# EXPERIMENTAL INVESTIGATION ON TEXTURED SOLAR PV CELLS COATED WITH NANO $Al_2O_3$AND NANO ZnO Paper Title

R. Dhinakaran, R. Elansezhian, R. Muraliraja, R. Sridhar

*Pondicherry Engineering College, Puducherry, VISTAS Chennai*
*muralimechraja@gmail.com*

***Abstract***

*This paper deals with the improvement of absorption efficiency of the solar cell by making texture of uniform size on the surface of the glass above the panel and coating it with nano antireflective coating. The nano materials chosen are nano Al2O3 and ZnO because they have good thermal conductivity and has good solar radiation trapping properties and further ZnO has good self-cleansing properties which helps in long-term usage of the solar cell. The process of texturing was tried by directly engraving the texture on the surface of the glass by means of laser cutting. The energy of laser was high the glass cracked therefore the textured glass available in the market was procured and coating was done by electroless technique. The method adopted for coating the nano particles is electroless coating, in which a bath of oxidizing agent and reducing agent is mixed and the material to be coated is added and allowed to deposit on the required surface.*

***Keywords:*** *Electroless technique, Anti reflection coating, UV Spectrophotometer, EDAX, Solar Simulator, Electrolysis, Vapor deposition method.*

## 1. Introduction

A solar cell or photovoltaic cell (earlier known as solar battery) is a transducer which converts light energy (photons) to electrical energy by the photovoltaic effect. Photovoltaic effect is a physical and chemical phenomenon by which light energy is transformed in electric energy. It is a form of photovoltaic cell, defined as a device whose electrical characteristics including current, resistance, voltage vary when exposed to light i.e. solar rays. Solar cells are the building block of the photovoltaic module which is also referred to as solar panels as shown in figure 1.

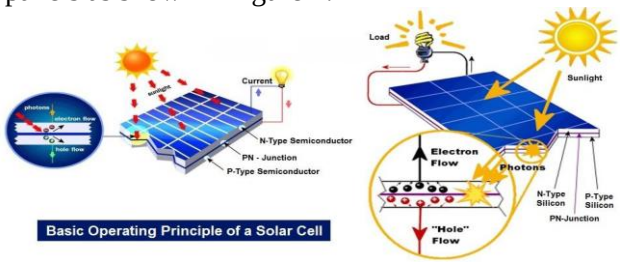



Figure 1 operating principle of a solar cell

Solar cells are referred to as photovoltaic cells irrespective of the source whether it is an solar source or an artificial source. They are used in various applications such as radiation detectors or for detection of electromagnetic radiation near the visible range or measuring light intensity

The basic operation of solar cell consists of three parts:

The absorption of light, generating either electron-hole pairs or excitons.

2. The separation of charge carriers of opposite types.

3. The extraction of the produced carriers to an external circuit separately.

In contrary to a solar cell, solar thermal collectors refer to a type of device which collects thermal energy from the solar rays and uses it for direct heating purpose of water or for indirect power generation methods such as steam production and later on used to run over a turbine. There is also a type of device called solar electrolytic cell which refers to a type of photovoltaic cell or it is also known for the process of splitting water into hydrogen and oxygen using only solar illumination.

The advantages of the solar powered source are:

1. It is an everlasting, renewable energy source.

2. It is a clean energy source, no potential damage to the environment.

3. It is a very large source of energy. The power from the sun intercepted by the earth is about 1.8*1011 MW, which are many thousand times larger than our current power consumption from all sources.

4. Additionally, solar energy is free, does not cause pollution and is available to all at fairly equal manner, unlike fossil fuel sources, which are concentrated at same locations only. This fact provides a chance that an individual can generate his/her own energy depending on the requirement, at his/her place of choice. This equitable availability can also play a role in social development, especially in developing countries such as India.

