Journal of Al-Nahrain University Vol.16 (1), March, 2013, pp.79-83 Science

Fabrication and Characteristics Study Ni-nSiC Schottky Photodiode Detector

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Abstract

In the present work, schottky photodiode have been mode on n-type SiC by depositing of thin layer of Ni. Electrical characteristics included I-V (dark and illumination) have been investigated. Ideality factor is 2.9 and barrier height is 0.52 eV was calculated from I-V and Isc-Voc characteristics, Ideality factor is 2.32 and barrier height found to be 0.54 eV, and from optoelectronic characteristics have found sensitivity results show that peak response of photodiode was 550 nm. The maximum value of Specific detectivity D^*reached (1.6×10^{11} w^{-1} $Hz^{1/2}$ cm).

Keyword: photodiode, SiC, Schottky contact, Thin films.

Introduction

One very interesting semiconductor material is silicon carbide. Silicon carbide is a promising material, in comparison with Si, for high-power, high-frequency and high-temperature electronics [1-2]. This material is characterized by a wide band gap, high thermal and chemical stability and the property to crystallize in different structural modifications. The material has extremely high thermal conductivity, can withstand high electric fields before breakdown and also high current densities. The wide band gap results in a low leakage current even at high temperatures and the gap of SiC depends on the present poly-type [3]. SiC thin polycrystalline or epitaxial films on SiC have also attracted considerable interest for solar cells or high power heterojunction devices. Moreover, SiC is an advantageous substrate material for SiC films in comparison to Si because of the considerable lower costs, larger wafers and the established technology, [4, 5]. All the properties mentioned above make SiC promising as a power device material. The electro-technical industry, with applications at high voltages could thus in the future advantageously replace Si power transistors, thyristors and rectifiers with SiC devices [6,7].

The successful use of the Schottky Photodetector structure depends on strict control of the metal-semiconductor interface. Among several types of photodetectors, Schottky photodiodes are particularly attractive due to their unipolar structure. Schottky detectors are majority carrier devices and do not suffer from minority carrier diffusion, which makes them suitable for high-speed applications. The ease of growth and fabrication is another advantage of Schottky photodiodes. Schottky diodes with relatively lower leakage current and on-resistance compared to Si Schottky diodes can be fabricated on SiC. These Schottky diodes have the potential to be a valuable alternative to Si-based switching devices for applications where both power and speed need to be delivered. We have consistently achieved good results with this approach [3].

Experimental

In this experiment, 3C-SiC wafer with 100µm thick and n-type conductive was used as substrate, the SiC wafers were chemically etched in dilute hydrofluoric acid to remove native oxides, high purity Ni about 99.99% are used to deposition on SiC. The evaporation chamber was evacuated to 10^{-6} torr using (BALZER BAE 370).in university of technology Baghdad in order to ensure the evaporation homogeneity, the heating temperature was gradually scaled by 50°C step until the Ni began to vaporize. After 15 minutes, the system was turned off and 50nm thick Ni film (using optical method) were deposited on the SiC substrate in $0.25cm^2$ area were fabricated by photolithographic patterning and lift off. Then, this procedure was repeated to deposit Al-metal on SiC by same technology above to make back-side contact, Samples were kept in an evacuated vessel before they were tested.

Electrical measurement include I-V, in dark conditions were carried out at 300k, I-V characteristic under illumination (120W halogen lamp) were investigated using potential sweeper. The spectral responsivity was measured in range spectral 400-900 nm with aid monochramator and electrometer after making power calibration.

Results and Discussions

The forward and reverse current–voltage (I-V) characteristics measured for quantitative determination of Schottky diode parameters such as the Schottky barrier height, the ideality factor, the effective area-Richardson's constant product, and the series resistance of the diodes. The relationship under thermionic emission theory is given by [8].

$J = J_s\,[\exp(qV/\eta KT) - 1]$ ....(1)

Where η is the ideality factor and J_s is Saturation current density, k is Boltzmann constant, T is Absolute temperature, J is current density. If the applied voltage V is much larger than (KT/q), then the exponential term in the above equation dominates, and can be approximated as

$J = J_s[\exp(qV / \eta KT)]$.....................................(2)

where

$J_s = A^* T^2 \exp(-q\Phi_{Bn} / k_s T)$.............................(3)

Φ_{Bn} is High barrier voltage semiconductor-metal connection and A^* is the Richardson constant = 72 $A/cm^2\,K^2$ [9]. The value of J_s is determined by extrapolating the straight-line region of I-V plot into the point V = 0, and the saturation current density is 0.005 A/cm^2 and the value of Φ_{Bn} is 0.52 eV was extracted from eq. (3). Semi-log I-V plot under forward bias for Al-nSiC is presented in Fig. (1).

