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Effect of multiwalled carbon nanotubes incorporation on the performance of porous silicon photodetector

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ABSTRACT

In this study, porous silicon photodetectors incorporated with multiwalled carbon nanotubes MWCNTs were investigated. Anodization technique was used to fabricate porous silicon photodetectors at 16 mA/cm^2 for 15 min. The characteristics of porous silicon and MWCNTs were investigated by using x-ray diffraction XRD, atomic force microscopy AFM, Fourier transformation infrared spectroscopy FT-IR, photoluminescence PL, and scanning electron microscopy SEM, Dark and illuminated current-voltage I-V characteristics, capacitance-voltage characteristics C-V, spectral responsivity, specific detectivity, and minority carrier life time MCLT of photodetectors were investigated before and after incorporation. Significant improvement was noticed in photosensitivity and detectivity of the porous silicon photodetector after incorporating the MWCNTs into the porous matrix.

1. Introduction

Carbon nanotubes have stimulated great interest for photovoltaic applications because of their excellent optical and electronic properties, ability to tune their band gaps over a wide range by controlling the tube diameter [1]. Their high carrier mobility along their 1-D axes [2,3] and ballistic transport characteristics, CNT films have been considered as the best replacement for Si in future optoelectronic devices [4]. CNT is known to be an agglomerated material that will bundle together and entangle [5], therefore the homogeneous dispersion of CNTs into the host media, which can be in the form of liquid, is one of the major challenges encountered in the area of CNTs applications [6]. Porous silicon (PS) has become the material of favor for sensing applications due to low cost, low power consumption, and its compatibility with silicon-based technologies. It has been proven that the sensitivity of PSi depends upon the morphological characteristics of pores; including pores diameter and uniformity, regularity of the surface and the thickness of porous layer [7]. Extensive studies were reported on the performance improvement of porous silicon photodetectors [8]. Up to best of our knowledge, few data have been reported on enhancement of porous silicon photodetectors with aid of nanoparticles incorporation. Recently, Chou et al. [9] have reported an increased photosensitivity of porous silicon photodetector from 0.062 to 0.24 A/W at 1000 nm after embedding a porous layer with CdSe/CdS/ZnS quantum dots. In this paper, we report on the enhancement of performance of porous silicon photodetectors after incorporation with multiwalled carbon nanotubes.

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Fig. 1. Freshly prepared MWCNTs dispersed in DMF solution.

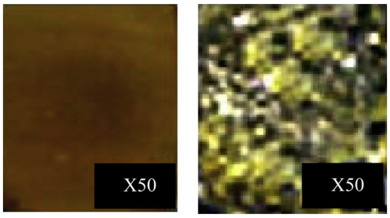

Fig. 2. Optical microscope images of porous silicon surface before incorporation (left) and after incorporation (right) with MWCNTs.

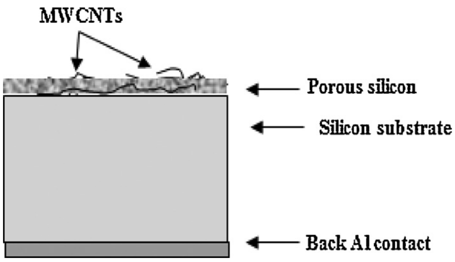

Fig. 3. Cross-sectional view of MWCNTs—incorporated porous silicon photodetector.

2. Experiment

All the chemicals used in this study were analytical grade. Mirror-like single crystalline Si substrates of 10 Ω cm electrical resistivity and (100) orientations were used in this study. The porous layer was prepared by electrochemical etching process. The substrates were cut into rectangles of (1.5 cm × 1.5 cm) areas. After chemical treatment on the backsides of the wafer, 0.1 μm thick high purity aluminum film was deposited by using thermal evaporation technique. Electrochemical etching was carried out by using a Teflon cell with an electrolyte containing 48% HF and 99.9% ethanol, 1:1 by volume. The silicon samples were etched at 16 mA/cm^2 for 15 min at room temperature. After anodization, the silicon samples were washed out with deionized water for 10 min and dried under N_2 ambient. 0.26 mg/mL (0.028 wt%) concentration MWCNTs powder with diameter (20–60 nm) and (10–15 μm) length; provided from NanoTech Labs, Inc.USA was dispersed in DMF by sonication for 24 h as shown in Fig. 1.

Drop casting technique was employed to incorporating the porous silicon (PSi) samples with MWCNTs. After solvent evaporation, the samples were heated at 90 °C under nitrogen to enhance the MWCNTs adhesion on the porous silicon surface. Fig. 2 illustrates porous silicon images before and after MWCNTs incorporation.

Fig. 3 shows a sketch of cross-sectional view of MWCNTs incorporated porous silicon photodetector. Structural, morphological and optical properties of porous silicon and MWCNTs were investigated by means of (CuKα) XRD-6000, Shimadzu x-ray diffractometer, Shimadzu SL 174 PL. spectrophotometer, Fourier transformation infrared spectroscopy, JEOL (JSM-5600) scanning electron microscopy, Angstrom AA 3000 atomic force microscopy and Cary 100 Conc plus UV–vis spectrophotometer. The spectral photosensitivity of the porous silicon photodetectors before and after incorporation with MWCNTs was measured in the range of 400–950 nm by using a monochromator. Sanwa silicon power meter was used for monochromator calibration. All the above characteristics were investigated at room temperature.