International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 10, October 2017
www.ijarse.com
IJARSE
ISSN 2319 - 8354

A Review on Enhancing Solar Cell Glass with Nanoparticles

Upendra Sharan Gupta[1], Kratika Sohale[2], Mayank Bansal[3]

[1]Reader, [2,3]UG Scholar, Dept. of Mech. Engineering, SVITS, Indore (India)

ABSTRACT

Solar cells or Photovoltaic cell is an electric device that convert the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomena. However many researches are conducted in which solar cell in glass has been shaped. Glass is used in "photovoltaic modules" as layers of protection against the element. In thin film technology, glass also serve as the substrate upon which the photovoltaic material such as "Transparent Conductive Oxides" are deposited. Photovoltaic glass (PV glass) is a technology that enables the conversion of light into electricity. To do so, the glass incorporates transparent semiconductor-based photovoltaic which are also known as solar cells. The cells are sandwiched between two sheets of glass. Photovoltaic glass is not perfectly transparent but allows some of the available light through. Buildings using a substantial amount of photovoltaic glass could produce some of their own electricity through the windows. The PV power generated is considered green or clean electricity because its source is renewable and it does not cause pollution. On introducing nanotechnology (i.e) nanoscopic particles in solar glass, environments where too much heat gets in with light, the reduced transparency can also save on air-conditioning costs. Variations have been designed for environments where more light is desired.

Keywords: Surface Plasmon, Photovoltaic Modules, Transparent Conductive Oxides

I. INTRODUCTION

Deriving plentiful electricity from sunlight at a modest cost is a challenge with immense implications for energy, technology, and climate policy, this approach has the potential to greatly improve the ability of solar cells to harvest light efficiently. Worldwide photovoltaic production capacity at the end of 2017 is estimated to be about 360 GW. Current solar cells cannot convert all the incoming light into usable energy because some of the light can escape back out of the cell into the air. Additionally, sunlight comes in a variety of colors and the cell might be more efficient at converting bluish light while being less efficient at converting reddish light. The nanoparticle approach seeks to remedy these problems. The key to this new research is the creation of a tiny electrical disturbance called a "surface plasmon". When light strikes a piece of metal it can set up waves in the surface of the metal. These waves of electrons then move about like ripples on the surface of a pond. If the metal is in the form of a tiny particle, the incoming light can make the particle vibrate, thus effectively scattering the light. If, furthermore, the light is at certain "resonant" colors, the scattering process is particularly strong. A light-absorbing coating transforms a low-efficiency solar cell made of an inexpensive form of silicon into one with promising performance. Many properties provided by supramolecular chemistry, nanotechnology and

IJARSE
ISSN 2319 - 8354

catalysis only appear in solids exhibiting large surface areas and regular porosity at the nanometer scale 1–4. In nanometre-sized particles, the ratio of the number of atoms in the surface to the number in the bulk is much larger than for micrometre-sized materials, and this can lead to novel properties.

II. LITERATURE REVIEW

a) Fully transparent solar cell could make every window and screen a power source

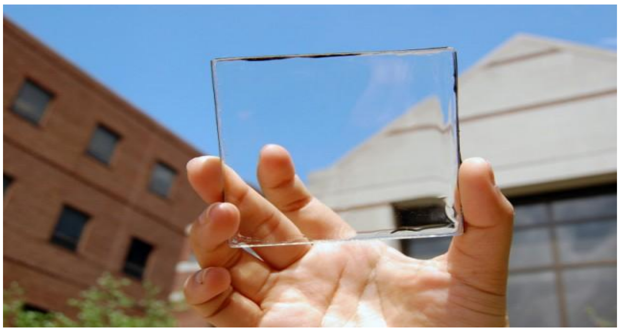

Fig. 1 Transparent Solar Cell

Researchers at Michigan State University created a fully transparent solar concentrator, which could turn any window or sheet of glass (like your smartphone's screen) into a photovoltaic solar cell. Unlike other "transparent" solar cells that we've reported on in the past, this one really *is* transparent, as you can see in the photos throughout this story. Essentially, what they're doing is instead of shrinking the components, they're changing the way the cell absorbs light. The cell selectively harvests the part of the solar spectrum we can't see with our eye, while letting regular visible light pass through. Scientifically, a transparent solar panel is something of an oxymoron. Solar cells, specifically the photovoltaic kind, make energy by absorbing photons (sunlight) and converting them into electrons (electricity).