## 1.1 PHOTOVOLTAIC EFFECT

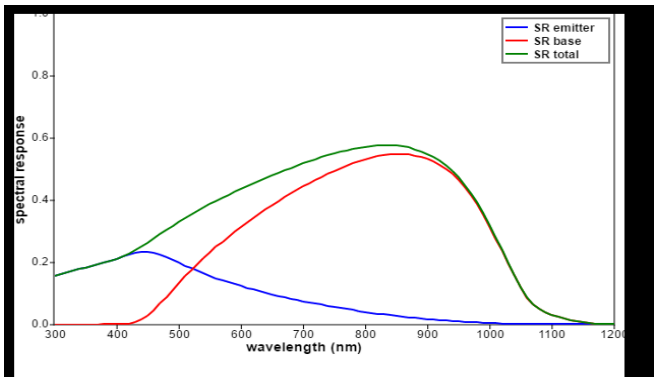
The photovoltaic effect is similar to photoelectric effect in many ways including the fact that both required solar UV radiation to excite the electrons out of atoms or other charge carries out of the atoms. The area where they both vary is in the place that in photoelectric effect the charge carrier or electron discharged is pushed out of the material while in the case of the photovoltaic effect it is contained within the material in which it is produced. In both cases an electrical voltage is produced across the surface of the panel which is utilised in the process of the electrical energy production. The entire process can be explained as, when the photons i.e., the solar UV radiation falls on the low energy state atoms on the surface of the PV cell it tends to get excited thus releases the electrons or other charge carriers in the valence band, which then is made to pass through the potential barrier which is the band gap between the P and N surfaces which produces an electrical voltage across the panel. This potential can be tapped by an external circuit and can be dissipated by an external electrical circuit with a load to use that.

With an increase in the need for an alternate source of energy solar panels and other technologies based on the solar radiations are becoming more interesting and has an immense potential in research and development for more efficient production of power. With increase in the need for alternative source to oil and other non-renewable energy resources wind, solar, hydraulic and ocean thermal energy production are becoming major players of energy production. With advent of space exploration and rapid growth in space vehicle technologies, solar panels has gained rapid growth since no other power production device can be attached to such a vehicle with less possibilities of failures. Although the space solar cells are way more expensive than the usual ones, the advantage of using solar cells for mobile energy production and their portability was identified and has been put to production for terrestrial solar panels which has more efficiency than the regular ones and are not so expensive as the space solar panels.

1.2 SPECTRAL RESPONSE

Spectral response is similar to quantum efficiency of a solar panel. Quantum efficiency of a solar panel is defined as the ratio of number of electrons produced by the number of photons incident on the surface of the panel. While the spectral response is defined as the ratio of amount of power generated to the amount of power incident on the surface of the panel.

The general spectral response curve of a solar panel is given:




It is evident from the spectral response curve that the entire amount of power falling on the surface of the panel is not utilised or converted to the electrical energy. The theory behind this is the fact that the incident rays with energy less than energy required to excite the electrons or charge carriers above the band gap or potential barrier is not absorbed as it is of no use to electrical energy production. While the higher power rays are also not absorbed by the surface of the panel as it is too heavy to handle by the electrons on the panel. Thus, it goes to the heating of the panel. This explains why unlike the square QE curves it is less on the low and high wavelength of the spectrum. Thus, the inability of the single PN junction diode solar cell to utilise the high-energy incident radiation and low energy radiation reduces the overall efficiency of the panel by a considerable amount.
EXISTING PROBLEMS AND METHODOLOGY

**1.3 EXISTING PROBLEMS**

- Location and Availability of Sunlight
- Initial Cost
- Pollution
- Reliability
- Installation Area

The major problem that we are more concerned about is that.,
**Inefficiency:** Since not all the light from the sun is absorbed by the solar panels therefore most solar panels have a 40% efficiency rate which means 60% of the sunlight gets wasted and is not harnessed. New emerging technologies however have increased the rate of efficiency of solar panels from 40 to 80% and on the downside, have increased the cost of solar panels as well.

