

# Nanotubes, Nanostructures and Solar Cells

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## Abstract

Nanotechnology is the key to new solar cells devices in search of sustainable and renewable sources of energy. Although silicon cells based on solid-state p-n junction devices have dominated the field, they are inherently expensive. Thus, a “promising third generation” of photovoltaic (plastic solar cells, dye sensitized solar cell, nano-technology cell, and the hybrids) has been researched; and are beginning to enter the market. Dye sensitized solar cell (DSSC) is a promising generation concept for achieving efficient solar-to-electric energy conversion with inexpensive materials and manufacturing processes. The presentation will include the synthesis and characterization of nanoscale materials devices for DSSC and on some of the more novel approaches to photovoltaic power generation using nanotubes and nanostructures.

## Introduction

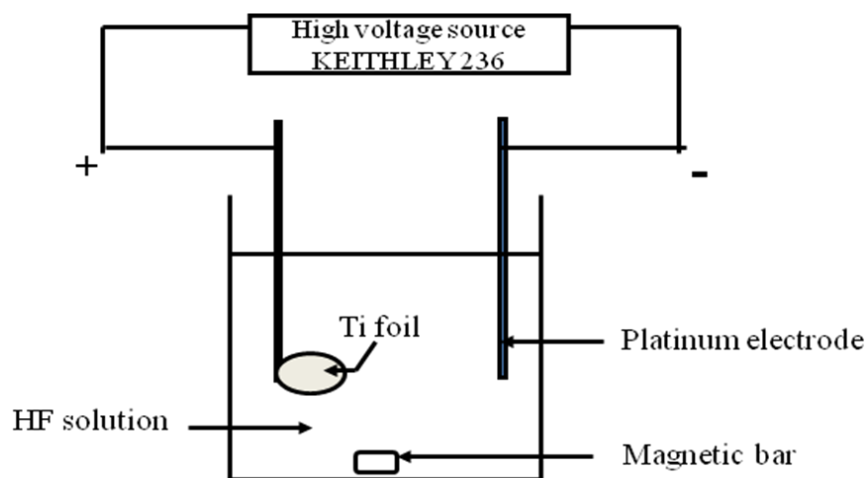
Until recently, the conversion of sunlight to electrical power using photovoltaic technology has been dominated by single crystal silicon cells based on solid-state p-n junction devices. However, they are inherently expensive to significantly influence energy production market. Essential component of future global energy production must be economically competitive with fossil fuels, mechanically flexible, durable, disposable, and of high efficiency. The dominance of inorganic solid state junction devices are being challenged by the organic based PV devices which is referred to as the next generation or third generation photovoltaic technology. This next generation PV technology which includes dye sensitized solar cells (DSSC), polymer base solar cell and the hybrid technology are promising with the potential to significantly lower cost because of the use of lower cost materials, relatively cheap to fabricate and much simpler manufacturing process that does not require high temperature and high vacuum deposition. Hence, the next generation technology seeks to combine high efficiency, low cost, flexibility and durability, which have attracted many investigators.

Recently, several organic based solar cell devices have been investigated, and are predominantly hetero-junction between electron-donating and electron-accepting molecules. Examples include polymer-fullerene blends [1, 2], polymer-perylene donor pair [3, 4], polymer-polymer blends [5, 6], polymer-quantum dot [7], halogen-doped organic crystals [8], the dye sensitized solar cell [9, 10], and polymer-single wall carbon nano-tubes (SWCNT) [11]. However, these devices have yielded efficiencies currently at 2 to 5 percent for polymeric and hybrid devices and 11 percent for the liquid electrolyte based DSSC. These efficiencies are much lower than those of their inorganic counterparts [12]. More work still needs to be done to understand the device physics and to fabricate high efficiency organic based device that would compete favorably with their inorganic counterparts.

Since the advent of DSSC more than a decade ago [9], this conventional (electrolyte based) DSSC remains the most efficient of the organic based PV devices. A lot of interests have been focused on the production of nanostructured oxide ceramics as evidenced from the published work [1-7], especially that of titania. Titanium dioxide is a large band gap semiconductor, which has a wide range of applications. It is used in photo and thermal catalysis, in solar cells, as gas sensor, white pigment, and corrosion protective coating. However, the specific surface area is a determining factor that enhances these applications. The larger the specific surface area of titanium dioxide, the more suitable it is for these applications. The fabrication of porous or tubular structures has been considered desirable for these applications due to their large surface area and reactivities. Different geometrical shapes and microstructure have been fabricated using various techniques [1,8-12], such as sol-gel synthesis, electro-deposition, anodization, and chemical methods. While many of these techniques are complex due to the chemical process involved, in this work, a simple anodization technique was employed. Unique titanium dioxide thin films nano-square-structure was fabricated by anodizing pure titanium sheets in aqueous solution containing hydrofluoric acid. The TiO<sub>2</sub> nanostructure produced was further used for the fabrication of dye-sensitized solar cells.

