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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 SiO_2 and SiN_x are used as dielectric layers which has a wavelength of 285 to 700 nm an incident angle of 60° [2].The current density is 1.43and 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 antireflection 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].Heterojunctioninterdigitated 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-ChenChunget 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_3N_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_4 as reaction gases and therefore SiH_4disassociate 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 is been used [1].An excellent device performance is achieved by using high quality ARC.

YanyanWanget alrecommended that using SiO_2 and SiN_x as a dielectric nano structures on window layer of the GaInP solar cell the surfacereflection 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 SiO2 layer [2].

JungWooLeemet alsuggested 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

MinwooNamet alproposed 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.

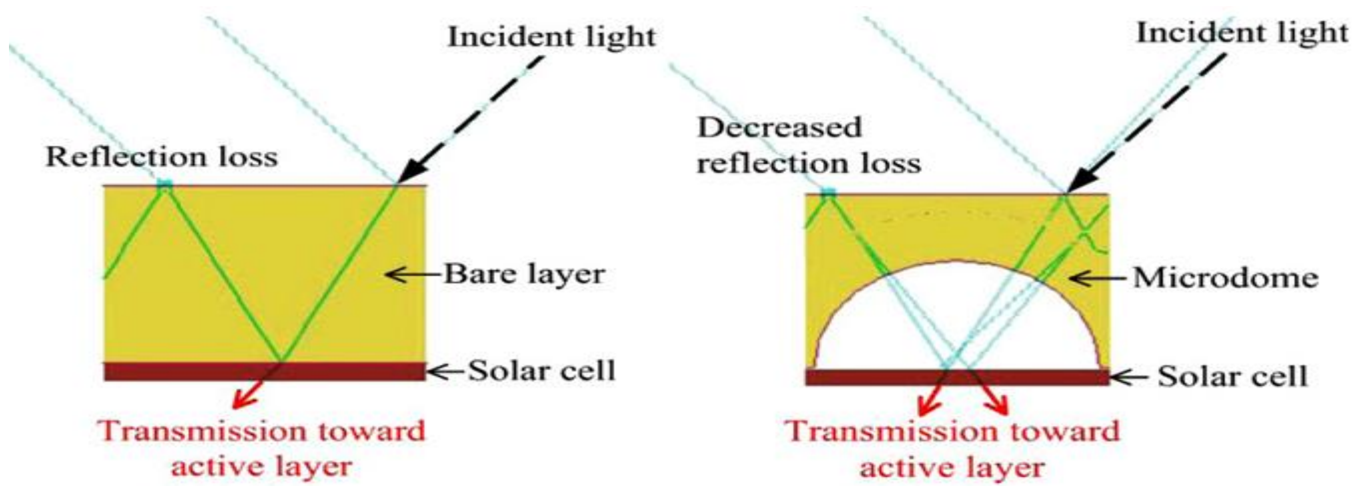

Fig. 1: Protective Layers

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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 MDA's obtained from quartz considered as master mould for PDM MDA's [4].suggested

C. Based on Absorptivity

JianYuet alrecommended that the useLocalized 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 Heterojunction solarcells was fabricated on wafers with three surface textures that affect the PDMS scattering layer on front surface solarcell. 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 Cl_2.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 canbe 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 of300nm 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 TiO_2 electrode, antireflection coating is done on front surface of the substrate. The SiO_2 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 LPD-SiO_2 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 nanostructuresmade of Si_3N_4 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. TheSi-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 optimizedantireflection 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 800-850 nm. 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 ormask 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 siliconneeds periodically structured array .Here in this technique when a silicon solar cell issubjected to the patterning process, patterned silicon surface is produced with lowreflectivity.Wafers are polished in an acidic bath set up. The Si square wafers are coatedwith JSR. Patterning is proceeded using DUV and the ion etching process. It is covered bya PDMS layer [17].

Few materials Makes the reflected rays bounce back to the same surface Silicon waferetching, reactive Ion etching with chemical etching gives increase in efficiency.But Silicontextured by inductively coupled plasma ICP etching produces nanopillars race and the atomic layerdeposition 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 givesrise to diffusion and implementation. The polymeric layer over the solar cell traps more numberofphotons which in turn increases efficiency.

