EFFECT OF CALCIUM TITANIUM OXIDE COATING ON THE POWER GENERATION OF SOLAR CELLS

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ABSTRACT

The present study aims in analyzing the effect of Calcium Titanium Oxide ($CaTiO_3$) coating on the power generation of polycrystalline solar cells. $CaTiO_3$ offers unique characteristics such as orthorhombic, biaxial, non-radioactive and non-magnetic with electron bulk density of 3.91 g/cm^3. $CaTiO_3$ film deposition on the solar cell substrate has been carried out using RF magnetron sputter coating technique. This method has advantages in terms of controlling the film thickness, low processing temperature with high stability, multi-layer coating and maintaining chemical stoichiometry. $CaTiO_3$ coating on the substrate has been performed with varying time duration (15-45 min). Constant process parameters are maintained during coating, which are depicted as follows, argon pressure of 0.7 bar, vacuum chamber pressure $6x10^{-2}$ mbar and process current 80 mA. Deposition of $CaTiO_3$ film on the substrate has been confirmed using scanning electron microscopy. Pure polycrystalline solar cell (dimension- 2 cm^2) portrays total radiation level of 1114 to 846 W/m^2 and temperature range of 48.7 °C to 49.7 °C during day time (10 am to 4 pm). Average open circuit voltage observed through multimeter shows generation of 531.8 mv for uncoated solar cell. Solar cells with variation in coating time of $CaTiO_3$ portray 1.01% (15 min), 1.73% (30 min) and 1.09% (45 min) improvement in open circuit voltage compared to control. Uniformity in deposition of $CaTiO_3$ film could be achieved for the coating time of 30 min.

Keywords: Calcium Titanium Oxide, DC Magnetron Sputter Coating, Open Circuit Voltage.

I. INTRODUCTION

There are several of viable renewable energy resources in progress; among them photovoltaic's is the most promising technique as a future clean and sustainable energy technology to replace fossil fuels. Increase the usage of photovoltaic (PV) requires the development of high efficiency with low cost silicon solar cells. And as well enhancing the optimization method leads to cut the ''cost'' to ''efficiency'' ratio for larger scale mass production. Lately, multi crystalline silicon (mc-Si) solar cells pre govern the market share and account for 50% of all the PV modules manufactured worldwide because of its lower manufacturing cost, high conversion efficiency and high reliability. However, the efficiency of these photovoltaic devices is restricted by optical losses caused by the reflection of solar radiations from the crest surfaces of the solar cell. So the sputter coating method is used for anti reflection coating which must be included at the top surface of the solar cells is still the important manufacturing step of silicon solar cell devices. This antireflection coating has been already applied in the spectacle lenses to increase the light transmission capacity and it reduced reflectance. The anti reflection coating material is selected for our project is calcium titanium oxide, because it can have stable conducting property at high temperature, high anti reflection of incoming solar radiation, high photo reactivity. The surface of the silicon substrate can be covered by single or double antireflection coating. Various techniques can be used to deposit the AR coating like Chemical Vapour Deposition (CVD), spray coating, spin ion or screen printing and sputter coating. We choose sputter coating. For good spread of ions, possible to maintain atmospheric temperature at the time of coating, possible to vary the thickness by controlling the time.

II. EXPERIMENT DETAILS

A. Coating material

Calcium Titanium Oxide is the anti reflection coating material for our study. It is also called as Calcium Titanate . It comes under the category of Perovskite. The general formula of Perovskite is ABX_3. In this both A and B will denote the metal and X will denote the oxygen molecule. The chemical formula for our material is $CaTiO_3$. Hence this comes under the formula of Perovskite. In addition to this Calcium Titanate is foremost material founded in the class of Perovskite. We choose this material because of its unique material property. They are given below

- High photo reactivity
- High temperature superconductors
- High oxygen ion vacancy tolerance
- Have stable structure till 120 GPa pressure and 2500K
- No magnetic field is produced during charge transfer
- Available in the powder form

B. Die construction

For sputter coating target need to make a die with the specification of 2 inch inner diameter and 3 cm outer wall thickness. To achieve this shape, we need to prepare a die for this dimension.

The material of mild steel is used for manufacturing the die. It mainly consists of

- Hollow block
- Compressing shaft
- Cover plate

Inner diameter of hollow block is 2 inch and outer wall thickness is around 3cm, thickness of cover plate is 5mm and compressing shaft diameter is 2 inch.

Figure 1. Photo view of die

C. Pelletisation process

In this pelletisation process UTM (Universal Testing Machine) machine is used to make the target material. The bottom of the die is covered with cover plate and the 15 gm of $CaTiO_3$ is kept in the hollow block. Then the compressing shaft is placed over the powder from the top of the hollow block. This set up is placed under the UTM machine. The load of 5000 kg is applied on the compressing shaft. The cover plate is removed and the target material is taken out carefully. To remove the moisture content of the target material to heat up to 100 °C for an hour.

D. Sputter coating

In this deposition process, both the target and substrate are placed on the respective holders. The vacuum is generated in the chamber with the help of rotary pump. The power of the deposition process is maintained as 80 Watts. The distance between the target and substrate is maintained as 5 cm. Then, the sputter- ion pump is started and the argon gas is introduced into the chamber which acts as a working medium to deposit the target particles over the substrate. Before the deposition process plasma state attains in the system as shown in Fig. 2.