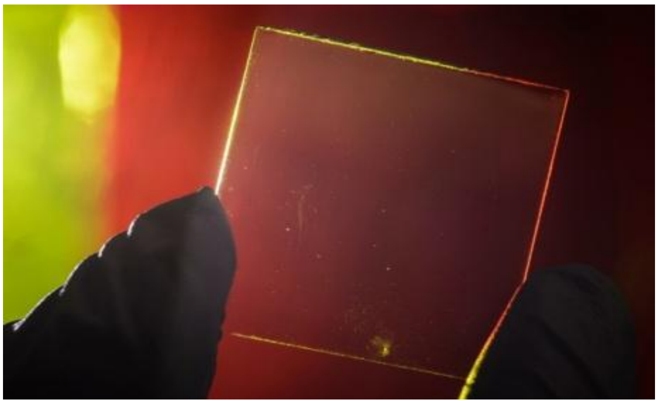

Fig. 2 A transparent solar glass cell and

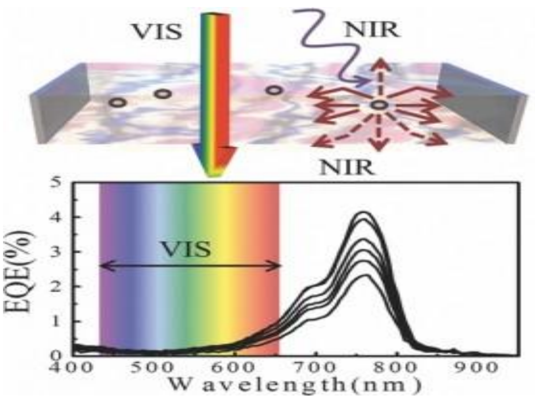

Fig. 3 The organic salts absorb UV and infrared, emit infrared — Process that occur outside of the visible spectrum, so that it appears transparent.

Instead of trying to create a transparent photovoltaic cell (which is nigh impossible), they use a *transparent luminescent solar concentrator* (TLSC). The TLSC consists of organic salts that absorb specific non-visible wavelengths of ultraviolet and infrared light, which they then luminesce (glow) as another wavelength of

IJARSE
ISSN 2319 - 8354

infrared light (also non-visible). This emitted infrared light is guided to the edge of plastic, where thin strips of conventional photovoltaic solar cell convert it into electricity.

The prototype TLSC currently has an efficiency of around 1%, but they think 10 & should be possible once production commences. Non-transparent luminescent concentrators (which bathe the room in colorful light) max out at around 7%. On their own these aren't huge figures, but on a larger scale — every window in a house or office block -the numbers quickly add up. And while we're probably not talking about a technology that can keep your smartphone or tablet running indefinitely, replacing your device's display with a TLSC could net you a few more minutes or hours of usage on a single battery charge.

b) Towards ultra-thin plasmonic silicon wafer solar cells with minimized efficiency loss