### Experimental Procedure

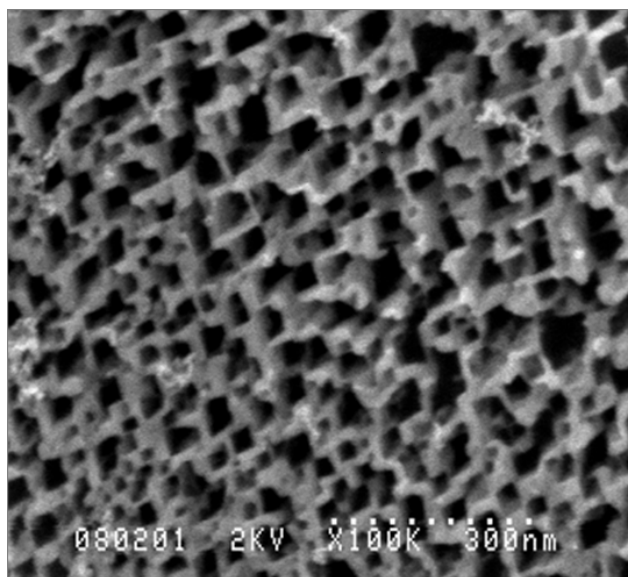
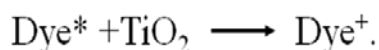
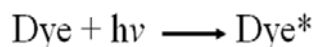
A simple anodization technique was employed. Pure titanium foil (99.5 % purity) of thickness 0.0127 mm was anodized in aqueous solution containing hydrofluoric acid with magnetic agitation of the electrolyte. The anodization was conducted using two electrodes electrochemical cell with a platinum foil as cathode; the experiment was carried out at room temperature. Anodizing voltage was kept constant. The current was observed to decrease drastically then remained stable. Figure 1 is a schematic of the anodization experiment. At the end of the experiment, the sample was rinsed in distilled water and air dried. The morphologies of the titanium dioxide films obtained were characterized using Hitachi S-900 field emission scanning electron microscope (FE-SEM).



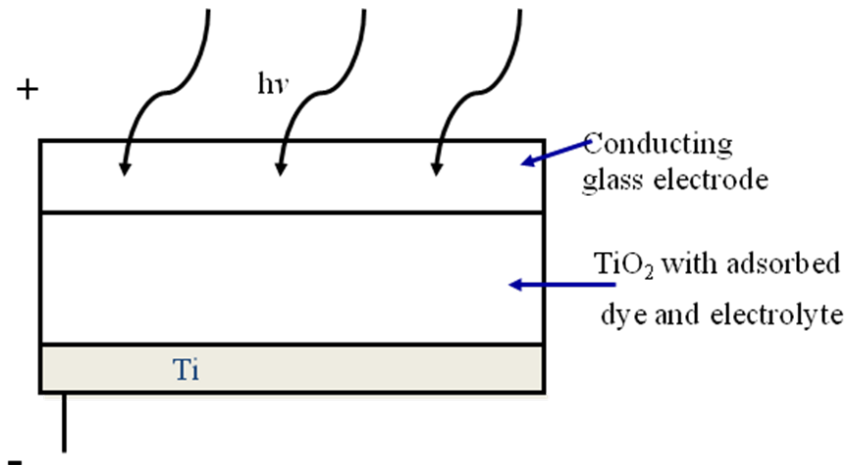
**Figure 1: Schematic of the anodization experiment.**

## Result

Figure 2 shows SEM top view image of unique nano-porous titanium oxide film.  $\text{TiO}_2$ , a wide bandgap oxide semiconductor is the material of choice due to its stability, inertness, and low cost. The optical bandgap of  $\text{TiO}_2$  is 3.2 eV which lies in the ultraviolet region. However, the peak of solar spectrum lies in the visible region. Therefore, the quantum efficiency of the PV devices based on  $\text{TiO}_2$  nano-particles is increased by sensitizing titania surface with dye molecules. A mono-layer of dye molecule is attached to the surface of the nano-porous film of  $\text{TiO}_2$  whose purpose is to harvest solar light. When illuminated, the dye absorbs the energy from the sun in the form of photons, becomes excited and transfers electron into the conduction band of the semiconductor oxide by a process called injection or sensitization. The electrons lost by the dye are replaced by the iodide in the electrolyte solution to produce iodine or tri-iodide, which in turn obtains electrons at the counter electrode after flowing through the load. The equations below describes this process, where  $\text{Dye}^*$  stands for excited dye. Figure 3 shows the device fabrication.



**Figure 2: The morphology of the titanium oxide films characterized using Hitachi S-900 field emission scanning electron microscope (FE-SEM)**



**Figure 3: Device fabrication**

## Conclusion

Unique nano-square tubes of titanium dioxide were fabricated by anodizing pure titanium sheets in aqueous solution containing hydrofluoric acid. The surface area of the specimen was  $2 \text{ cm}^2$ . The irradiance was  $1000 \text{ Wm}^{-2}$ . The device fabricated produced six percent efficiency. The work presents a controllable procedure to obtain nano-square structures of  $\text{TiO}_2$  in titanium which has potential for use in micro and nanotechnology applications such as for DSSC, gas sensing, smart surfaces, as well as optical and electronic devices.

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## **Biography**

Lawretta Ononye is an Associate Professor of Physics at the State University of New York in Canton. She received her Ph.D. in Materials Science and Engineering from the University of Tennessee in Knoxville. Before becoming a faculty at SUNY Canton, she was a faculty at Rochester Institute of Technology. She is a recipient of the first awards for Networked Digital Library of Theses and Dissertations (NDLTD) – Electronic Theses and Dissertation (ETD) Award 2008 ([www.ndltd.org/community/awards/ndltd-etc-awards-powered-by-scirus-2008-winners](http://www.ndltd.org/community/awards/ndltd-etc-awards-powered-by-scirus-2008-winners)). Dr. Ononye has authored or co-authored several peer reviewed journal papers. She has several years of teaching experience.