## 2. EFFECT OF ANTI REFLECTION COATING AND SURFACE TEXTURING

The efficiency of a solar panel is directly proportional to the amount of light entering through the glass surface over the panel and incidenting on the wafer surface. Thus, a bare silicon glass has a high reflection percentage of over 40% which has a considerable effect on the efficiency of the panel. That gives a need to apply an ARC (Anti Reflection Coating). An ARC coating is similar to a dielectric thin layer which diffuses the light rays incidenting on the surface of the glass and makes it out of phase with the light rays reflecting from the surface of the panel and thus when these two rays interfere destructively makes the overall amount of the light reflected to be zero. Though the entire amount of the light cannot be avoided from reflection, the effort to reduce the amount of reflection light will have a considerable effect in the efficiency of the panel.

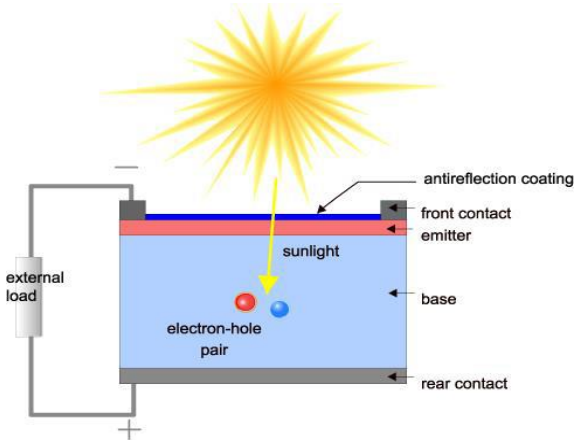



Figure 2 Effect of ARC

Then coming to the surface texturing, it has considerable effect of improving the optical transmittance efficiency of the glass if done properly. Several shapes such as pyramids, inverted pyramids, cuboidal and other groove shapes can also be used to increase the light transmitted through the glass surface.

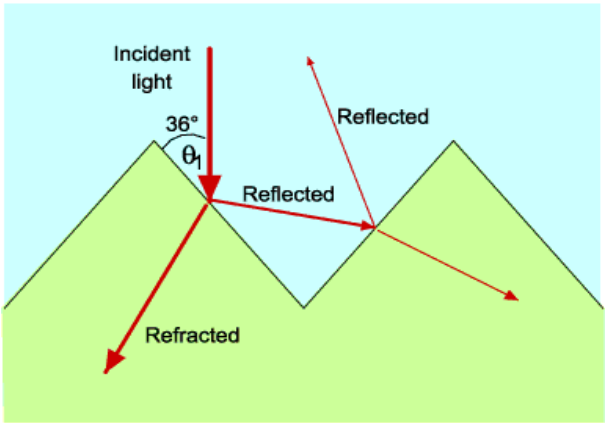



Figure 3 Effect of Surface Texturing.

Surface texturing is done in many ways ranging from the etching of the glass surface to create it to pre-ordering glass for required surface roughness and texture in the company. A glass surface with pyramid structure on the surface is shown in the below diagram.

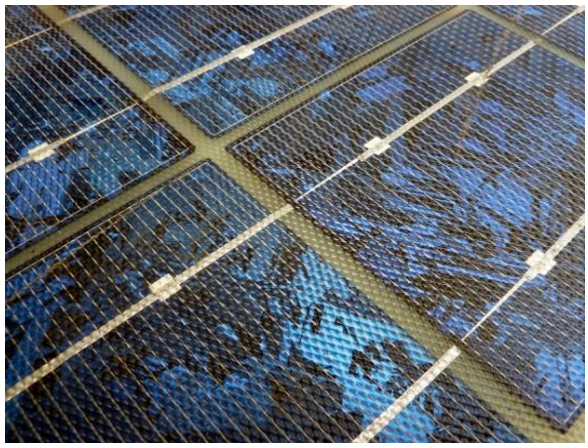


Figure 4 Pyramid texture on Polycrystalline silicon solar PV cell

Similarly a inverted pyramid groove on the surface of the glass is given below. In this type of grooving the structures are etched downwards from the surface to get the required shape of the groove accurate calculations have to be carried out. Thus, a combination of textures and ARC will have considerable improvement over plane and normal glass. This leads to a more economical and more simple way to improve the overall efficiency of the solar panel.