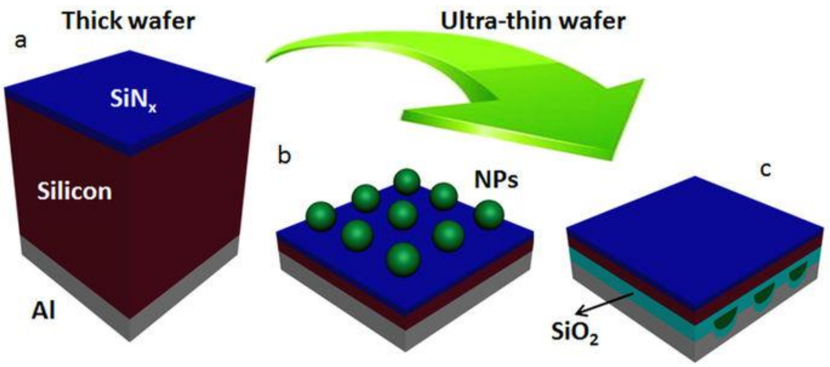

Fig. 4 Plasmonic silicon wafer solar cell

The cost-effectiveness of market-dominating silicon wafer solar cells plays a key role in determining the competiveness of solar energy with other exhaustible energy sources. Reducing the silicon wafer thickness at a minimized efficiency loss represents a mainstream trend in increasing the cost-effectiveness of wafer-based solar cells. using the advanced light trapping strategy with a properly designed nanoparticle architecture, the wafer thickness can be dramatically reduced to only around 1/10 of the current thickness (180 μm) without any solar cell efficiency loss at 18.2%. Nanoparticle integrated ultra-thin solar cells with only 3% of the current wafer thickness can potentially achieve 15.3% efficiency combining the absorption enhancement with the benefit of thinner wafer induced open circuit voltage increase. This represents a 97% material saving with only 15% relative efficiency loss. These results demonstrate the feasibility and prospect of achieving high-efficiency ultra-thin silicon wafer cells with plasmonic light trapping. An effective way of cost reduction is to make the wafer thinner since the wafer cost accounts for approximate 50% of the solar cell cost. In the past few decades, the wafer thickness has been reduced from 400 μm to the current 180 μm and the trend of reduction is continuing. Apart from the cost saving consideration, thinner wafer can potentially lead to a higher open circuit voltage, Voc, due to the lower bulk recombination and more efficient electron-hole pair extraction. Metallic nanoparticles, which support localized surface plasmons, have been demonstrated to be able to provide advanced light trapping mechanisms to significantly enhance the light absorption in solar cells by the scattering and near-field effects_So far, most of the plasmonic solar cell research has been focused on the thin film technology Only limited work has been conducted on Si wafer solar cells using Ag or Al nanoparticles due to the fact that thick silicon wafer cells absorbs almost 90% of the sun light higher than the bandgap. There is

IJARSE
ISSN 2319 - 8354

limited room to further increase. However, as the wafer thickness reduces, the nanoparticles are expected to play an increasingly important role.

C) Innovative new coating provides 1.2% efficiency boost on triple junction solar cells

MetaSOL nanotechnology coating can provide a 1.2% (absolute) efficiency boost for triple junction solar cells. MetaSOL is a nanoparticle embedded glass-based coating that increases solar cell efficiency using advanced light trapping technology. The patent pending formula is spray coated directly onto the existing anti-reflective coating on the solar cells and hardens at room temperature, forming a transparent ~200nm glass film.

