by:

$$\phi_{B0} = \frac{kT}{q}\ln\left(\frac{A^*T^2}{J_0}\right) \tag{4}$$

The experimental values of ϕ_{B0} and n are determined from intercepts and slopes of the forward ln$J$ vs. V plot, respectively. The experimental values of 1.14 and 0.48±0.02 eV is obtained for the ideality factor (n) and zero bias barrier height (ϕ_{B0}) of diodes Ni/n-Si, respectively. The obtained value of the zero bias barrier height (ϕ_{B0}) is good correlation with [1].

3.2. Morphological Investigation

The microstructures of Ni electro-deposited n type Si are illustrated in Fig. 2a-2b with different magnifications. The Ni is distributed uniformly but as irregular shaped volumes embedded in the matrix. The irregular shaped volumes are related to the deposition time, applied current, electrolyte pH and the deposition potential.

Fig. 3 shows EDX analysis micrograph. The obtained spectrums at signed area onto micrograph demonstrated that in microstructure Ni, O, C, N, S have been observed. These grades are labelled also in Fig. 4.

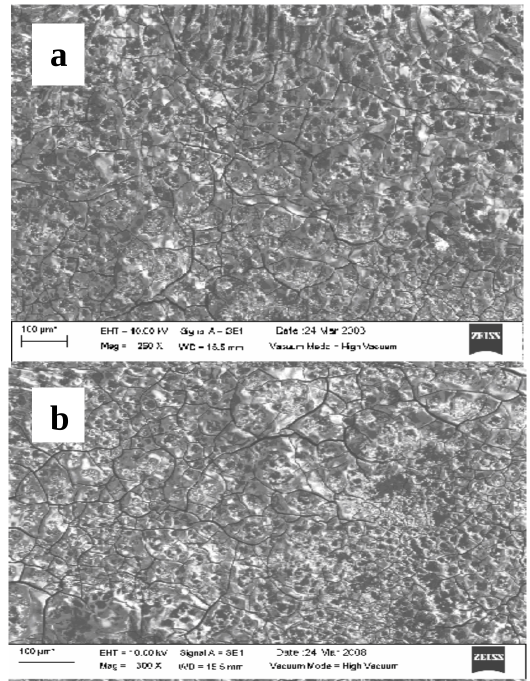

Fig. 2a-2b. SEM micrographs of the microstructures of Ni electro-deposited onto n-Si samples different microstructure fields.

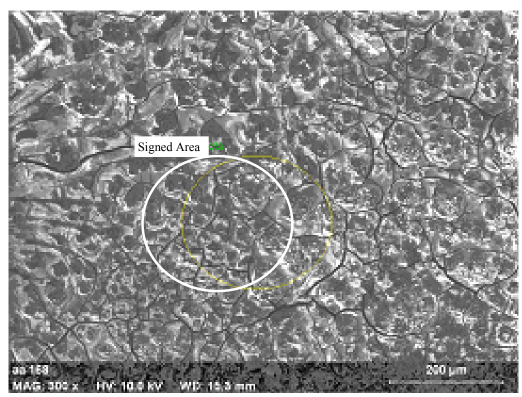

Fig. 3. EDX analysis applied field.

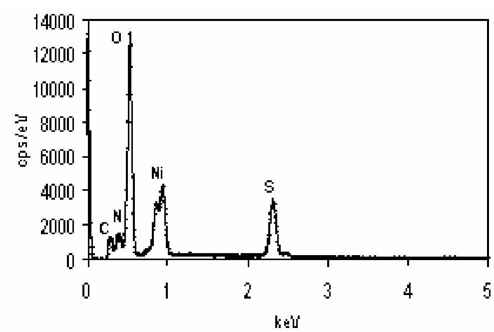

Fig. 4. EDX patterns of Ni/n-Si SBDs.

4. Conclusions

In the present work, we investigated the main electrical properties of the SBDs formed by electrodeposition of Nickel onto n-Si (100) from 2 mol/L Nickel Sulphamate, 0.5 mol/L Boric Acid solutions, through the zero bias BH, the ideality factor *(n)*, by using current-voltage (*I–V*) characteristics. The experimental values of 1.14 and 0.48±0.02 eV obtained for the ideality factor (*n)* and zero bias BH (ϕ_{B0}) of Ni/n-Si SBDs, respectively. The morphological investigations show that the final microstructure of the Ni/n-Si SBDs revealed irregular shapes due to different current and potentials used

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