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Experimental Investigation of SiO2 Coating on the Performance of Solar Panel

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Abstract:
Sun is source of enormous and infinite source of renewable energy. This energy is continuously available at free of cost. Use of this clean energy for the purpose like Power generation, water desalination, drying is need of hour. Solar energy can be effectively used for the generation of electricity either by photovoltaic or concentrated solar power in last few decades. The main challenge with this is the heavy loss of heat during this conversion. Researchers have made efforts to reduce this loss so as to increase efficiency of solar panels.

In this paper, the effect of SiO2(Sol-gel method) coating on the performance of multicrystaline Solar panel has been examined. Multiple Solar Panels with different coatings at same orientation, inclination, location has been tested for analyzing improvement in performance. For the analysis of performance of Solar Panel, hourly readings of Voltage and Current have been taken with the help of Multimeter.Hourly trends in energy generation, efficiency has been analysed.

Keywords:*Solar panel, photovoltaic, Silicon, SiO_2, Nanoparticles.*

I. INTRODUCTION

In the recent years, effective and efficient harnessing of solar energy played a crucial role in providing environment-friendly energy for domestic, industrial, agricultural and other needs of mankind. Solar energy is more relevant for developing countries whose energy requirements are increasing rapidly as a result of large scale industrialization and growing population. Solar photovoltaic field is getting high priority in countries like USA, Italy, Japan, England, France, and India. There is a considerable interest, effort and funding in this field. Solar cells have been standard wellspring of intensity for space vehicles and satellites for most recent 40 years and this is as yet one of the significant utilizations of sun based cells. Their utilization of providing power for earthbound applications will be inescapable when the issue of monetary accessibility of sunlight based cells is explained. The difficulties of delivering solid and aggressively monetary electrical force for earthly applications prompted exceptional research exercises in practically all creating nations during recent decades. There are a few semiconductor materials which can be changed over into sun based cells yet just Silicon, Cadmium sulfide, gallium Arsenide have indicated empowering results.

Single crystal Silicon cells have high refractive index. Significant portion of a solar radiation is reflected from the surface of the photovoltaic converter cell and, as a result, this does not contribute to the carrier pair generation process. This results in efficiency reduction of these cells. Hence it becomes really important to search about antireflective coatings and the search for the materials for their production.The coatings antireflect the light of a visible spectrum are applied on the protective glasses or directly onto the front surface of the solar cells[1]. Different techniques have been used to deposit SiO2 films, including sputtering, sol-gel, chemical vapor

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deposition (CVD), atomic layer deposition (ALD), chemical spray pyrolysis (CSP), screen printing, pulsed laser deposition (PLD), sputtering, and hydrolysis [3].In the present research work SiO_2 have chosen to prepare single layer anti reflective coatings. The SiO_2 has good passivation and scratch resistant properties and chemically stable at elevated temperatures [2]. For the analysis of performance of Solar Panel, hourly readings of Voltage and Current have been taken with the help of Multimeter. Hourly trends in energy generation, efficiency have been analysed.

II. FACTORS AFFECTING EFFICIENCY OF SOLAR CELLS

A. SUN INTENSITY

During midday exactly when the sun is in its zenith (extraordinary), the most sun arranged imperativeness is accumulated; along these lines, there is an extension in the power yield. Since fogs reflect a bit of the sun's shafts and most remote point the proportion of sun osmosis by the sheets during shady days, it contribute to the decrease in sunlight collection effectiveness [4].

B. HEAT BUILDUP

Right when the sun is in its apex (uncommon), the most sun situated imperativeness is accumulated; in this way, there is an extension in the power yield. Since fogs reflect a part of the sun's bars and most distant point the proportion of sun absorption by the sheets during. At high temperature output performance of solar panel reduces as compared to a lower temperature. According to estimation for every degree rise in temperature, efficiency of PV module decreases 0.5 percent[5].

C. PARTICULATE BUILD UP

As solar cell is placed outdoors, airborne particulates like dust settle on the glass surface of the module. This is similar to dust settling on glass automobile windshields. These particulates block the amount of light reaching the module and therefore reduce the power produced by the module [6].

D. INVERTER CONVERSION LOSSES, SYSTEM WIRING, SOLAR MODULE TILT ANGLE

Inverter Conversion Losses, System Wiring, Solar Module Tilt Angle are other factors which can affect performance of solar cell.

