UNIVERSITI TEKNOLOGI MARA

THE SYNTHESIS OF VERTICALLY ALIGNED CARBON NANOTUBES ON NANOSTRUCTURED POROUS SILICON TEMPLATE BY IN-SITU CATALYST DOUBLE THERMAL CHEMICAL VAPOUR DEPOSITION METHOD

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ABSTRACT

Nanastructured porous silicon template (NPSiT) was successfully prepared from [100] orientation p-doped silicon (Si) substrate by photo-electrochemically anodization method with optimization parameters of etching time and annealing temperature while the rest of parameters were fixed. Uniform porous structures, optimum surface roughness and high intensity of photoluminescence (PL) of NPSiT as an optimized samples. The optimized NPSiT was used as template to synthesis vertically aligned carbon nanotubes (VACNT). VACNT were synthesized on NPSiT using double thermal chemical vapour deposition (DTCVD) method with camphor oil as carbon source and ferrocene (Fe) as a catalyst. The synthesis was carried out by the in-situ catalyst with floated method in a DTCVD reactor without any pre-treatment of catalyst. The process was called in-situ catalyst due to same vaporization point, 180 °C of camphor and ferrocene. High percentage of vertically aligned, smallest diameter, uniform length, high graphite crystallinity and high growth rate of VACNT on NPSiT has been successfully synthesized with short synthesis time at 15 min. Single-Walled Carbon Nanotubes (SWCNT) was found at 15 min synthesis time gave lowest I_D/I_G ratio. Parametric studies were done such as ratio of catalyst to carbon source, synthesis temperature and synthesis time to determine optimum parameter in obtain VACNT on NPSiT. Field emission scanning microscopy (FESEM), High Resolution Transmission Electron Microscopy (HRTEM), atomic force microscopy (AFM), Energy Dispersive X-Ray Spectrometer (EDX), Raman spectroscopy, PL emission, Fourier transforms infrared spectroscopy (FTIR), Field Electron Emission Measurements (FEE) were selected for characterization. The measurements were used to analyse the structural, morphological, bonding, optical and electrical properties of the nanomaterials. Growth mechanism of VACNT on NPSiT based on experimental observation was discussed. The CNT was growth at pores and pillar with a mixed top and bottom growth model has been proposed. The tip growth model was proposed grow inside the pore while valley growth model was proposed grow on pillar of NPSiT. An excellent potential application of camphor oil based VACNT on NPSiT as electron field emitter was demonstrated. Lower turn-on field of 2.80 $V\mu m^{-1}$ at 0.1 $mAcm^{-2}$ and threshold fields of 3.30 $V\mu m^{-1}$ at 1.0 $mAcm^{-2}$ while maximum current of 1.20 $mAcm^{-2}$ at low applied field of 4.40 $V\mu m^{-1}$ with good emission stability. It can be concluded that the VACNT from the bio-hydrocarbon precursor camphor oil synthesize on optimum NPSiT was stable for applications in field emission devices such as flat panel displays and LED.

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CHAPTER ONE

INTRODUCTION

1.0 NANOTECHNOLOGY

Recently nanotechnology is interpreted as a revolutionary discipline in terms of its possible impact on industrial applications. The original idea of nanotechnology was introduced by Nobel Laureate Richard P. Feyman in early of 1959. Nanotechnology focuses on the control of matter, materials and devices assembled under geometrical dimension that lie within the size range of 100 nanometer or smaller [1]. Two most prominent factors which cause the properties of nanomaterial to differ significantly from bulk materials are the increased in surface area per volume and quantum confinement effects. These factors can change or enhance nanomaterial properties which resulted in highly efficient material for electronic, optical, mechanical and chemical application [2, 3]. Based on the nanoscale dimension, nanomaterials are categorized as one-dimensional such as thin films or surface coatings, two-dimensional such as nanotubes and nanowires and three dimensional such as quantum dots.

Various porous templates are employed and the nanostructures are synthesized within the pores. The nanostructures can remain inside the pores of the templates or they can be as ensemble of free nanoparticles. Nanotubes and nanorods of various materials can be synthesized using a template-based approach. Polymers, metals, semiconductors, carbons and other materials have been deposited within pores templates [4]. Porous carbon-based materials have wide range of potential applications in many fields such as catalysis, sensing and composites [5].