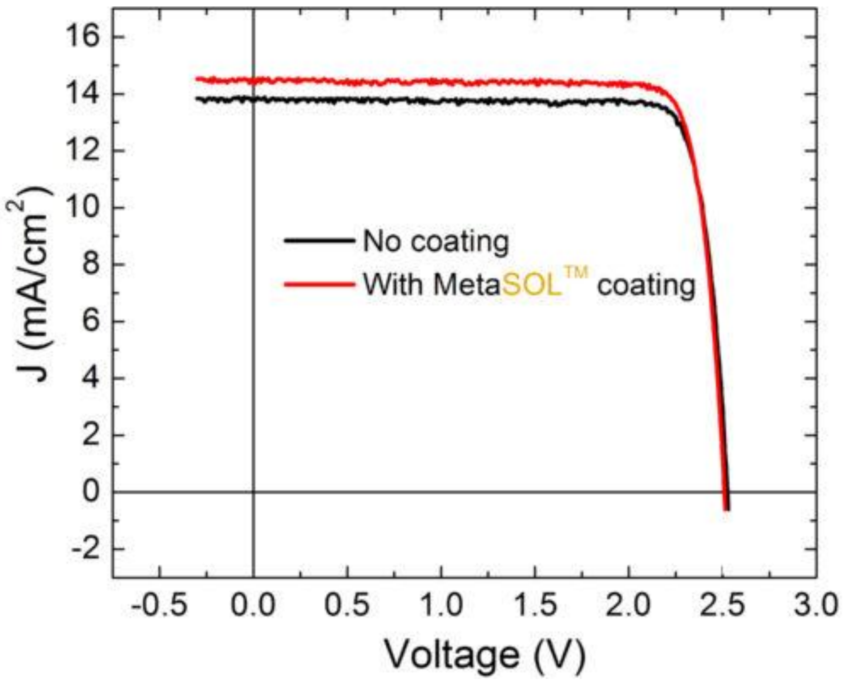

Fig. 5 Graph between Voltage to Energy produced, after a coating of MetaSOL

The embedded nanoparticles employ strong forward scattering to affect optical enhancement in solar cells. MetaSOL, when applied to triple junction solar cells, boosted their efficiency 1.2% (absolute). An analysis and advisory firm focused on the transformation of the global electricity industry, which predicted that efficiency of conventional solar panels is likely to improve by an average of about 0.2% annually. In the study, triple junction GaInP/GaInAs/Ge solar cells, were coated with MetaSOL. The solar cells used were not encapsulated and already had commercial AR coatings. The current voltage measurements (J-V curve) of the devices were measured under ***AM1.5*** simulated solar spectrum illumination at OAI-Optical Associates, before and after the coating was applied. The comparison revealed an increase in device efficiency from 29.39% to 30.59%, an absolute increase of 1.2%. Upon application, the product solidifies in air at room temperature and forms a thin film layer with refractive index of ~1.5. MetaSOL's light-trapping coating employs plasmonic and dielectric nanoparticles to enhance the forward scattering of light incident on solar cells, and hence increase the short circuit current and the overall photo-conversion efficiency of these devices.

d) Plasmonic Solar Cell

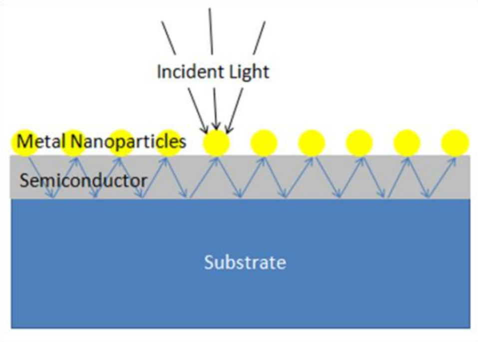

Fig. 6 Plasmonic Solar Cell

A plasmonic solar cell is a type of thin film solar cell that converts light into electricity with the assistance of plasmons. They are typically less than 2 µm thick and theoretically could be as thin as 100 nm. They can use substrate which are cheaper than silicon, such as glass, plastic or steel. One of the challenges for thin film solar cells is that they do not absorb as much light as thicker solar cells made with materials with the same absorption coefficient Methods for light trapping are important for thin film solar cells. Plasmonic cells improve absorption by scattering light using metal nano particles excited at their surface plasmon resonance. Incoming light at the plasmon resonance frequency induces electron oscillations at the surface of the nanoparticles. The oscillation electrons can then be captured by a conductive layer producing an electrical current. The voltage produced is dependent on the bandgap of the conductive layer and the potential of the electrolyte in contact with the nanoparticles. There is still considerable research necessary to enable the technology to reach its full potential and commercialization of plasmonic enhanced solar cells.

There are currently three different generations of SCs. The first generation (those in the market today) are made with crystalline semiconductor wafers, typically silicon. Current SCs trap light by creating pyramids on the surface which have dimensions bigger than most thin film SCs. Making the surface of the substrate rough (typically by growing SnO_2 or ZnO on surface) with dimensions on the order of the incoming wavelengths and depositing the SC on top has been explored. This method increases the photocurrent, but the thin film SC would then have poor material quality. The second generation SCs are based on thin film technologies such as those presented here. These SCs focus on lowering the amount of material used as well as increasing the energy production. Third generation SCs are currently being researched. They focus on reducing the cost of the second generation SCs. The third generation SCs are discussed in more detail under recent advancement.