Antireflective coating which is able to keep solar panel cool, able to make hydrophobic effect of cell surface canreduce the effect of fators A,B,C. Coating Solar panels with Nano materials had reduced these losses. In present work, an effort has been made to coat Solar panel with different materia ls and performance has been analysed.

III. EXPERIMENTAL SETUP

An experimental setup has been fabricated to test performance of multiple panels with same specifications, same tilt angle. Panels are coated with SiO2-Nano material coating (Sol-Gel method), TiO_2-Nano material dispensed in ethylene, third with Anti-Reflective Coating(Black dye). The performance of all solar panels tested over different seasons. Also performance of Solar Cell tested with semiautomatic tracker at various inclinations.

Experimental Setup for Fixed Inclination

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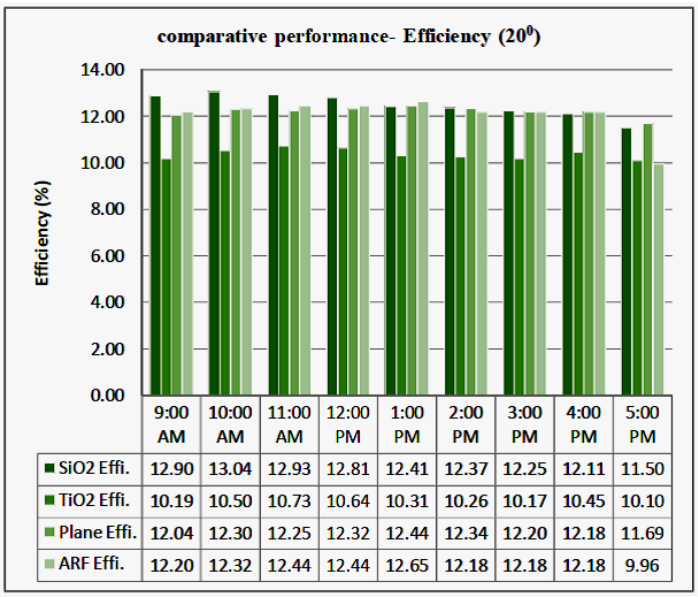
IV. EXPERIMENTAL RESULTS

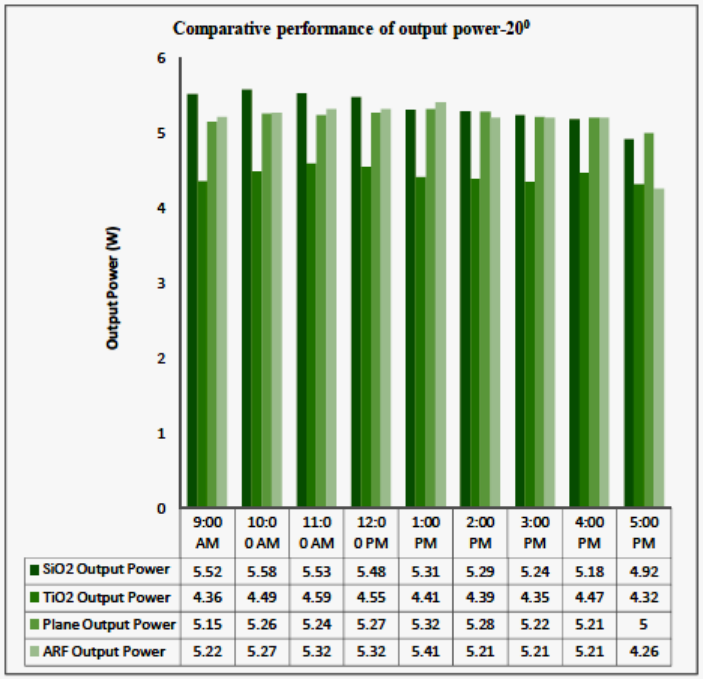
For the analysis of performance of Solar Panel, hourly readings of Voltage and Currenthave been taken with the help of Multimeter. The performance of various panels viz. SiO2, TiO2, Plane Panel and Antireflective Film are expressed graphically