## 3. EXPERIMENTAL DETAILS AND PROCEDURE

### 3.1 COATING TECHNIQUE USED

The coating method used to coat the chosen Nano – material over the glass substrate is electroless process. This process is chosen because of its major advantages such as uniform coating thickness even over irregular surfaces and high wear resistance and also gives improved hardness. In this process a series of redox reaction i.e., reduction and oxidation takes place so that the reducing agent in the bath releases negative ions and the oxidising metal agents produces metal ions which combines with the reducing agent forming metal particles which then deposits on the surface of the substrate. This entire process takes place without any external supply of current or voltage.

The advantage of using electroless process is that:

- Improved hardness
- Improved wear resistance
- Uniformity in coating thickness
- Corrosion resistance

Thus, as explained above electroless process is a self-propelled process without any external supply of voltage or current to keep the reaction going on.

### 3.2 ELECTROLESS ZINC OXIDE COATING PROCESS

The electroless process is explained as follows:

(I)Activation and sensitization of glass substrate.

Activation and Sensitization of glass substrate is carried out in electroless process because glass is not a conducting material. It is started by polishing the glass substrate using emery sheet. The surface was washed using methanol and acetone. Then the glass substrate was immersed in the SnCl2 solution of 0.127mol/dm3, pH 0.74 for 5 minutes and then immersed in PdCl2 of concentration 1.69mmoldm−3, pH 0.77 for 5 minutes. This process has been represented using flow chart which is given as follows:

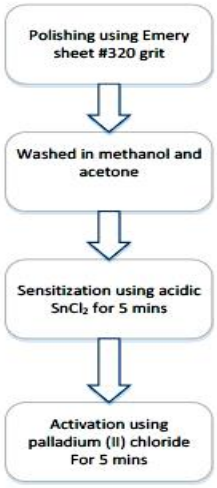



Figure 5 Working flow chart

### 3.3 ELECTROLESS COATING OF ZNO

The bath required for the electroless coating of ZnO was prepared using chemicals like zinc nitrate and dimethylamino borane. The bath was prepared with concentration of 0.05M of both zinc nitrate and dimethylamino borane. Then the activated and sensitized glass substrate was immersed in this chemical bath and the chemical bath was kept in water bath at 50 degC, pH 7 for 2 hours. At last the substrate was washed in the deionised water. The following flow chart shows this process.

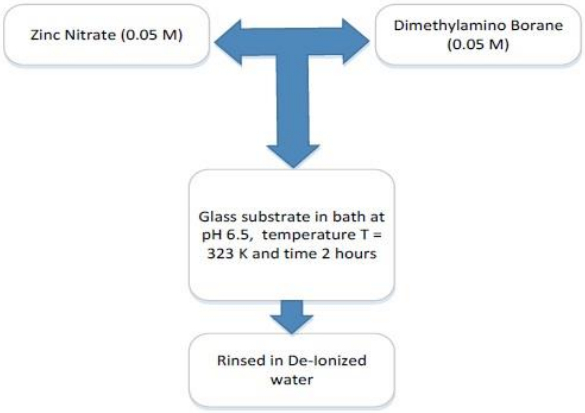



Figure 6 Flow chart for electroless ZnO coating

# 4. RESULT AND DISCUSSION

## 4.1 PHYSICAL MODEL ANALYSIS

The physical model of the solar panel has been carried out using the above-mentioned procedure which is electroless coating process.

The obtained model of the panel is further tested extensively to obtain the transmission increase in the coated glass the various results are discussed below:

1. UV spectrophotometer results to obtain optical characteristics of the glass substrate.

2. SEM analysis to note down the surface morphology of the glass substrate.

3. EDAX results to confirm that the chemical has been coated on the glass.

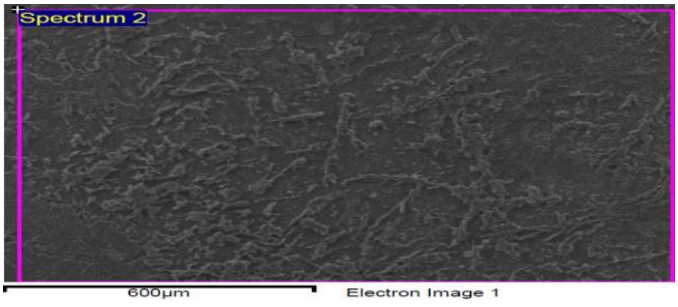
4. Solar simulator results to know the increase in the production of the current in the coated model.

