RENEWABLE ENERGY, BIOCLIMATIC CONSTRUCTIONS & SUSTAINABILITY CONFERENCE
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INCREASING SOLAR CELL EFFICIENCY Using NanoCoating

Solar energy is one of the cleanest energy sources in the world, being virtually unlimited and having reduced waste when compared with other sources of energy. That is why it is important to harness it by maximizing the efficiency of solar cells.

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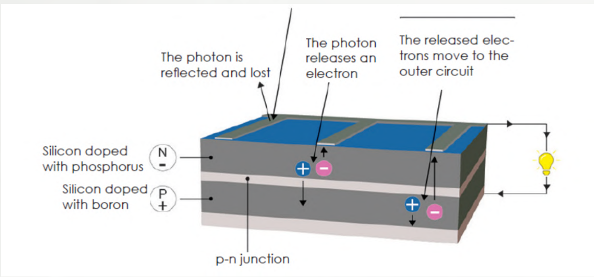
ABSTRACT

This project will be a walk-through of the conception, design, and impact of implementing nanotechnology within the coating structure of solar panels to improve the overall efficacy.
This will also be a brief introduction into how the use of materials science and technology is applied in real-life, to help solve one of the world's most pressing issues: energy waste.

Solar Panels

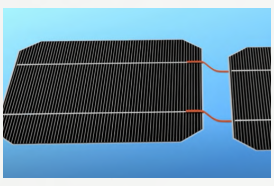
How do they Work?

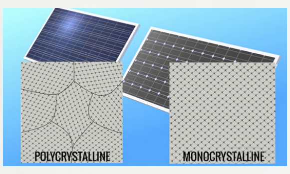
Each panel is made of a bunch of photovoltaic (PV) cells, inside each, we find a silicon wafer. The use of silicon is explained by its properties as a semiconductor material. When light from the sun hits the silicon atoms, they release an electron that moves. Two types of silicon are used to have an electric current: p-type (Silicon doped with phosphorus), and n-type (Silicon doped with boron). This layering creates an electric field. When exposed to the photons emitted by sunlight, a direct current is created due to the exchange of the electrons from the n-type part to the p-type within the electric field (depletion region).



Structure of a Solar Panel

A solar panel is made of interconnected PV cells. The PV panel is generally put between two sheet to protect from shock dirt. The cells are connected to each other following a specific series-parallel configuration.





There are two difference appearances of PV panels because of their internal polycrystalline and monocrystalline structures. While both types essentially function in the same way, Monocrystalline PV panels offer higher electrical conductivity, but are costlier and not as largely used as Polycrystalline.

Properties of Silicon

The drawback of such cells is inefficiency; at around only a 20% efficiency, silicon cells are not that good at converting a lot of solar energy into electricity.

Atomic Density	Density	Lattice Constant	Melting Point	Thermal Conductivity	Thermal Expansion Coefficient
5×10^{28} m^{-3}	2328 kg m^{-3}	0.5431 nm	1415°C	150 W m^{-1} K^{-1}	2.6×10^{-6} K^{-1}

Energy Bandgap	Intrinsic Carrier Concentration	Relative Permittivity	Maximum Electron Mobility	Maximum Hole Mobility
1.12 eV	1×10^{16} m^{-3}	11.9	0.143 m^2 V^{-1} s^{-1}	0.047 m^2 V^{-1} s^{-1}

By observing the properties above, we can conclude that the reason behind the inefficiency is the energy bandgap. In fact, the incoming photons from sunlight, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy, then it will pass through. If it has more energy than the band gap, then that extra energy will be wasted as heat (reflected). These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell.

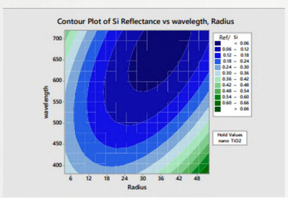
Solution

Potential advancements in nanotechnology may open the door to the production of cheaper and slightly more efficient solar cells. The most effective ways trough which we can improve the efficiency and lower costs of PV solar cells is to use a NanoCoating of TiO2

What is Nanotechnology?

