AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics and Communications Engineering Department

Study of the Photovoltaic Behavior of Coaxial Nanowires

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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ABSTRACT

In a traditional planar pn junction used in a photovoltaic (PV) device, light absorption and minority carrier collection occur in the same dimension. The device must be thick enough to effectively absorb the maximum number of incident photons. It must also be fabricated using materials having a minority-carrier diffusion length long enough to allow for efficient collection of the photo-generated carriers. This sets a lower limit on the absorber material quality. Therefore, highly efficient PV devices currently require highly pure materials and expensive processing techniques.

The radial pn junction design was suggested to decouple light absorption in a direction perpendicular to minority-carrier transport. This allows the device to be thick enough for effective light absorption, while also providing a short pathway for carrier collection.

This thesis investigates the radial pn junction design for vertical-aligned nanowire (NW) PV devices. First, the performance of Silicon (Si), an indirect band-gap semiconductor, and Gallium Arsenide (GaAs), a direct band-gap semiconductor as the NW material are compared. The fill factor, the power conversion efficiency, the optimum device length, the spectrum of the quantum efficiency and the sensitivity to temperature variations are investigated. Moreover,

other materials like germanium (Ge), gallium indium phosphate (GaInP) and gallium indium Arsenide (GaInAs) are tried as the NW material. The array effects for nanowires of each material alone then of arrays of mixed types are simulated.

The effect of increasing the cell efficiency by enclosing the NW in a nanoring optical antenna to increase the electric field in the near field region is then investigated. The five materials stated above are selected to maximize the absorbed solar spectrum. In addition, the position and diameter of the NW are controlled through a random distribution to optimize the total output efficiency. Results show that the ring antenna geometry and the NW random spatial distribution are effective in both spectral widening and optical field concentration which result in an increase of the cell efficiency.

The use of nano-fractal antenna for plasmonic coupling to enhance the NW PV efficiency is also considered. Sierpinski and Apollonian nano-fractals are used with three different topologies. Electric field enhancement and the total efficiency are calculated.

All simulations are verified by comparing with the available published experimental and computational results.

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