III. DISCUSSION

The proposed SWS/graded SiN_x 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 SiH_4 and N_2 replaces 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_x and 5.5 % then single antireflection layer coated GaInP solar cells respectively [2].

surface reflection is strongly dependent on the thickness of layer.TiO_2 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-basedsphericalandnon-sphericalMDAs,thebare quartz plate,thePDMS-basedsphericalMDA,andthebarePDMS film were23.95%,23.58%,23.13%,23.72%,and22.98%,respectively [4].Absorption loss can reduce the benefits from DARC. In300-400nm range .Thus 500-1200nm is more effective. Further improvement is by reducing IR absorption with IWO film there is an efficiency gain of0.25% on 5in. bifacial SHG solar cell with DARCs [5].

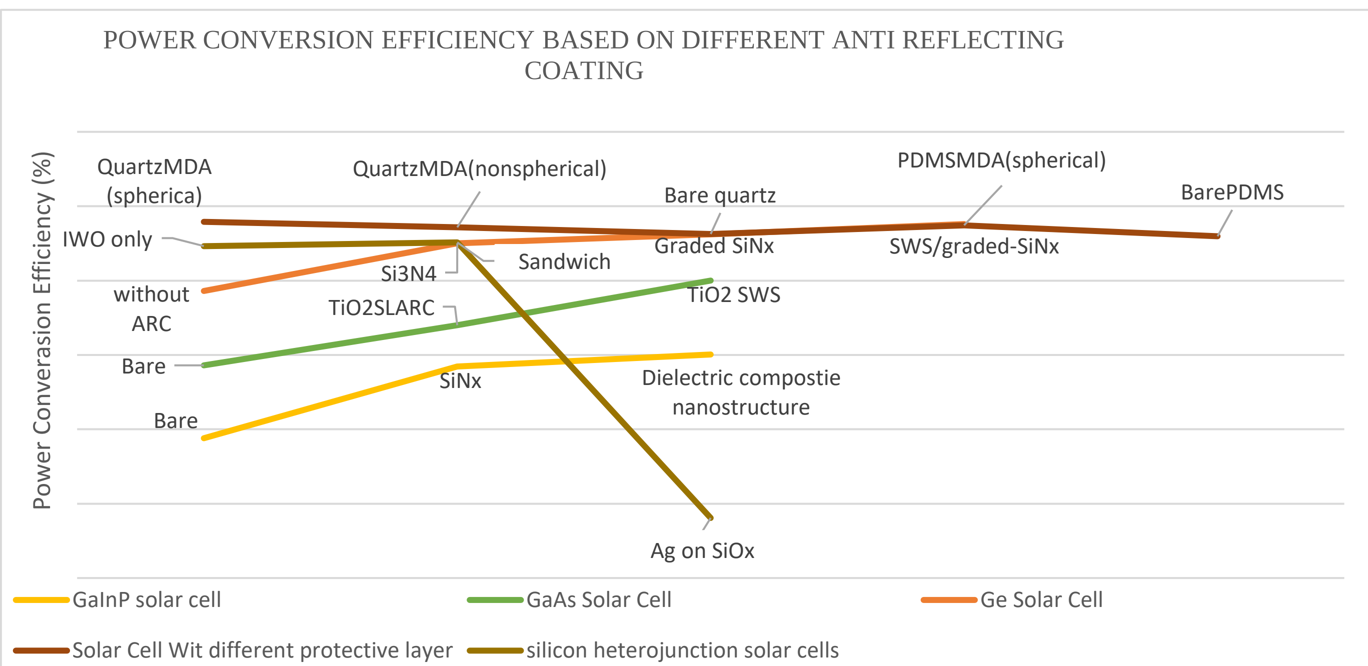

Fig. 2: Power Conversion Efficiency Based on Different Anti Reflecting Coating

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 de decreased and the efficiency of the solar cell could be increased.

