ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 12, December 2017

Super Hydrophobic Antireflective Coating to Enhance Efficiency of Solar PV Cells

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***Abstract*: -- Efficiency of solar panels is greatly affected by dust and soiling. Solar panel reflects a considerable amount of light which also decrease the efficiency. Every day cleaning of solar installation is time consuming and costly. Hydrophobic coating works as anti dust coating so it will enhance the efficiency and decrease the cost of cleaning of solar cells. In India most of solar projects are situated in arid areas (MP, Gujarat etc) where dust decreases efficiency of solar cells. Thus by combining these two properties and applying superhydrophobic and antireflective coating we can increase the efficiency of solar cells by 25-40%.**

Keywords — **Superhydrophobic, antireflective, efficiency, selfcleaning, coating.**

I. INTRODUCTION

Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies. For heating and lighting homes and other buildings solar energy can be used directly or indirectly. It is also used for generating electricity, solar cooling, and for hot water heating. Solar energy is used for variety of commercial and industrial purposes. A large number of solar cells spread over a large area and produce enough power to be useful in various purposes. Nowadays Solar energy plays a very important role in providing clean and sustainable energy [1].

Figure1: Layers of Solar panel

The efficiency of solar panels decreases by dust and reflection process. Snow, Dust, dirt and other particles covers the panel surface and hence it cause loss in power. There are many sources by which dust are generated such as volcanic eruptions, pollution, by wind. The amount of the dust deposited on the solar panels affects the energy delivered by the solar panels on daily, monthly and annually basis. Dust deposition reduces solar cell performance considerably. B. Ghosh and A.K. Ghosh in their study reported that dust-assimilation on the surface of solar PV panels can reduce system out-put to 16-40% in a month investigation [2]. Dust and rain water droplets get accumulated over the glass surface of solar panels and it causes corrosion in solar panels. Due to soiling effects, the optical parameters are affected which reduces the energy generation due to low light transfer hence causing additional loss in the overall efficiency [3].Therefore regular cleaning of the solar panels becomes indispensable which causes scratches on the glass panels. Super
hydrophobic coating will act as anti-dust coating and reduce accumulation of dust particle on it. It also helps to repels water, viscous liquids, and most solid particles. Superhydrophobic coatings make surface highly water repellent and water droplets form contact angle of more than 1500 with the surface. When water droplets fall on the coated surface it rolls down caring dust particles and hence the panel surface remains clean for long time[4].

Figure 2: Picture depicting rolling down of water droplets carrying dust particles on a super hydrophobic surface.

A monocrystalline silicon solar cell absorbs only two-thirds of the sunlight falling on the panel's surface and one-third of the sunlight reaching the surface of a solar panel has a chance to be reflected. An anti-reflective coating or glass can reduce the sunlight reflection and increase the amount of sunlight that is absorbed. The covering of a solar cell system is made of glass or plastic. Glass and common plastics have indices of refraction in the range of 1.45–1.7, so they also reflect from 4% to over 6.5% of normally incident light on each air/substrate interface. The transmitted energy of a solar cell system will be lost considerably from multiple reflections. The reflectivity of a surface, The reflection is reduced by creating textures and by applying anti-reflection coatings (ARC) to the surface [5]. The properties of the glass surface can be modified by applying an anti-reflective coating which possesses self-cleaning and high transparency to visible light. Thus by combining these two properties in a coating form on solar panels we can enhance its efficiency upto 40%. Methods

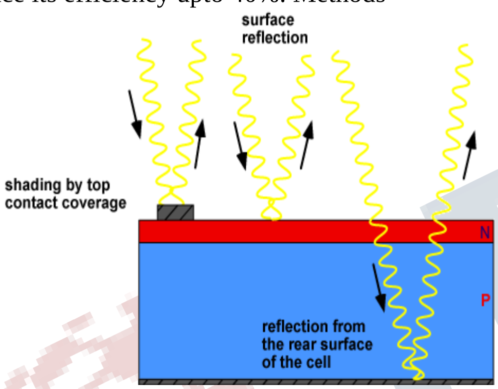

Figure 3: Different type of reflections on solar panel

II. MATERIALS USED IN SUPERHYDROPHOBIC ANTIREFLECTIVE COATINGS

For this approach, the biggest challenge is the availability of material which possesses the refractive index lower than that of glass (n < 1.5) and also able to create nanostructures for super hydrophobicity. Various compounds are available which can be used either single or in combination with other to create super hydrphobic antireflective coatings. Some chemical compounds which are used as coating material for super hydrphobic antireflective properties and their properties are given in table 1. Super hydrophobic and antireflective coatings are made by many different materials. The most effective coating used is silica nano-coating [6-7]. Silica nano-coating is the gel based coating which can be easily applied on the object into the gel or via aerosol spray. Some materials which are used in these coating are as given in table 1:

Table 1 Materials used for superhydrophobic antireflective coatings

Material	Property	Reference
nano silica	Super hydrophobic	6-8
TiO_2	Antireflective	9-10
ZnO	Antireflective	9,11-12
MgF_2	Antireflective	12
CuO	Super hydrophobic	13-14
MnO_2	antireflective	15
poly(vinylidene fluoride) (PVDF)	Super hydrophobic	16
Poly tetra fluoro ethylene	Super hydrophobic	17
Polystyrene	Super hydrophobic	18-20

Low surface energy maximizes the surface hydrophobicity. Units of surface energy and surface tension are same Surface energy has the same units as surface tension (dynes/cm). A high surface tension liquid like water will have maximum hydrophobicity and hence show poor wetting (high contact angle) over a coated surface having low surface energy. Table 2 shows that variation in surface energy dependent on the nature of the surface that comes in contact with water [21]. For example, a coating of polyhexafluoropropylene (12.0 Dynes/cm) on the surface results a more hydrophobic surface than that of polymethylmethacrylate (EU) (40.2 Dynes/cm). Thus to provide more hydrophobicity, the material's most hydrophobic moiety should be positioned on the surface. Presence of Perfluoro and aliphatic (EU) groups at the coating surface results more hydrophobicity compared to ester or alcohol groups.