	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
SiO2 Effi.	12.90	13.04	12.93	12.81	12.41	12.37	12.25	12.11	11.50
TiO2 Effi.	10.19	10.50	10.73	10.64	10.31	10.26	10.17	10.45	10.10
Plane Effi.	12.04	12.30	12.25	12.32	12.44	12.34	12.20	12.18	11.69
ARF Effi.	12.20	12.32	12.44	12.44	12.65	12.18	12.18	12.18	9.96

Fig2. Comparative performance(efficiency wise) of different panels at the fixed inclination (Day 1)

Above plot of Hourly efficiency for different panels which shows the variation of efficiency for different panels at an inclination of 20^0 (tilt angle) due south. It is observed that Panel which is having a coating of SiO_2 (Nanoparticles) gives the maximum efficiency in the range of 11.5% to 13.04% throughout the day. The other panels i.e. TiO_2, Plane panel and Antireflective film coating gives the lesser efficiency as compared SiO_2 (Nanoparticles) coated panel.



	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
SiO2 Output Power	5.52	5.58	5.53	5.48	5.31	5.29	5.24	5.18	4.92
TiO2 Output Power	4.36	4.49	4.59	4.55	4.41	4.39	4.35	4.47	4.32
Plane Output Power	5.15	5.26	5.24	5.27	5.32	5.28	5.22	5.21	5
ARF Output Power	5.22	5.27	5.32	5.32	5.41	5.21	5.21	5.21	4.26

Fig 3. Comparative performance efficiency wise) of different panels at the fixed inclination (Day 1)

Above plot shows hourly Output power for different panels shows the same trend of power output at 200 tilt angle due south and indicates that maximum power output for SiO2(Nanoparticles) coated panel is more than TiO2 coated panel. The power output SiO2(Nanoparticles) coated panel is more than TiO2 coated panel in the range of 13% - 26%. It is also observed that the power output of Plane Panel and Antireflective film coated panel is little bit lower till 4.00 PM, but the uniformity of power output for SiO2 (Nanoparticles) coated panel is more consistent as compared to other 3 panels.

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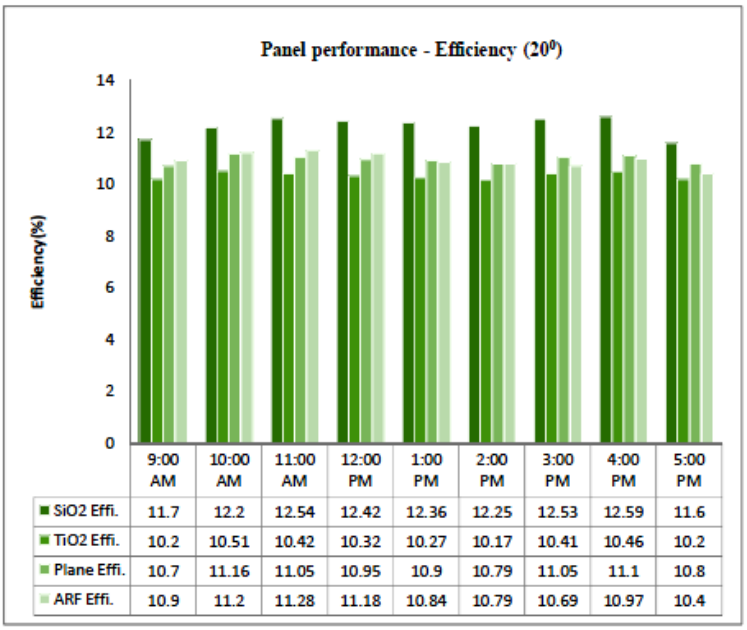
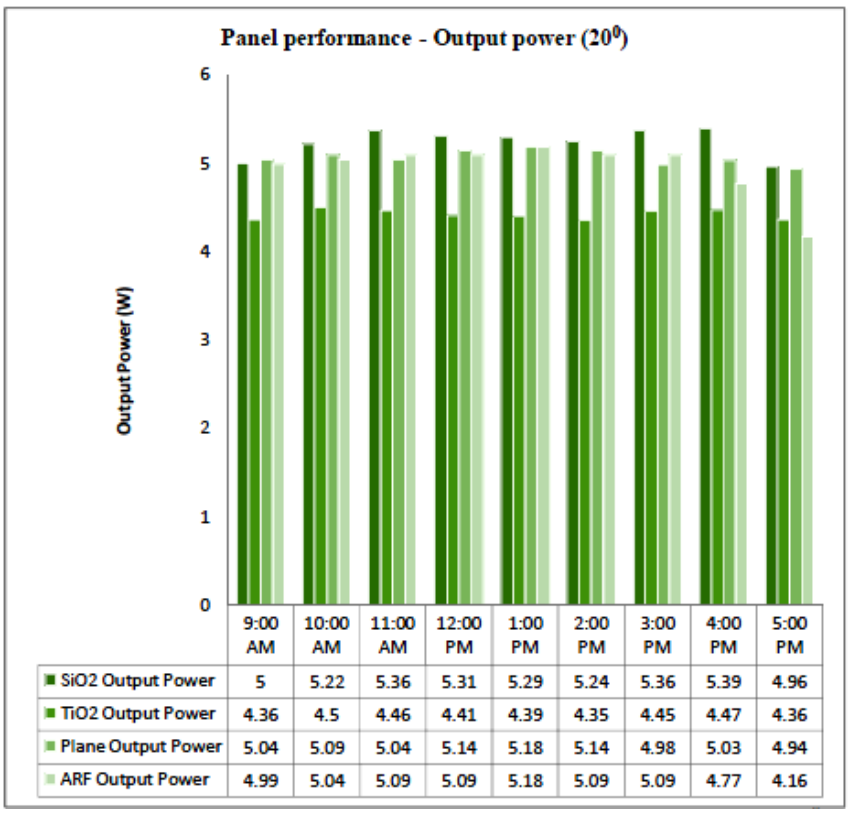


