IOP Publishing Journal of Physics D: Applied Physics
J. Phys. D: Appl. Phys. **58** (2025) 195301 (12pp) https://doi.org/10.1088/1361-6463/adc7c4

Temperature-dependent parameters of spatially inhomogeneous heterojunctions single-walled carbon nanotubes/Si

L A Dronina[1], N G Kovalchuk[1], A L Danilyuk[1], E V Lutsenko[2], A V Danilchyk[2] and S L Prischepa[1,*]

[1] Belarusian State University of Informatics and RadioElectronics, P. Browka str. 6, Minsk 220013, Belarus
[2] Stepanov Institute of Physics of NAS Belarus, Nezavisimosti Av. 68, Minsk 220072, Belarus

E-mail: prischepa@bsuir.by

Received 24 January 2025, revised 23 March 2025
Accepted for publication 1 April 2025
Published 10 April 2025

Abstract

The influence of the inhomogeneities of single-walled carbon nanotube (SWCNT) film/Si Schottky barriers (SB) on their parameters was studied by measuring the current–voltage characteristics over a wide temperature range, from 20 K to 315 K. Data were analyzed both within the thermionic emission theory and its modification employing the Gaussian distribution of the SB height. The entire temperature range was divided into three sub-ranges for an adequate description of the experimental data. It was also necessary to consider the decrease in the effective area of the heterojunction, caused by the morphology features of the SWCNT film, and the increasing role of additional factors of current transport through the barrier, in addition to thermionic emission, with decreasing temperature.

Keywords: single-walled carbon nanotube thin film, Schottky barrier parameters, Gaussian distribution, Schottky barrier inhomogeneity, thermionic emission, I-V-T measurements, effective Richardson constant

1. Introduction

Carbon nanotubes (CNT)-based heterojunctions are the subject of intense research activity because of the wide range of phenomena they allow for study. For example, CNTs, owing to their unique optical, electrical, and chemical properties, have been widely investigated as components of field-effect transistors, photodetectors, solar cells, and gas sensors. Much effort has been devoted to improving the sensitivity of photodetectors by adopting thin films of CNTs [1–3]. Although multifunctional CNT-based heterojunction device architectures offer various promising functionalities [4–6], several fundamental issues of the interface between an array of CNTs and metal or semiconductors are still not well understood. In particular, the emerging interface charge states, surface roughness, loose contact of nanotubes to the material, and natural inhomogeneous oxide, all contribute to the distortion of the ideal picture of contact between the tubes and other materials. Understanding the properties of inhomogeneous heterojunctions leads to a unique opportunity to influence and control them. As a result, the study of new fundamental physics at the interface opens prospects for the creation of a new generation of carbon-based devices.

Semiconductor nanotubes in contact with a metal and metal nanotubes in contact with a semiconductor form a Schottky barrier (SB), the parameters of which can be estimated

* Author to whom any correspondence should be addressed.