Table 2 – Surface Energy of Various Materials

Material	Surface Energy (Dynes/cm)
Hepta decafluoro hexyl-trimeth oxysilane	12.0
Poly hexa fluoro propylene	12.4
Poly tetra fluoro ethylene	19.1
Octa decyl trichlorosilane	20.24
Nona fluoro hexyl-trime thoxysilane	23
Paraffin Wax	26.0
Poly viny lidene Fluoride	30.3
Polyethylene	32.4
Poly methyl methacrylate	40.2
Polystyrene	40.6
Poly vinyl edene Chloride	41.5
Polyester	43-45
Polyethylene terephthalate	45.5
Epoxy polyamide	46.2

III. COATING TECHNIQUES

A. Spin Coating:

For the application of thin films, spin coating process has been used. In this process a fluid is deposited at the centre of the substrate and then spinning of the substrate is done at a very high speed around 3000 to 8000 RPM. The fluid will spread by the centripetal acceleration and then a thin film of fluid on the surface is formed. The properties of the film depend upon the nature of the fluid [22].Many researchers have successfully prepared superhydrophobic antireflective coatings on glass substrate by using spin coating techniques [23-25].Spin coating technique gives a result of uniform coating on entire surface but the main limitation is that we can coat only on small substrates (~6 inch diameter). It is not possible to coat large substrate by Spin coating method. Thus for preliminary research work on solar panels coatings we can use this method but we cannot go for large scale use. This technique utilizes very low amount of coating material and hence there is no wastage of coating material.

B. Spray Coating:

Spray coating technique is used in the polymeric solar cell. Ultrasonic spray coating is used in both thin film & amp; Photovoltaic crystalline Silicon applications. Due to low velocity and high uniformity of atomized droplets during the coating process, a micron and highly uniform thick layer can be formed on thin solar film cells and c-Si [26].

superhydrophobic antireflective coating by using Ultrasonic spray coating was employed by many researchers [27-29] and found uniformity in coating thickness on entire substrate.

C. Dip Coating

In dip coating method a precise and controlled immersion and withdrawal of substrate in a liquid coating material takes place. After dipping and withdrawal cycle a thin layer of cating material is deposited on substrate. This technique is generally used for the formation of thin films by sol-gel and self-assembly techniques.

Among the various coating methods for thin film diposition the dip coating is oldest commercially applied coating method. The industrial useof dip coating was originated in 1940s in the seminal works at Schott [30]. In late 1950s it was used in the production of automotive rear mirrors. This method is also suitable for large area optical coatings like antireflective and solar control glasses. No doubt Dip-coating is the easiest and fastest method to prepare thin films of chemical solutions with the highest degree of control which make it highly appropriate for R&D and small scale production. In specific high technology cases, it is used to deposit coatings on large surfaces [31].

D. Chemical Vapour Deposition

Chemical vapour deposition is a technique in which Formation of non volatile solid takes place by the deposition of gaseous reactant onto a substrate. Chemical Vapour deposition process is used to build micro-/nanoparticles and conversion of

nanorods into ordered microscopic structures [32]. This technique is used to produce high quality solid materials. This technique is also used to produce thin films in semiconductor industry [33-35]. Hsieh et al [36] used catalytic chemical deposition method, decorating carbon nanotube into microsized carbon fibers produced a fabricated superhydrophobic carbon fabric with micro/nanoscaled two-tier roughness

E. Physical vapor deposition

Physical vapor deposition (PVD), is a coating method in which bombardment of the substance to be coated with energetic positively charged ions on the substrate takes place in vacuum condition. PVD is of two type

i. Evaporation beam evaporation in which cathodic arc or electron beam sourcesare used for bombardment.

ii. Sputtering in which magnetic enhanced sources or "magnetrons"used for bombardment

Typical working pressure for PVD is 10-2 to 10-4 mbar and reactive gases like acetylene, nitrogen or oxygen may be used to create various compound coating compositions. PVD results in is a very strong bond between the coating and the substrate with tailored physical and structural properties of the film [37]. Sputtering is a suitable method for anti-reflective coatings on glass for optical applications as low substrate temperatures used

IV. CONCLUSION

Initial capital cost of solar panel installation is too high. Large investment is one the primary reason why solar energy is still not used by many people all over the world. It is important not to focus solely on initial capital investments but efficiency, energy yield; stability and lifetime of solar panels are also important factors. By using antireflective super hydrophobic coating on solar panel we can reduce the cost of PV electricity by reducing its maintenance and increasing energy output. This coating will also increase the life time of solar panel by protecting it from natural environmental factors like acid rain, scale formation etc. This type of coating can be easily applied on preinstalled solar panels. It is very simple technique to enhance solar panels efficiency.

V. ACKNOWLADGEMENT

The authors would like to thank Department of Science and Technology - Clean Energy Research Initiative (DST-CERI) India, for financially supporting this research.

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