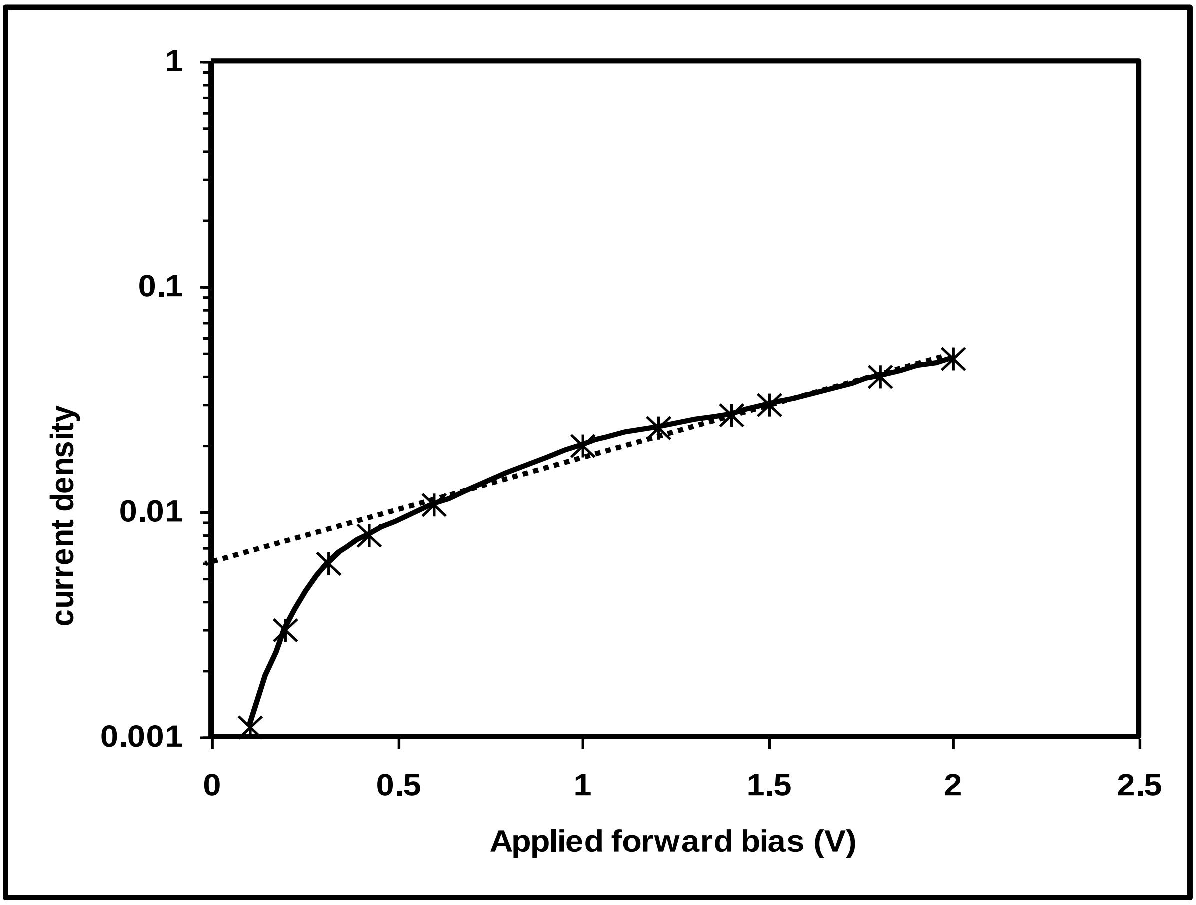

Fig.(2) Jsc-Voc Characteristics of Ni -nSiC Contact.

