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ORIGINAL ARTICLE

Properties of single-walled carbon nanotube film/Si heterojunctions fabricated in situ

L. A. Dronina[1] · N. G. Kovalchuk[1] · I. V. Komissarov[2] · A. L. Danilyuk[1] · V. A. Labunov[1] · E. V. Lutsenko[3] · A. V. Danilchyk[3] · P. I. Gaiduk[4] · Roman Sobolewski[2] · M. Salvato[5,6] · S. L. Prischepa[1]

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Abstract

Single-walled carbon nanotube (SWCNT) film/Si heterojunctions were obtained by depositing SWCNT films directly on a Si substrate by the floating catalyst chemical vapor deposition. The single-walled nature of the nanotubes was proven and confirmed by Raman and infrared spectroscopy, respectively. An additional ethanol post-growth treatment improved the properties of the heterojunctions by increasing densification of SWCNTs and decreasing their sheet resistance. Peaks positions of radial breathing mode obtained from the Raman mapping analysis demonstrated a random chirality (varying between armchair and zigzag) of tube structures and their very narrow diameter distribution, centered at ≈ 1.06 nm. This latter result was also confirmed by infrared spectroscopy. Properties of SWCNT/Si heterojunctions, such as ideality factor, Schottky barrier height, series resistance, SWCNT film work function and density of interface states are presented. To obtain the last two parameters by a self-consistent method, the intermediate nanolayer of silicon oxide between the SWCNT film and Si is considered. Impact of interface states and the native silicon oxide at the SWCNT/Si interface on the properties of heterojunctions is also discussed. Finally, such basic optoelectronic figures of merit as the responsivity, detectivity, and external quantum efficiency in the visible spectral range were determined and found to be comparable to the best reported for other SWCNT-based photodetectors.

Keywords Single-walled carbon nanotube thin film · Floating catalyst chemical vapor deposition · Raman spectroscopy · Schottky barrier · Work function · SWCNT-based photodetector

Introduction

A film of single-walled carbon nanotubes (SWCNTs) is a three-dimensional sample usually tens of nanometers thick, consisting of an intertwined mesh of single-walled nanotubes. While each of the tubes is characterized by its physical and electronic properties depending on the diameter and chirality, a distinctive feature of the mesh of tubes is the averaging of their properties over the ensemble (Wu et al. 2004). This characteristic makes it possible to consider a SWCNT film as an integral object, which strongly simplifies the interpretation of physical data. Among the great potential device applications of SWCNTs, one should especially note their prospects in photonic integrated circuits. This is due to several distinctive features of SWCNTs, such as low resistivity, high transparency in the visible and near-IR wavelengths (Wu et al. 2004), ability to deliver photoinduced charge carriers to the electrode at high speed (Rutherglen et al. 2009), possibility to tailor the Fermi level and conductivity by

✉ S. L. Prischepa
prischepa@bsuir.by

1 Belarusian State University of Informatics and RadioElectronics, P. Browka Str. 6, 220013 Minsk, Belarus

2 Department of Electrical and Computer Engineering, University of Rochester, Rochester, NY 146270231, USA

3 Stepanov Institute of Physics of NAS Belarus, Nezavisimosti Av. 68, 220072 Minsk, Belarus

4 Belarusian State University, Nezavisimosti Av., 4, 220030 Minsk, Belarus

5 Dipartimento di Fisica, Universita di Roma 'Tor Vergata', Via della Ricerca Scientifica 1, 00133 Rome, Italy

6 INFN, Universita di Roma 'Tor Vergata', Via della Ricerca Scientifica 1, 00133 Rome, Italy

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