e) Graphene nanoparticles in solar cells

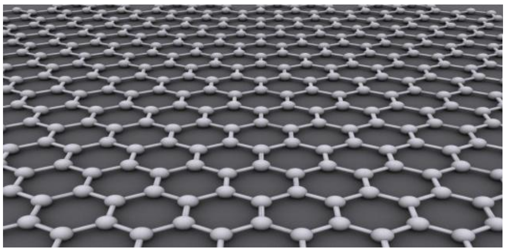

Fig.7 Structure of Graphene

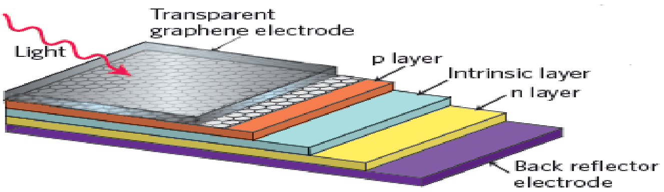

Fig. 8 Schematic of inorganic solar cells with Graphene

International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 10, October 2017
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Graphene is a two-dimensional material with honeycomb structure. Its unique mechanical, physical electrica and optical properties makes it an important industrially and economically material in the coming years. One of the application areas for graphene is the photovoltaic industry. Graphene has a low coefficient of light absorption 2.3% which indicates that is an almost completely transparent material. In fact, it means that solar cells based on graphene can significantly expand the absorbed spectrum wavelengths of electromagnetic radiation. Graphene additionally is a material with a very high tensile strength so it can be successfully used on the silicon, flexible and organic substrates as well. So far, significant effort has been devoted to using graphene for improving the overall performance of photovoltaic devices. The strongest bond in nature, the C-C bond covalently locks these atoms in place giving them remarkable mechanical properties. Study determine the elastic limit of graphene in the range of 1 TPa, and Young's modulus of 0.5 TPa. This material is 100 times stronger than steel. And if so, graphene can come into the new super durable, yet very flexible materials replacing or reinforcing plastic and metal. To be able to introduce such use graphene need to find him a suitable substrate.

III. MATERIALS & METHODS WHICH INCREASE THE EFFICIENCY OF SOLAR CELL.

1. *To increase the efficiency of solar cell glasses.*
2. *Using transparent solar concentrator in order to harness much sunlight, which could turn any window or sheet of glass (like your smartphone's screen) into a photovoltaic solar cell.*
3. *In summers car must be sweltering, fitting such glasses in cars containing nano-sized particles that trap the heat and keep cool atmosphere inside.*

IV. METHODOLOGY

To increase the efficiency as solar cell glass we use two layers of nanoscopic particles sandwiched between TLSC sheets of glass.

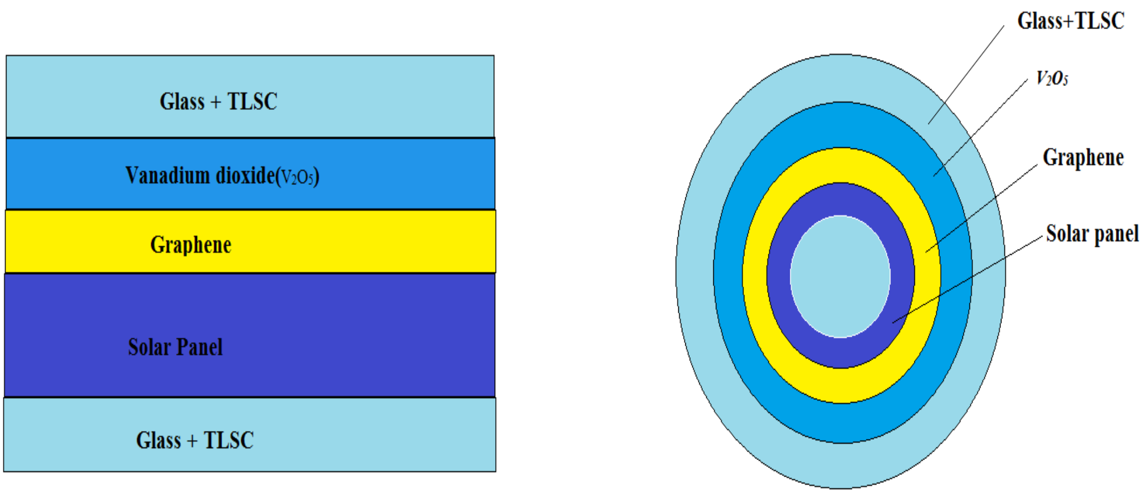

Fig.9 The Arrangement of layers in solar cell glass.

