Performance of Photovoltaic Cell Based on Reflectivity and Absorptivity

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Abstract:-The recent decades have seen the increase in solar power demand for reliable and clean sources electricity. Solar cells which converts solar radiations into electricity is employed in today’s world to overcome the demand of electricity. several factors like temperature, dust, affects the performance of solar cell hence the efficiency of a solar cell is decreased due to the increase in temperature, low absorptivity and high reflectivity of solar radiations at the surface of solar cell. Hence there is a way to boost up the efficiency of solar cell by increasing the light intensity incident on the solar cell also by reducing the amount of radiations reflected from the photovoltaic module. This paper describes about the improved performance of solar cell by using coating materials in the layer of solar cell and by using dome structures as the protective layer. Anti-reflection coatings are applied on the layer of solar cell which reduces the amount of light reflected from the surface of solar cell and makes them to get incident on the cell thereby by leading to increase in efficiency of solar cell.

Keywords:-Antireflective Coating, Dielectric Nano Structures, Power Conversion Efficiency.

I. INTRODUCTION

World energy demand of nearly 13% is coming from different renewable sources. Sun is one of the natural resource which offers immense potential for electric power generation. The Photovoltaic is an effect which converts solar energy into electricity. To increase the absorptivity and to decrease the reflectivity of a solar cell by using various composite semiconducting materials.

One of the simplest technique in which solar cell efficiency could be increased is by anti-reflective coating (ARC) [1-4]. Solar cell efficiency increased by adopting antireflection coating over the surface of the solar cell. In GaInP solar cell SiO₂ and SiN₄ are used as dielectric layers which has a wavelength of 285 to 700 nm an incident angle of 60° [2]. The current density is 1.43 and 1.05 Times higher than that of bare cells and with single anti-reflection coating. As a result call conversion efficiency of 15.01% was achieved which is 5.91% higher than that of bare cells and 1.05 times higher than solar cells single anti-reflection layer [3].

ARC consists of a dielectric layer which have some demerits like low reflectivity and narrow bandwidth [1-2]. In order to overcome this drawback biometric sub wavelength structures (SWS) are used Sub-Wavelength Structure (SWS) is a newly developed application, to reduce the reflectance and increase transmission [1-4]. The combination of SWSARC for multi-junction solar cell is very challenging, because the current generated is limited by the sub-cell. In this we demonstrate a chemical way of synthesising InGaP/InGaAs/Ge in a triple junction solar cell [1]. The Defects like uniformity lacking, performance degrading and fabrication are complex. To overcome all these a method is proposed and demonstrated successfully that includes antireflective could be easily achieved by Triple Junction (T-J) solar cell. SWS decreases surface reflection thereby leading to increase in efficiency. SWS fabrication involves dry etching and dewetting process, followed heat treatment process at 300 to 900°C for Au, Ag, Cu, Ni, and Al so it is not suitable for solar cell [3]. Glancing angle deposition (GLAD) method which reduces thermal dewetting temperature. Thus SWS for GaAs solar cell fabrication is done by GLAD method [3].

The external factors like temperature, moisture content, and physical shocks degrade the efficiency of solar cell. In order to protect the solar cell from these external factors protective layers are employed. These protective layers cause reflection of sunlight thus leading to reduction in power conversion efficiency [4]. In order to overcome this problem anti-reflection coating was applied on the surface of solar cell but this coating involves complicated fabrication process and also increases the cost. Thus one of the alternative method is providing a dome shaped anti-reflective microdome array (MDA), which has high transmittance and great mechanical stability is used as protective layer on the top surface of solar cell [4]. Polymer and quartz are two commonly used materials for producing MDA’s. Amorphous and crystalline hetero junction (SHG) solar cell is cheap and has low recombination. Transparent conductive oxide (TCO) is used as contact layer.
for SHG. Reflection loss is common in SHG. Thus anti-reflecting coating is used to reduce it where percentage reflectance is zero. Double anti-reflecting coating is used to obtain low broad range reflectance [5].

Formation of nanostructured back electrode for enhancing the light absorption in polymer solar cells by light scattering of the electrode [7]. Enhancing the performance of polymer solar cells with iodine doping concentrations [8]. Reduction of efficiency loss in n-type multicrystalline silicon solar cell by improvement of material qualities [9]. Heterojunction interdigitated solar cell is employed to access the efficiency progress [10].