	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
SiO2 Effi.	11.7	12.2	12.54	12.42	12.36	12.25	12.53	12.59	11.6
TiO2 Effi.	10.2	10.51	10.42	10.32	10.27	10.17	10.41	10.46	10.2
Plane Effi.	10.7	11.16	11.05	10.95	10.9	10.79	11.05	11.1	10.8
ARF Effi.	10.9	11.2	11.28	11.18	10.84	10.79	10.69	10.97	10.4

Fig4. Comparative performance (efficiency wise) of different panels at the fixed inclination (Day 2)

Fig.4 shows hourly efficiency for different panels for Day-2, shows the variation of efficiency for different panels at an inclination of 20^0 (tilt angle) due south. It is observed that Panel which is having a coating of SiO_2 (Nanoparticles) gives the maximum efficiency in the range of 11.6% to 12.54% throughout day. This panel shows maximum efficiency throughout the day. The other panels i.e. TiO_2, Plane and Antireflective film coating gives the lesser efficiency as compared SiO_2 (Nanoparticles) coated panel.



	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
SiO2 Output Power	5	5.22	5.36	5.31	5.29	5.24	5.36	5.39	4.96
TiO2 Output Power	4.36	4.5	4.46	4.41	4.39	4.35	4.45	4.47	4.36
Plane Output Power	5.04	5.09	5.04	5.14	5.18	5.14	4.98	5.03	4.94
ARF Output Power	4.99	5.04	5.09	5.09	5.18	5.09	5.09	4.77	4.16

Fig. 5 which is a plot between hourly Output power for different plates for Day 2, shows the same trend of power output at 20^0 tilt angle due south and indicates that maximum power output for

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SiO_2(Nanoparticles) coated panel is upto 7% more than Plane panel. It is also observed that the power output of Plane Panel, Antireflective film coated panel is nearly same. But the uniformity of power output for SiO_2 (Nanoparticles) coated panel is more consistent as compared to other 3 panels.