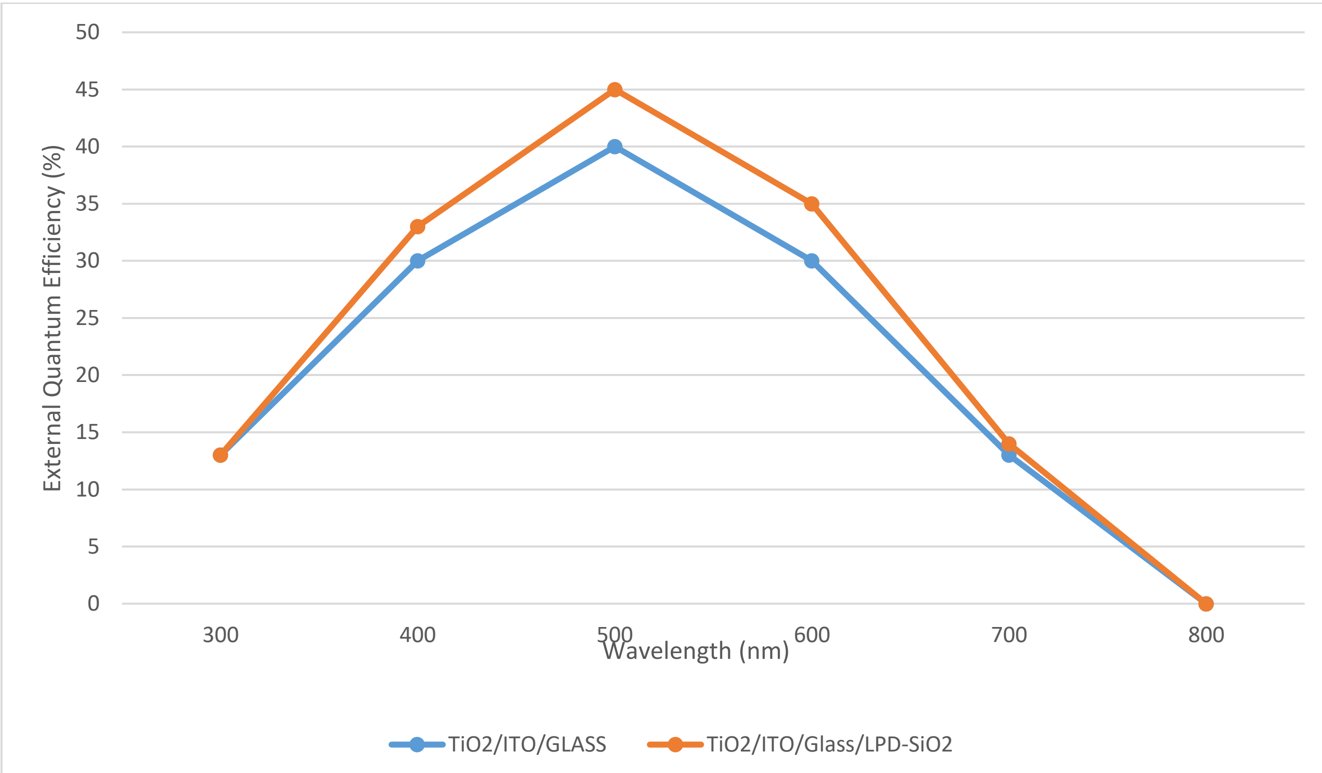

Fig. 3: External Quantum Efficiency

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 upto 33.9mA/cm2 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 Si3N_4 as dielectric layer with optimised nanostructures the absorptivity is increased by 0%[15].