II. PERFORMANCE OF PV CELL

A. Based on Reflectivity

For the uses of space and solar power plants, cells with the combination of GaAs has been used widely as it has higher efficiency, to attain its efficiency different process of fabrication has been carried out. Chen-Chen Chung et al suggested that under the conditions of refractive index and thickness, reflection losses could be minimized by fabricating ARC (Antireflective Coating) [1]. Two types of coatings could be done either by a single layer ARC or double layer ARC whereas multiple layer increases the cost. The commercial T-J solar cell has Si$_3$N$_4$ single layer of ARC and is prepared by two different combinations i.e., SiH$_4$+N$_2$ and SiH$_4$+NH$_3$ in a plasma-enhanced chemical vapour (PECVD).

SiN$_x$ film gets deposited by PECVD using SiH$_4$ and N$_2$ as reaction gases and therefore SiH$_4$ dissociate with the plasma to form SiH$_2$ where the deposition increases as SiH$_4$ also increases. The results obtained shows an ammonia-free process favours the anti-reflecting throughout the whole spectrum. For the quality controlling N$_2$ has been used [1]. An excellent device performance is achieved by using high quality ARC.

Yanyan Wanget alrecommended that using SiO$_2$ and SiN$_x$ as a dielectric nano structures on window layer of the GaInP solar cell the surface reflection and carrier leakage is significantly reduced [2]. 10 nm thick SiO$_2$ after reactive ion etching (RIE) process combines with SiN$_x$ film and act as double layer dielectric antireflection coating which reduces the reflection from SiO$_2$ layer [2].

Jung Woo Leem et al suggested that TiO$_2$ has excellent transmittance, hardness, durability hence it can be used as material for anti-reflective coating. TiO$_2$ which has refractive index of (1.90 to 2.45) between cover glass and (3.5) could be used as ARC [3]. SWS is fabricated on the top layer of TiO$_2$ or GaAs substrate by dry etching of Au Nanomaterial’s [3]. After heat treatment process dotted Au Nano patterns are formed following by dry etching leads to Sub wavelength structure. After this process optical reflectance properties are measured by simulation software [3]. For comparison of TiO$_2$ layer with quarter wavelength thickness (63 nm) is also prepared as single layer ARC.

B. Based on Protective Layers

Minwoo Nam et al proposed a method for reducing the reflectivity is by providing microdome array (MDA) shaped protective layer. When MDAs is placed above the solar cell the reflected radiation has multiple opportunities to reach the active layer either by refracting several times in micro dome or by penetrating through adjacent Dome [4]. Due to this reflection is reduced and the light gets dispersed at active layer of solar cell more efficiently thus resulting in increase in efficiency of solar cell.

![Protective Layers](image)

Fig. 1: Protective Layers
Optical simulation for refraction modelling of the incident light passing through the bare plate (left) and the proposed micro-dome structure (right) [4].

Two MDAs based on quartz and PDMS where fabricated and tightly bounded to GaAs single junction solar cell. Quartz is chosen as primary MDA because of its high stability and transparency [4]. In fabrication process chromium is placed above the crystal and is allowed for chemical wet etching process to form 2 micrometre circular hole [4].

Two different etching time is performed to form different shapes of MDA s, when the etching time is 90 min then spherical MDA is formed and when time is 120 min non-spherical MDA is formed. These MDAs obtained from quartz considered as master mould for PDM MDAs [4]. suggested

C. Based on Absorptivity

JianYuet al recommended that the use Localized plasmonic resonance as an efficient light trapping scheme. Silver gating surfaces employed to excite the plasmonic effect for TM mode. Structure demonstrates enhanced absorption in the wavelength range of 600-1000nm. The plasmonic properties of metal nanoparticles for light trapping increases the internal reflections which will enhance efficiency in solar cells [6].

Fabrication of n-type mc-Si TOPC on solar cell for reduction of material related efficiency loss. To improve the active layerlight harvesting capability for efficiency enhancement. Optical absorption shifting conductivity of pentacene increment by iodine doping. HJIBC solar cell was fabricated to minimize light reflection [7-10].