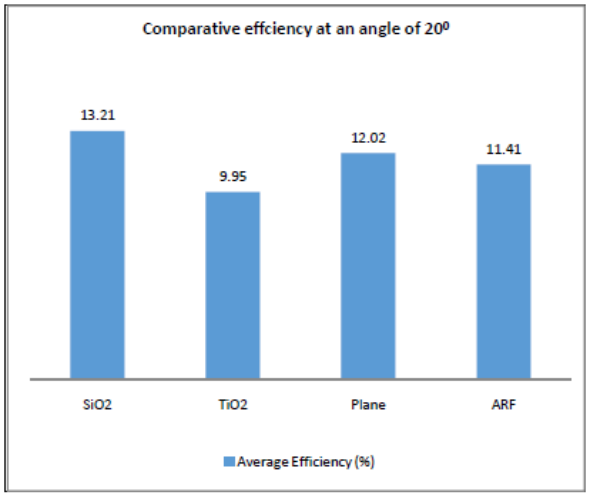


Fig 6. Comparative efficiency of all panels at the inclination of 20^0

Fig. 6 is a plot of Efficiency at an angle of 20^0 which clearly indicates that Panel coated with SiO_2 shows an Average Efficiency of 13.21%. The increase in efficiency of SiO_2 (Nanoparticles) coated panel is 32% more as compared to TiO_2 coated, 20% more as compared to Plane panel and 14% more as compared to panel with Antireflective film.

V. THEORETICAL MODEL

Experimentally :

- The output power of a cell can be calculated as $\mathbf{P_{out} = VI.}$
- The input power received by the cell is $\mathbf{P_{in} = G*A}$
- The efficiency is defined as $\mathbf{\eta_{exp} = P_{out}/ Pi_n = P_{mp}/ (G*A)}$**……(i)**

Theoretically:

- Mathematically Temperature of Solar Cell and ambient temperature are related as:
  $\mathbf{T_{cell}(^oc) = T_{air} + 0.035*G}$**……(ii)**
  Where T_{air} is in °C, G in W/m^2
- Cell Temperature is also a function of Wind velocity, it is related as :
  $$\mathbf{Tcell = Tair + \frac{0.32}{8.91+2Vw} * G}\text{……(iii)}$$
  Where V_w = Wind Velocity in m/s
  *

Theoretically efficiency of Solar cell is calculated as:

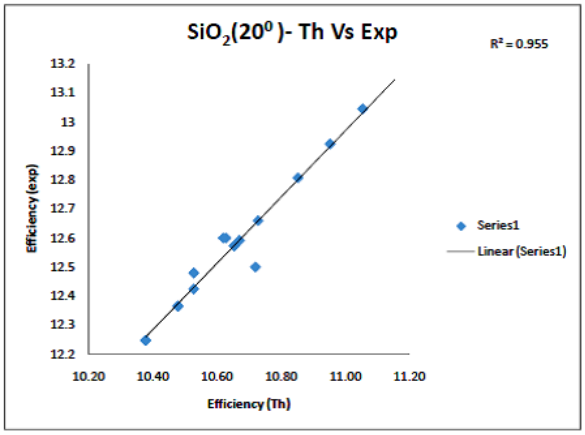
$\mathbf{\eta_{th.} = 12.757 - 0.05T_{cell}}$ .....(iv)

It is found that

$\mathbf{\eta_{exp} = G_f * \eta_{th.}}$ .....(v)

G_f – Correction factor which varies from 0.96 to 1.18

For SiO_2 coating (Sol-gel) is found to be most efficient. G_f varies between 1.1 to 1.18 for SiO_2 coating.



The figure reflects that the SiO_2(Nanoparticles) coating material is justifying the mathematical model as discussed above and is in good agreement with theoretical model

VI. CONCLUSION

The absorption factor of a PV cell is the fraction of incident solar irradiance that is absorbed. This absorption factor is derived from spectral reflection and transmission measurements for a set of crystalline Silicon samples. The fact that texture and AR coating reduce reflective losses and increase the absorption factor. SiO_2 nano particles get seated in the troughs of Glass surface. This reduces reflection of incident sunlight and consequently absorption increases. Temperature is one more concern for the

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performance of solar cells. Temperature effects are the result of inherent characteristics of solar cells. They tend to produce higher voltage as the temperature drops and, conversely, to lose voltage in high temperatures. The energy conversion efficiency is increased by reducing the reflection of incident light.

Cleaning and prevention of dust are two main options to counter the deposition problem in SPV panels. Cleaning can be achieved by various manual processes, but they seem to be energy-intensive and time-consuming efforts. Therefore, the present work reflects that the SiO_2 (Nanoparticles) coated panel is more efficient than the Plane panel, which is in use today.

In view of market point, it is observed that Multi-crystalline Silicon panels are cheap and have less efficient in the tune of 11% conversion . The present work shows that if the same Multi-crystalline Silicon panel is coated with SiO_2 (Nanoparticles) then the efficiency increases to 13.2% as against 10.90% . The percentage enhancement in efficiency of the panel is 21.1%.

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