IV. SUMMARY

S.No	Journal Title	Authors	Types of coating material and solar cells used	Discussion	Conclusion
1	Broadband antireflection sub-wavelength structure of InGaP/InGaAs/Ge triple junction solar cell with composition-graded $SiN_{x.}$	Chen-ChenChung, et al.	InGaP/InGaAs/Ge triple junction solar cell,SWS/graded-SiN_x ARC.	The triple layer multi junction solar cell (GaInP, GaAs, and Ge) has higher efficiency compared to single layer cell. By using antireflection layer on the surface of the triple layer cell efficiency is increased.	SWS/Graded SiNx as anti-reflecting coating has increased the light absorption by 30% thus solar cell efficiency is increased.
2	Efficiency improvement of GaInP Solar cells by broadband omnidirectional reflection through dielectric Composite nanostructures.	Yanyan Wang, et al.	GaInP Solar, Dielectric nanostructures, $SiN_{x.}$	Dielectric composite nanostructures consists of nan patterned SiO_2, beneath this layer there is a thin film of SiO_2 and SiNx layers. This dielectric composite structures also reduces the dark saturation current.	GaInP solar cell with composite nanostructures has improved the cell conversion efficiency by more than 1% and 5.5% compared to SiNx coated and bare cells.
3	Efficiency improvement of III–V GaAs solar cells using biomimetic TiO_2 Sub wavelength structures with wide-angle and broadband anti-reflection properties.	J.W.Leem, et al.	GaAs solar cells, TiO2 sub wavelength structures.	Anti-reflecting coating is applied on solar cell to reduce the reflectivity of radiation. Thus TiO_2 is prepared by dry etching of Au nanomaterial.	TiO_2 as a material for anti-reflecting coatingat broad wavelength has enhanced the power conversion efficiency of solar cells.
4	Efficiency improvement of solar cells by importing microdome-shaped anti-reflective structures as a surface protection layer.	Minwoo-Nam, et al.	Solar cell, Quartz MDA, PDMS MDAs.	Since solar cell is affected by dust and other external factors protective layers are employed on the surface of solar cell. When micro dome shaped structures are used the reflectivity is greatly reduced.	When the GaAs Solar cells covered by These MDAs has increased the power conversion efficiency by 3.5%.
5	Improved opto electronic properties of silicon hetero-junction solar cells/Tungsten-doped indium oxide double anti-reflective coatings.	JianYu, et al.	Silicon Hetro Junction solar cell, Tungsten-doped indium oxide (ARC).	SiOx/MgF_2 as anti-reflecting layers present a cost effective solar cell with higher efficiency.	SiOx film prepared by plasma enhanced chemical vapour deposition at low temperature as ARC has high transparency and low reflectivity.

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6	Improved efficiency of thin film solar cell by plasmonic properties of silver.	M Faramarzi nezhad, et al.	Silver nano grating, one-Dimensional quazi photonic crystal composed of SiO2/Si layers.	Cell efficiency increases in TM mode due to plasmonic effect.	Cell efficiency is increased by 8.2% with SiO_2 grating.
7	Efficiency improvement of polymer solar cells with a random micro nanostructure back electrode formed by active layer self-aggregation.	Xiong Li, et al.	Propylene glycol mono methyl ether acetate (PGMEA).	Active layer self-aggregation and mold free methodology to manufacture high performance polymer solar cell with micro-nanostructured back electrode.	Efficiency improvement of 17.9% as compared to the planar device.
8	Efficiency improvement of polymer solar cell by iodine doping.	ZuliangZhuo, et al.	Hetrojunction polymer solar cells, iodine.	Cell efficiency increases by different iodine doping concentration.	Conductivity of pentacene quantum efficiency is increased. For 5%of iodine 1.5% of efficiency is increased.
9	Optimized multicrystalline silicon for solar cells enabling conversion efficiency of 22%.	Florian Schindler, et al.	Multicrystalline n-type silicon, boron.	Fabrication of TOPC on solar cells based on optimized n-type HP mc-Si substrate for enhancing the efficiency of mc-Si solar cell.	Efficiency in the range of 22.5% for n-type mc-Si TOPC on solar cells was increased.
10	Exceeding conversion efficiency of 26% by Heterojunction Interdigitated back contact solar cell with thin film Si technology.	Kunta Yoshikawa, et al.	-	Fabrication of Heterojunction Interdigitated back contact solar cell for efficiency enhancement of solar cell.	Efficiency of 26.6% was obtained using HJIBC solar cell.
11	Broadband anti-reflection coating using dielectric Si3N4 nanostructures. Application to amorphous Si-H solar cells.	M.H. Elshorbagy, et al.	Amorphous Si-H solar cells, Si_3N_4	The amorphous Si-H solar cells can be increased by using dielectric nanostructures made of Si3N4.	The total reflectance obtained by the optimized nanostructures is around 20%.By using Si3N4 as dielectric layer with optimized nanostructures the absorptivity is increased by 20%
12	Improved light management in planar silicon and perovskite solar cells using PDMS scattering layer.	Salman Manzoor, et al.	Poly-dimethyl siloxane, silicon Heterojunction solar cells	The silicon Heterojunction solar cells with wafers on three surfaces textures that decreases the reflection on PDMS scattering layer on front surface Cells.	The PDMS scattering layer of silicon cell with planar front surface coupled with rear surface texture has reduced reflectivity by 10.6%.