The scattering layers made from polydimethyl siloxane (PDMS) polymers will reduce the losses and provides an efficiency of 10.6% the plasma cell and module would enhance light trapping in silicon cell at front surface and reduce reflection. An antireflection foil carrying the retro reflective texture on top surface will reduce the reflectance loss from 9.2mA/sq.cm to 4.7mA/sq.cm. one wafer is double side polished and another was textured on rear surface and third was on both surface silicon Hetero junction solar cells were fabricated on wafers with three surface textures that affect the PDMS scattering layer on front surface solar cell. The PDMS scattering layer of silicon device with plasma front surface with rear surface texture as reduced reflectivity [11].

The front surface texture increases the chance for short wavelength absorption by increasing the surface area. The lower texture density can be obtained by size of increase in structure and smaller size population is replaced by largest sized pyramids. The reactive Ion etching (RIE) is done on Silicon surface, it attacks the highly reactive Ion plasma with Cl₂ Texturization is controllable in final texturing size which further enhanced by using metal catalyst like Cr and Al in RIE process which has lowest reflectance. The texture front surface reduces reflectivity and increased current density [12].

Light absorption in ultrathin crystalline Silicon solar cells with composite grating structures can be reduced using three dimensional rigorous coupled wave analysis. The composing grating which is a superposition of two sub grating with different length scales increases light trapping in a broad spectral range. The nano structures like nanospheres, nanowire, nanocore and nano pyramid which is made of silicon were optimized for low reflectivity and enhance the absorption in active layer. The double grating which is coated at front and rear layers has the wavelength of 300nm to 1100nm which has improved absorption. The nano pyramids have high absorptivity by coating it with composite grating on top and silver mirror at the back surface to reduce transmission loss and increase absorptivity [13].

Dye-Sensitized solar cells (DSSCs) has low production cost, simple fabrication process and high energy conversion efficiency. To improve light absorption in dyed TiO₂ electrode, antireflection coating is done on front surface of the substrate. The SiO₂ thin film was proposed by liquid phase deposition. The Silicon oxide anti-reflective film was deposited on glass substrate using liquid phase deposition. The lower surface roughness of LDPSiO₂ film with H3BO3 concentration of 10M, reduce light loss due to scattering and reflection [14].

D. Based on Types of ARC Materials

The amorphous Silicon hydrogenated solar cells can be increased by using dielectric nanostructures made of SiN₄ that acts like antireflection coating. The absorption Si-H solar cells are used with a layer structure. The buffer suggest electric field photo generated charge carrier separation The Si-H solar cell thickness increases overall performance of solar cells. Larger the thickness layerlarger will be the absorption. The Dielectric nanostructures for Si-H cells, with optimized antireflection coating layer will increase the current density [15].

The surface of multi-crystalline silicon wafers are textured with ion etching and alkaline to reduce their solar reflective and increase efficiency. The process reduces to <2% wavelength of range 800-850nm. The wafers are textured by THE process in order to reduce the reflectivity. Light trapping techniques are used to observe light such as surface texturing and anti-reflection multilayer coatings are applied as fabricating. Many fabricating techniques are used which includes photo-lithographic and masked or mask less reactive ion etching (RIE) texturing. The RIE does a single side surface reflection with little material loss. Self-masking is achieved without using the nano scale mask and lithographic [16].

Wet edging chemical is simple whereas texturing of multi-cuisine silicon needs periodically structured array. Here in this
technique when a silicon solar cell is subjected to the patterning process, patterned silicon surface is produced with low reflectivity. Wafers are polished in an acidic bath set up. The Si square wafers are coated with JSR. Patterning is proceeded using DUV and the ion etching process. It is covered by a PDMS layer [17].

Few materials make the reflected rays bounce back to the same surface. Silicon wafers etching, reactive ion etching with chemical etching gives increase in efficiency. But Silicon textured by inductively coupled plasma ICP etching produces nanopillars race and the atomic layer deposition on NP race to study the properties. This increases the efficiency by 9.2 to 10.8 %. Alternative is non-thermal lasers using laser scanners [18]. It melts the surface without heat and gives rise to diffusion and implementation. The polymeric layer over the solar cell traps more number of photons which in turn increases efficiency.