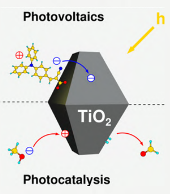
Nanotechnology has become a buzzword, revolutionizing different fields from medicine, to engineering and energy. It simply refers to the process through which we can manipulate materials at the nano scale, meaning in the range of 1 to 100 nanometers. At these nanoscales, materials can exhibit different properties when shrunk to the nanoscale.

As an example, we can see the diagram on the right of how the property of refractiveness in Silicon (Si) changes as a function of the radius. The more the material shrinks, the lower the refractiveness.



Use of Titanium Dioxide (TiO2)

Why Titanium Dioxide?



Titanium dioxide TiO2 is a promising material for photovoltaic device. It is an n-type semiconductor that acts like a material with an energy gap between 3.06 and 3.23 eV. When the molecule absorbs a photon with energy higher or equal to that value, it passes to an excited state and can produce negative electrons in the conduction band, leaving positively charged holes in the valence band. This allows it to absorb 8% of the sunlight spectrum, ensuring an effective process of electron transport.

Properties of Titanium Dioxide

Particle type	TiO_2 nanoparticles
Particle size	21 nm
Molar mass	79.87 g/mol
Specific surface area	35–65 m^2/g (BET)
Odor	Odorless
Density	4.26 g/cm^3
Melting point	1843°C
Energy Gap	3.23 eV
Refractive Index	1.66–1.7
Reflectivity	Less than 2%
Light Absorption	Less than 415 nm
Dielectric constant	31-114
Crystal Structure	Tetragonal

Properties of Solar Panels after NanoCoating

The TiO2 layers have a transmittance in the range of 75-85% and a refractive index of 1.66-1.76 for 632 nm wavelength. The integration of the TiO2 layers on the solar cells surface assures a minimum reflectivity less than 2% at 575 nm and less than 5 % in the range 500 – 700 nm. This type of antireflective layer integrated in the solar cell structure leads to an improvement of the output power with 28% as compared to the classical solar cells

Manufacturing Process

There are several methods for the TiO2 manufacturing: sol-gel deposition, chemical vapor deposition pulsed laser deposition, and reactive sputtering.
We will focus on the method that consists of anodizing metallic Ti while making the TiO2 coatings. This method has the advantage of being compatible with the technology for SiO based solar cells. Combined with an annealing process, this method is done respecting a TiO2 to Si (TiO2:Si) thickness ratio in order to reduce the reflective properties, effectively increasing the solar panels' efficiency.

1 Sonification

First, nano-TiO2 needs to be sonicated inside CH3CHOHCH3 using the ultrasonicator bath to create a well-dispersed solution

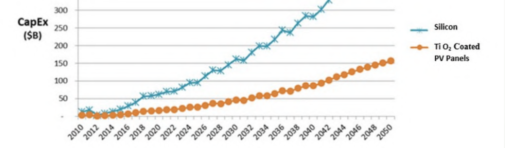
2 Stirring

Following that, nano-TiO2 is stirred inside the CH3CHOHCH3 using a magnetic stirrer at room temperature. During the stirring process, APTES and MMS are dripped to the nano-TiO2 mixture and are stirred again

3 Fabrication

Finally, the solution is fabricated onto PV panels via dip-coating method. The coated PV panels are dried under room temperature, before subjecting to further characterization. The fabrication process for solar cells structures with an antireflective layer of TiO2 is optimized to obtain an increase of the output power by reducing the reflection losses at the solar cell surface. The TiO2 coatings are usually obtained by an anodizing process of 90 nm Ti deposited on Si wafers in

Cost Effectiveness Analysis



TiO2 is a non-toxic, abundant, biocompatible, and inexpensive semiconductor with unique optoelectronic properties and high chemical stability. This substance gives potential for making cost-effective and very efficient solar cells coating. In addition to its relatively affordable manufacturing process cost, it helps increase the efficiency of solar cells, rendering their use a very interesting innovation

Evolution of the cost of regular PV solar cells vs. TiO2 coated solar cells