The three layers are:

Layer 1 – Transparent Luminescent Solar Concentrator (TLSC)

The arrangement of nano- particle sheets will be done in the way shown above. Firstly on the glass where light is incident, Transparent Luminescent Solar Concentrator is used, in which organic salts absorb specific non-visible wavelengths of ultraviolet and infrared light, which they then luminesce (glow) as another wavelength of infrared light (also non-visible). This emitted infrared light is guided to the edge of plastic, where thin strips of conventional photovoltaic solar cell convert it into electricity.

Layer 2 – Vanadium Dioxide – A Thermo-chromic

The second layer will be of vanadium dioxide which is a thermo-chromic material , this thermochromic nanoparticles infrared transparent to infrared reflective when they heat up, which will help to keep office building, homes and even cars cool. Vanadium dioxide changes its optical transmission with temperature, at cooler temperature it is transparent to infrared light. When it heats up, it becomes metallic and reflects infrared or IR radiations without obstructing the view of visible light. Vanadium dioxide nanoparticles switch due to temperature instead of from applying electricity like electrochromic material.

Layer 3 – A sheet of Graphene

Graphene additionally is a material with a very high tensile strength so it can be successfully used on the silicon, flexible and organic substrates as well. So far, significant effort has been devoted to using graphene for improving the overall performance of photovoltaic devices. The strongest bond in nature, the C-C bond covalently locks these atoms in place giving them remarkable mechanical properties. Study determine the elastic limit of graphene in the range of 1 TPa, and Young's modulus of 0.5 TPa. This material is 100 times stronger than steel. And if so, graphene can come into the new super durable, yet very flexible materials replacing or reinforcing plastic and metal. To be able to introduce such use graphene need to find him a suitable substrate.

IV. EFFICIENCY

The most important parameters a characterizing the properties of photovoltaic cells are:

1. Current-voltage characteristic
2. Current density [mA / cm^2]
3. The open-circuit voltage [V]
4. Fill factor (FF)
5. Power conversion efficiency η = PCE [%]
6. Stability in air

In research on new solar cells or modifications of existing cells ones is precisely these parameters are compared with each other to determine whether a new type of cell has better or worse properties.

The basic characteristic defining the important parameters of a solar cell is current – voltage characteristic. With this Characteristics we can read such values as short-circuit current (Isc) and open-circuit voltage (Voc). Furthermore, you can determine the current (Im) and the voltage(Vm) for maximum power cells. With this data is easy to calculate further parameters such as: the fill factor FF, the maximum power (Pmax) or cell efficiency "η". Current – voltage characteristics for ideal solar cell should be in the shape of a rectangle with sides (Isc) and (Voc). In practice, of course, we did not find the perfect cell. The maximum power of the actual cell is always smaller than the cell's power ideal, equal to the product of open circuit voltage (Voc) and short-circuit current I

