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GROWTH AND CHARACTERIZATION OF SILICON NANOWIRES FOR SOLAR CELL APPLICATIONS

By

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for degree at any tertiary education institution

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ABSTRACT

Silicon nanowires (SiNWs) have received considerable attention as base materials for third-generation photovoltaic (PV) devices because they lend themselves to large-scale production with enhanced light trapping and increased overall performance. Previous studies have grown SiNWs on indium tin oxide-coated glass substrates by the pulsed plasma-enhanced chemical vapour deposition method (PPECVD) using tin (Sn), aluminum (Al), gold (Au) and zinc (Zn) as catalysts.

Various catalysts (Sn, Zn, Au and Al) with thin film thicknesses from 10nm to 100nm, were used in this study of SiNW growth. Surface morphology analysis, by scanning electron microscopy (SEM) and transmission electron microscopy (TEM), of the grown SiNWs showed the influence of the catalyst type and thickness. The wires became thicker and shorter as the catalyst thickness increased. However, the SiNWs catalyzed by Al metal were thicker than those grown using Sn, Au and Zn metals. The density of the SiNWs decreased as the catalyst thickness increased. For example, the 10nm thick Al catalyst produced the greatest SiNW density of 20NW/μm^2, whereas the 100nm-thick Au resulted in the lowest density of 6NW/μm^2.

The effect of catalyst type and thickness on the structural properties of the grown SiNWs was investigated through X-ray diffraction (XRD). The XRD measurements showed that the SiNWs grown with Au catalysts had higher crystallinity than those grown using other catalysts. Moreover, the diffraction peaks became sharper with increasing wire diameter, indicating that the crystallinity of the grown SiNWs was enhanced. The optical properties of the prepared SiNWs were investigated by photoluminescence (PL) and Raman spectra. A red emission band was clearly observed in the PL spectra of all the prepared SiNWs. In the Raman spectrum, the first-order

transverse optical mode (1TO) was exhibited in all SiNWs catalyzed using Sn, Au, Al and Zn. However, the 1TO peak location depended on the catalyst type and thickness. Important results were observed at a catalyst thickness of 80nm for all catalysts because the 1TO Raman peak was closest to the crystalline Si peak location for all the prepared samples, except for the SiNWs prepared using 100nm of Au metal.

The crystal size of the grown SiNWs was calculated from the Raman spectra. In general, the crystal size of the grown SiNWs using 10, 20, 40, 60 and 100nm of Sn, Al and Zn metals decreased with increasing thickness of catalyst. However, the SiNWs prepared using 80nm thick Sn, Al and Zn catalysts had the largest crystal size. In contrast, the crystal size of SiNWs catalyzed by Au increased with increasing the catalyst thickness.

Several designs of solar cells based on SiNWs were fabricated by the PPECVD method at 400°C on an ITO-coated glass substrate using the two most promising catalysts, Zn and Au. The first one was a p-type SiNWs/i-amorphous Si/n-type amorphous Si (p-i-n) structure using the Zn catalyst. The photocurrent density of the fabricated device was 13.3mA/cm^2 and the open-circuit voltage was 0.5V. A high-performance nanowire solar cell fabricated in this work had 2.05% light conversion efficiency.

The other device structures were fabricated by doping SiNWs catalyzed with Zn and Au as p and n type to fabricate p-n homo-junction SiNW solar cells. The fabricated pn junction solar cell based on the Zn-catalyzed SiNWs showed a higher efficiency of 1.01% compared with the Au catalyzed SiNW solar cell with an efficiency of 0.67%. These promising results provide a basis for further studies aimed at optimizing the device designs.

DEDICATION

I would like to warmly dedicate this dissertation to my darling children whose love shines bright like beautiful candles upon my soul and sustains me…..

To my precious sister for all her support and encouragement and who has always been like a second mother to me……

To all those who continued to remember me in their prayers to make this PhD a success…….

Finally, to all those I love and all those who love me.

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LIST OF ABBREVIATIONS & ACRONYMS

Amorphous Silicon	**a-Si**
Crystalline Silicon	**c-Si**
Chemical Vapour Deposition	**CVD**
Current-voltage	**IV**
Current Density-Voltage	**JV**
Field Emission Scanning Electron Microscopy	**FESEM**
Hydrogenated Amorphous Silicon	**a-Si:H**
Hot Wire Chemical Vapour Deposition	**HWCVD**
Indium Tin Oxide	**ITO**
Molecular Beam Epitaxy	**MBE**
Microcrystalline Silicon	**µc-Si**
Nanocrystalline Silicon	**nc-Si**
Nanowire	**NW**
Plasma Enhanced Chemical Vapour Deposition	**PECVD**
Pulsed Plasma Enhanced Chemical Vapour Deposition	**PPECVD**
Quartz Crystal Microbalance	**QCM**
Radio Frequency	**RF**
Scanning Electron Microscope	**SEM**
Silane	**SiH_4**
Silicon Nanowire	**SiNW**
Solid Liquid Solid	**SLS**
Transmission Electron Microscope	**TEM**
Ultra High Vacuum	**UHV**
Vapour Liquid Solid	**VLS**
Very High Frequency Plasma Enhanced Chemical Vapour Deposition	**VHF-PECVD**

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