Figure 2. Plasma state in sputtering process

III. RESULT AND DISCUSSION

A. Analysis of film in standard environment

The thin film coated solar cell is placed under the sodium vapour lamp to examine its voltage production capacity of the cell. During this observation the IR- thermometer is used to measure the temperature of the cell because in the normal case the temperature variation may affect the efficiency of the cell. The pyranometer is used to check the solar radiation flux density. The readings are taken for 20 min interval and listed in Table 1. The temperature and radiation versus cell voltage measured in standard condition were displayed in Fig. 3 and 4.

Table 1-Analysis of film in standard environment

Radiation from the light (W/m^2)	Temperature in ^oC	Coated cell voltage (mV)	Ordinary cell voltage (mV)	% Difference b/w two cells
705	43.3	536	533	1.005
732	54.8	494	488	1.01229
731	57.7	488	482	1.012448
733	58.7	485	477	1.01677

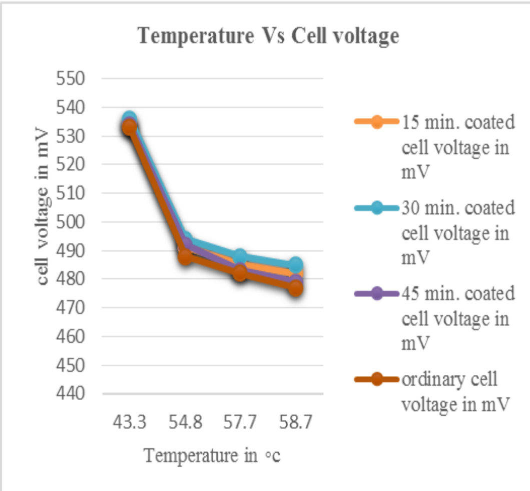

Figure 3. Temperature Vs Cell Voltage in standard condition

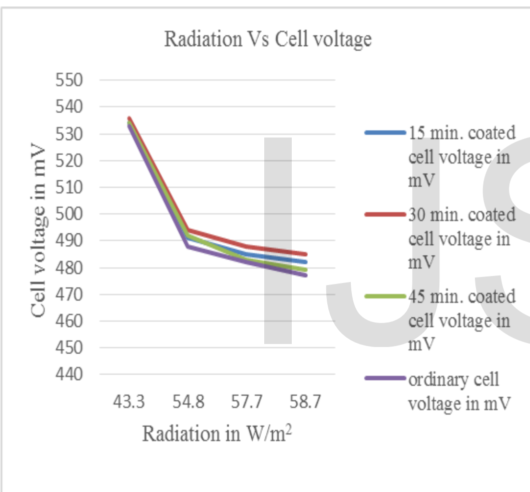

Figure 4. Radiation Vs Cell Voltage in standard condition

B. Analysis of film under the sun

The same procedure has been carried out under the power source. The only difference is that instead of using sodium vapour lamp, directly exposed to the sun and the readings are taken under 30 mins interval as listed in Table 2. The radiation versus cell voltage measured in standard condition were displayed in Fig. 5.

Table 2- Analysis of film under the sun

Radiation from the light (W/m^2)	Temperature in ^{o}C	Coated cell voltage (mV)	Ordinary cell voltage (mV)	% Difference b/w two cells
1114	48.7	533	536	-
1138	49.9	541	537	1.0074
1143	49.5	540	536	1.0074
1060	47	539	529	1.0189
1090	47.4	538	528	1.0189
1064	49	531	526	1.0095
987	50.3	537	532	1.0093
846	49.7	537	531	1.0129

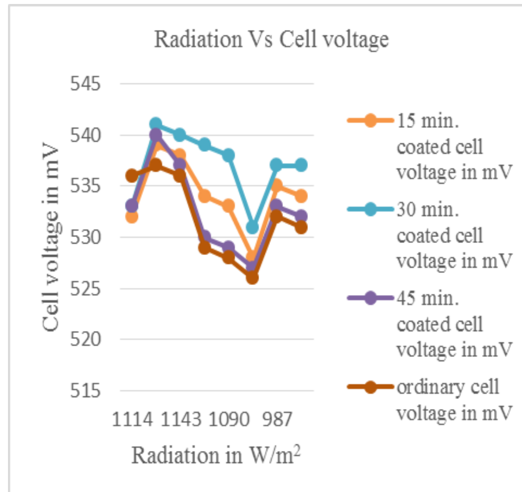

Figure 5. Radiation Vs Cell Voltage in atmospheric condition

From the above Tables 1 and 2 the coated film solar cell generates higher voltage than the ordinary one, when the temperature over the film increases. Hence the material coated over the film is stable under high temperature and it enhances the conversion efficiency of the cell.

IV. CONCLUSION

In this work, we tested the film in both controlled atmosphere and changeable environment. Sputter coating technique is most adaptive method for thin film coating on solar cell. The thin film coated solar cell generates higher voltage compared to the uncoated solar cell. So this material and method is suitable for increasing the efficiency of solar cells. In future optimizing the parameters like coating thickness, temperature, pressure and distance between the target and substrate the efficiency can improve.

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