Fig.(2) illustrates the variation in the open-circuit voltage (V_{oc}) against the short-circuit current density (J_{sc}). The linear variation enables one to determine J_o and corresponding value of Φ_{Bn}, the ideality factor (n) and saturation current density can be found from the following eq.[8]

$V_{oc} = (\eta K_B T/q)\ \mathrm{In} J_{sc} - (\eta K_B T/q)\mathrm{In} J_o$..............(5)

The value of Φ_{Bn} is 0.54 eV and The ideally factor is to be 2.32 According to Schottcky model, the barrier height of MS contacts is given by [8]:

$\Phi_{Bn} = \Phi_m - X_s$ ....(6)

where X_s is the electron affinity of the semiconductor, and Φ_m is the metal work function. Thus, the theoretical barrier height of Ni -nSiC is 0.38 eV. This result differs from our experience.

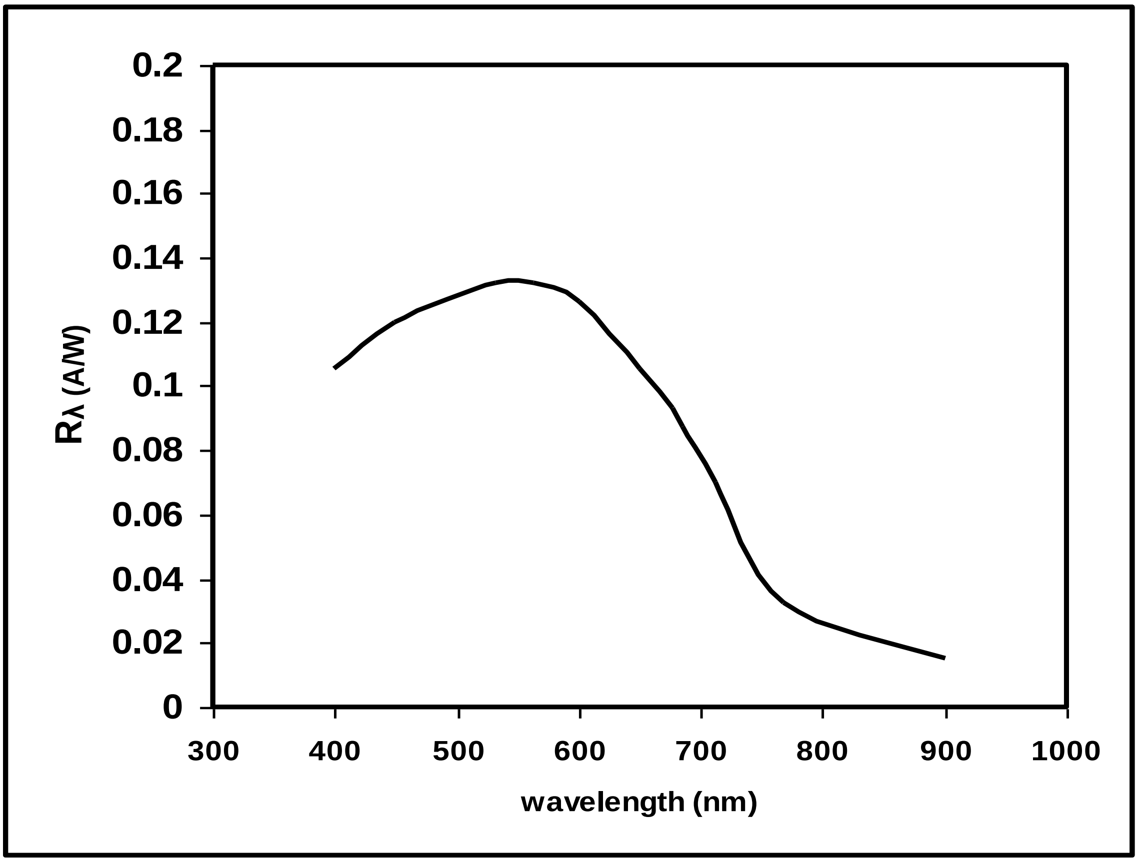

Fig.(3) Spectral responsivity of the Ni -nSiC contact.

Fig.(3) show spectral responsivity of this junction. The figures illustrate peak response at 550 nm which corresponds to the silicon carbide absorption. On the right side of the peak, responsivity shows down which is due to the contribution of Al layer, while the slow fall-down at the left side of the peak is a result of deep absorption in the bulk of the silicon carbide.

Fig. (4) Shows the variation of the specific detcctivity D^* as function of wavelength.