III. DISCUSSION

The proposed SWS/graded SiNx structure serves an effective ARC for the T-J solar cell. This technology offers a new thinking to further enhancement in light absorption of solar cell. The mixtures of SiH₄ and N₂ replace the traditional ammonia gas reactions and improves the light absorption by 30% [1].

GaInP decorated with dielectric players have low surface reflection. For dielectric materials reflection is lower especially in shorter wavelength. By using dielectric composite nanostructure the power conversion efficiency is 1% higher than SiN, and 5.5% then single antireflection layer coated GaInP solar cells respectively [2].

Surface reflection is strongly dependent on the thickness of layer. TiO₂ SLARC in wavelength of 350 to 900 nm at an incident angle 22-80 degree has solar weighted reflectance of 6.2%. SWS has Power conversion efficiency (PCE) of 33.3% compared to one without antireflection coating [3]. Thus PEC is enhanced due to increase in current density. SWS is efficient ARC to improve power conversion efficiency. Spherical MDA has higher transmittance percentage when compared to non-spherical MDA. PDMA which spherical shape has let's transmittance when compared to non-spherical MDA.

The measured PCEs for the solar cells covered with the quartz-based spherical and non-spherical MDAs, the bare quartz plate, the PDMS-based spherical MDA, and the bare PDMS film were 23.95%, 23.58%, 23.13%, 23.72%, and 22.98%, respectively [4]. Absorption loss can reduce the benefits from DARC. In 300-400 nm range, 500-1200 nm is more effective. Further improvement is by reducing IR absorption with IWO film there is an efficiency gain of 0.25% on 5 in. bifacial SHG solar cell with DARCs [5].

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**Fig. 2: Power Conversion Efficiency Based on Different Anti Reflecting Coating**
The above graph depicts about the power conversion efficiency variation on different anti-reflecting coating done on the layer of solar cell. When Ag is present on the SiO$_x$ coating the power conversion efficiency is very poor. From the graph when spherical shaped quartz MDA is placed over the top surface of Solar cell the efficiency is high. Thus by using anti-reflecting coating the reflectivity can be decreased and the efficiency of the solar cell could be increased.

![Graph showing external quantum efficiency](image_url)

**Fig. 3: External Quantum Efficiency**

Thin film silicon solar cell efficiency increases in TM mode due to plasmonic effect by employing one dimensional quasi photonic crystal, a grating surface and an anti-reflection layer. It is further enhanced by Heterojunction Interdigitated Back Contact to minimize the light reflection. Iodine causes increases in absorption coefficient and increased charge carrier mobility. TOPC cell concept enables efficiency exceed and reduce losses by material quality improvement. Micro nanostructured morphology on the surface of the active layer leading to significant enhancement in the power conversion efficiency over the solar cell [6-10].

The PDMS scattering layer of silicon device with planar front surface coupled with rear surface texture has reduced reflectivity [11]. Texturization is controllable in final texturing size which further enhanced by using metal catalyst like Cr and Al in RIE process which has lowest reflectance. The Texture front surface reduces reflectivity and increased current density[12]. The Optimised composite nanostructure yields a photocurrent up to 33.9mA/cm$^2$ at thickness of 2µm and by using Reactive Ion Etching using composite nanostructure light absorption is increased[13]. The Surface roughness was reduced and light absorption is improved from 10.71% to 13.43%. The energy conversion efficiency is improved from 4.76% to 6.03% with LPD-SiO anti-reflection layer[14]. The Total reflectance obtained by the optimised nanostructure is around 0%. By using Si$_3$N$_4$ as dielectric layer with optimised nanostructures the absorptivity is increased by 0%[15].
## IV. SUMMARY

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**V. CONCLUSION**

Solar cell efficiency can be improved by using anti-reflective coating on the layer of the solar cell. Microdome structures is also used as a protective layer which protects the solar cell from external factors like dust, fog, etc. and reduces the amount of solar light reflected from the solar cell which enhances the efficiency of photovoltaic cell. By using crystalline silicon thin film solar cells with textured surface coatings on both sides of surfaces which acts as a dielectric layer which increases the current density and reduces reflectivity.

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