13	Research and development efforts on texturization to reduce the optical losses at front surface of silicon solar cell.	M.F.Abdulla et al.	Silicon, RIE(Reactive Ion Etching).	The optical losses on front surface of silicon solar cell can be reduced by texturization process.	By using crystalline silicon solar cells with textured surface coatings on both sides of surfaces it increases current density and reduces reflectivity with increase in efficiency of 24%.
14	Efficiency enhancement in ultrathin crystalline silicon solar cells with composite surface gratings.	Heng Ma, et al.	Silicon cells, Nanosphere, nanowire, nanopyramid.	Light absorption in ultrathin crystalline silicon solar cells with composite grating structure can be reduced using 3-Dimensional rigorous coupled wave analysis.	By using inverted nan pyramid on two sides of silicon film it has 76% higher output efficiency than planar solar film.
15	Antireflection Coating of SiO2 Thin Film in dye-sensitized Solar Cell prepared by Liquid Phase Deposition.	Chao-Nan Chen, et al.	TiO2 electrode, H3BO3 concentration, SiO2 thin film.	To improve light absorption in dyed TiO2 electrode antireflection coating is done on surface of the substrate.	By using Liquid Phase Deposition method of Sio2 thin film with H3BO3 light absorption is improved from 10.71% to 13.43% and energy conversion efficiency from 4.76% to 6.03%.
16	0.76%absolute efficiency increase for screen –printed multicrystalline solar cells with nanostructures by relative ion etching.	Wen-hua chen, et al.	Anti-reflection nanostructures, multicrystalline silicon wafer, AR coating SiNx.	Nanostructures are created using the mask less RIE subsequent to alkaline etching (alkaline).	Self-masking is done by RIE process by developing high density nanostructure to reduce the reflectance about <2%.
17	solar cells efficiency ent with nano imprint technology.	S.landis, et al.	Si-c and Si-mc wafers, KOH etching, Pocl3.	Optical simulation to compute the reflectivity of the patterned surface to point out the impact of pyramid angle.	Sharpening pyramid shape will drastically reduce optical reflectivity .a very low optical reflectivity property lower than 3%was achieved whatever the crystalline orientation of the silicon grain. But there is a loss in open circuit voltage and fill factor.
18	enhancementof silicon using ARF laser induced micro/nanostructures on the polymeric layers of solar cells.	P.Parvin, et al.	ARF laser, micro/ nanostructures.	Efficiency enhancement using RF laser induced micro or Nano structure on polymeric layer of solar.	The polymeric structure in this method enhances the efficiency of the solar cells. The laser shots of 150 elevates the electron and hole generation rate from 7% to8%.

19	Potential of mixed phase doped layers in p type Si Heterojunction solar cells with ZnO: Al	Lucia v.mercaldo, et al.	Silicon Heterojunction with al doped ZnO by means of mixed Si and SiOx doped layers.	Four types of doped layers have been selected, two boron doped (p-type) and phosphorous based (n-type).	Mixed phase Si-SiOx based doped layers have been evaluated as possible advance emitter and black surface field layers for p-type Si-HJ solar cells with AZO.
20	An anti-reflection 1-D rectangle grating on GaAs solar cells using one step femtosecond laser fabrication.	Ruifang chan et al.	GaAs solar cells, femtosecond laser irradiation.	It is found that rectangle grating micro/nanostructure with a period of 700nm and width of 600nm is obtained.	Reflectance of plane and 1-D rectangle grating fabricated by femtosecond laser with single laser pulse energy of 20μJ, 30μJ, 40μJare measured.

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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