$D^* = R_\lambda (A\Delta f)^{1/2}/I_n$ ....(7)

R_λ: Spectral Responsitivity, A:area of detector, In: nosie current, Δf" :band width frequency.

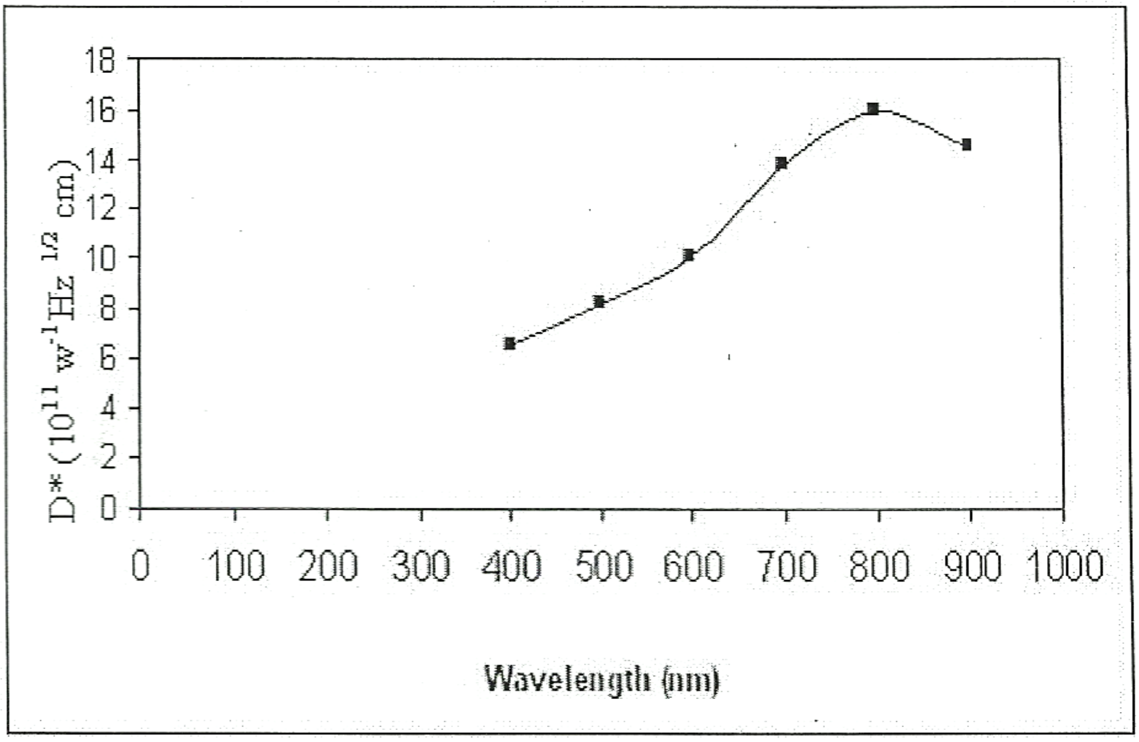

Fig.(4) Curve of changing specific detectivity D^*as function of Wavelength.

Conclusions

Experimental study for near ideal Ni -nSiC contact shows that barrier height does not obey the simple theory proposed by Schottky model, Because of the effect of series resistance contact. The calculated barrier height ΦBn and ideality factor η from illuminated Jsc-Voc plot was different from that obtained from dark J-V plot.

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الخلاصة

في هذا البحث جرى ترسيب معدن النيكل على طبقة من كاربيد السليكون بعدها تم دراسة الخصائص تيار–جهد في حالة الظلام والإضاءة و تم حساب ارتفاع حاجز الجهد ويساوي 0.52eV وعامل المثالية 2.9 من خصائص تيار جهد في حالة الظلام ومن فولتية الدائرة المفتوحة V_{oc} وتيار الدائرة القصيره I_{sc} تم حساب ارتفاع حاجز الجهد ويساوي 0.54eV وعامل المثالية 2.32 ومن دراسة الخصائص الكهروبصرية وجد ان للكاشف قمة استجابية عند الطول الموجي 550 nm. اما اعلى قيمة في مقدار الكشفية النوعة D^* فقد بلغت بحدود (1.6×10^{11} w^{-1} $Hz^{1/2}$ cm).