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Temperature dependence of current-and capacitance–voltage characteristics of an Au/4H-SiC Schottky diode

Murat Gülnahar *

Erzincan University, Vocational School, Department of Electrics, 24100 Erzincan, Turkey

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ABSTRACT

In this study, the current–voltage (*I–V*) and capacitance–voltage (*C–V*) measurements of an Au/4H-SiC Schottky diode are characterized as a function of the temperature in 50–300 K temperature range. The experimental parameters such as ideality factor and apparent barrier height presents to be strongly temperature dependent, that is, the ideality factor increases and the apparent barrier height decreases with decreasing temperature, whereas the barrier height values increase with the temperature for *C–V* data. Likewise, the Richardson plot deviates at low temperatures. These anomaly behaviors observed for Au/4H-SiC are attributed to Schottky barrier inhomogeneities. The barrier anomaly which relates to interface of Au/4H-SiC is also confirmed by the *C–V* measurements versus the frequency measured in 300 K and it is interpreted by both Tung's lateral inhomogeneity model and multi-Gaussian distribution approach. The values of the weighting coefficients, standard deviations and mean barrier height are calculated for each distribution region of Au/4H-SiC using the multi-Gaussian distribution approach. In addition, the total effective area of the patches NA_e is obtained at separate temperatures and as a result, it is expressed that the low barrier regions influence meaningfully to the current transport at the junction. The homogeneous barrier height value is calculated from the correlation between the ideality factor and barrier height and it is noted that the values of standard deviation from ideality factor versus $q/3kT$ curve are in

* Tel.: +90 0446 2266603; fax: +90 0446 2266615.
E-mail address: mgulnahar@erzincan.edu.tr

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close agreement with the values obtained from the barrier height versus $q/2kT$ variation. As a result, it can be concluded that the temperature dependent electrical characteristics of Au/4H-SiC can be successfully commented on the basis of the thermionic emission theory with both models.

1. Introduction

SiC is an indirect wide band-gap semiconductor material with a compound structure which belongs to IV–IV group in the periodic table. The electronic devices based on SiC have special importance technologically due to its useful capabilities such as high electron saturation drift velocity, high thermal conductivity, wide band-gap of 2.9 eV and large critical breakdown electric field [1–3]. In addition, SiC is resistant to chemical attacks and radiation effects due to the large Si–C bonding energy. This property of SiC ensures its stability at high temperatures. It is an attractive material for high power microwave applications, high power-high voltage switching applications, high radiation environments, high temperature electronics, high corrosion and high frequency device applications due to these excellent structural capabilities [4–6].

Compared with traditional Si, SiC has many superior advantages due to its electrical, chemical, thermal and mechanical properties, and it is considered as a semiconductor material that will turn silicon power technology into smart power. In result, SiC with this natural structure have received much attention and have become a swiftly developing semiconductor compound. The number of studies over electrical, optical properties and device applications of SiC keeps increasing in the electronic materials based on SiC Schottky diode. In consequence, the fabrication of electronic devices such as thyristors, metal–oxide–semiconductor field effect transistors (MOSFETS), pin diodes, insulated gate bipolar transistors (IGBTS) including SiC are processed successfully [5,7–10].

SiC Schottky rectifiers are the charming electronic devices of last decades and, considerable amount of research have been carried out on their electrical transport properties. However, the current transport properties of SiC remain still as a topic which is interested. In the literature, it is seen frequently that the researches connected with SiC Schottky rectifiers have majored on 4H-SiC [11–24] and 6H-SiC [15,25–28]. However, 4H-SiC is preferred due to the isotropic nature of its electrical properties, and the fact that, the electron mobility of 4H-SiC is twice that of 6H-SiC [4,29].

Although SiC have some inert physical advantages mentioned above, it has a lower crystal quality than that of silicon in industrial applications. It is considered that the doping inhomogeneities, dopant clustering contaminations, defects, dislocations, comets, micropipes and inclusions of different polytypes in the epitaxial layers existing in SiC and/or even in the other some semiconductors are responsible for Schottky barrier inhomogeneities. Moreover, these effects affect device performance or cause failures [30,31]. Schottky barrier inhomogeneities can influence Schottky barrier parameters extracted from I–V measurements due to poor Schottky interface quality of diode. As a result, C–V barrier height value exceeds the value deduced from I–V data. Already, in some papers, it is reported that this discrepancy is attributed to the existence of Schottky barrier inhomogeneities [32–34].

The quality of the metal/semiconductor interface influences strongly the electrical behaviors of a SiC Schottky contact. Also, each Schottky barrier is suitable for formation of the mechanisms such as the tunneling, generation–recombination and image force lowering and it is clear that these factors cause the barrier anomalies [32–35]. Due to these barrier inhomogeneities, the potential distribution of the interface enables the variation with bias of the parameters such as interface state density, barrier height and ideality factor. Moreover, it is seen that the characteristic of interface state density becomes an important research subject in literature [36–38].

So far, to depict Schottky barrier inhomogeneities are used two separate approaches. The first one is the single-Gauusian distribution approach developed by Werner and Güttler [34] on the basis of the