## 4.2 UV SPECTROPHOTOMETER

The inference from the above graph is that the amount of light entering through the glass i.e., the transmittance of the glass has been improved for the textured coated glass followed by the coated plane glass which is consequently followed by the textured and plane glass without coating.

The reflectance of all the samples are compared here on the above graph and is observed that the reflectance of the textured coated glass is the most minimal and followed by coated plane glass and then followed by the plane and textured glass respectively.

EDAX RESULTS:



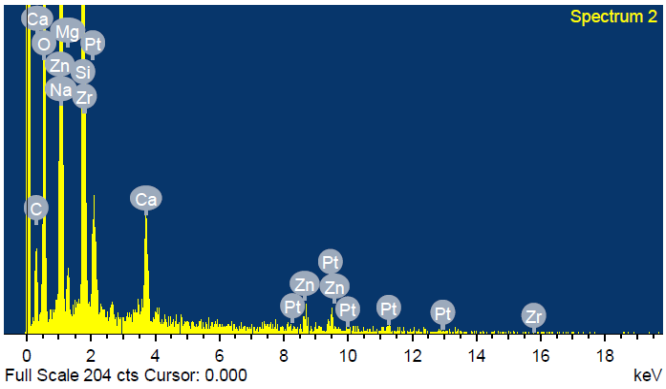



Figure 7 EDAX peaks of the coated glass

EDAX represents Energy Dispersion X-Ray Spectroscopy which is used to find the composition present in the sample. **:**

**Composition Table Obtained from EDAX test**

| Elements. | Weight% | Atomic% |
|---|---|---|
| C K | 2.94 | 19.34 |
| O K | 11.17 | 55.06 |
| Na K | 4.49 | 15.41 |
| Mg K | 0.21 | 0.67 |
| Si K | 2.47 | 6.94 |
| Ca K | 0.52 | 1.03 |
| Zn K | 0.64 | 0.77 |
| Zr L | 0.45 | 0.39 |
| Pt M | 0.96 | 0.39 |
| Total | 23.85 | |

Composition of different components on the glass substrate found using EDAX test are shown in the above table.

## 5. FUTURE SCOPE

- To improve the solar conversion efficiency.
- To improve the absorption parameters of PV cells.
- To verify increase in efficiency theoretically using FEA analysis.
- To increase the efficiency of the existing PV cells which is mass manufactured by adding certain Nano particles thereby not increasing the cost of the resulting PV cells, thus making it an alternate option for the existing solar cells.
- Effective methods to coat Nano ZnO.

## 6. CONCLUSION

Tests like UV Spectrophotometer, SEM, EDAX and Solar Simulator were carried out to verify whether there is increase in optical efficiency and the solar absorption efficiency of the different glass substrates. It was found that:

1. In UV Spectrophotometer, the transmittance of the plane glass was found to be 32%, then the coated plane glass was found to be 42% which has seen an improvement of over 10%, similarly the textured glass transmittance was around 45% and textured coated glass was found to be around 53%, thus these results shows that the textured coated glass has the most transmittance at working range of the solar panel.

2. In the SEM test it was found from the surface morphology has a uniform coating all over the surface of the glass substrate and the zinc particle was found to be in the nano region of 500 nm – 1000 nm.

3. From the EDAX results zinc was found to be having a weight percentage of 0.64% of overall glass composition weights which ensures that the coating has taken place over the glass substrate. And the atomic percentage was found to be 0.77%.
4. From the solar simulator the maximum performance was found to be in the textured coated glass and the efficiency of 14.3434% whereas the plane glass efficiency was found to be 13.27426% which has seen an improvement of over 1%.

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