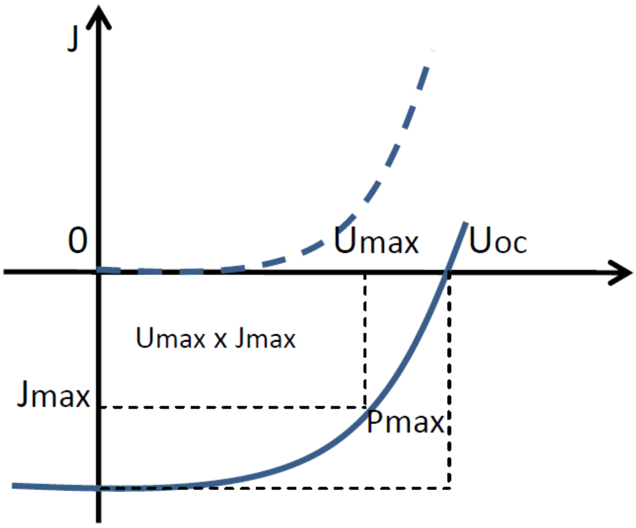

Fig.10 Maximum Power and Energy Characteristics of Nanoscopic Solar cell

Fill factor (FF) is an important parameter that determines the power conversion efficiency of an organic solar cell. It shows the extent to which current-voltage characteristics of the PV cells is close to ideal, that is, the area of rectangle. Fill Factor is calculated as a percentage (dimensionless) as a ratio of the area of a rectangle with sides (Im) and (Vm) to the field rectangle with sides (Isc) and (Voc).

FF = $I_m V_m / I_{sc} V_{oc}$

Power conversion efficiency η = PCE is the ratio of the maximum power recovery in the cell to the radiation power of sunlight falling on the cell. It can be calculated with the following formula:

$\eta = I_{mp} V_{mp} / J.s$

η- efficiency of the cell, J - the intensity of the radiation incident on the cell [W/m2]

S - the surface area of the cell [m2

The efficiency as theoretically expected to be 24.27% but practically it is not calculated.

V. CONCLUSION

In this paper, we have summarized the advances in the research of light trapping and the plasmonic enhancement of thin film solar cells glass. Metallic nanoparticles can excite localized surface plasmons, which benefit for light scattering and light concentration to enhance the light absorption in thin film cell.

The enhancement by these plasmonic modes is strongly related to the material, size, shape, refractive index of the medium, position in the absorber layer of metallic nanoparticles, The position of metal nanostructures has significant effect on the plasmonic solar cells.

Use of Vanadium oxide, graphene and TLSC in solar cell glass will enhance the production of electricity thereby reducing the cost and better utilization of green energy.

VI . SCOPE FOR FUTURE WORK

Worldwide growth of photovoltaic has been an exponential curve between (2007–2017). During this period of time, photovoltaic (PV), also known as solar PV, evolved from a niche market of small scale applications to a mainstream electricity source. Experience curves describe that the price of a thing decreases with the sum-total ever produced. PV growth increased even more rapidly when production of solar cells and modules started to ramp up in the USA with their Million Solar Roofs project, and when renewables were added to China's 2011 five-year-plan for energy production. Since then, deployment of photovoltaic has gained momentum on a worldwide scale, particularly in Asia but also in North America and other regions, where solar PV by 2015–17 was increasingly competing with conventional energy sources as grid parity has already been reached in about 30 countries.

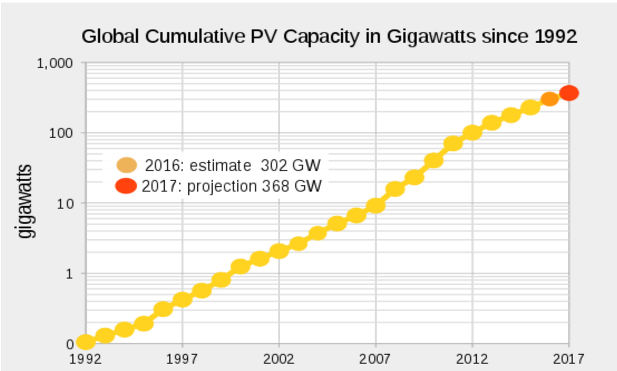

Fig.11 Growth of Global Cumulative PV Capacity in Gigawatts

Projections for photovoltaic growth are difficult and burdened with many uncertainties. Official agencies, such as the International Energy Agency consistently increased their estimates over the years, but still fell short of actual deployment.

By the end of 2016, cumulative photovoltaic capacity reached about 302 gigaWatts (GW), estimated to be sufficient to supply between 1.3% and 1.8% of global electricity demand. Solar contributed 8%, 7.4% and 7.1% to the respective annual domestic consumption in Italy, Greece and Germany. Installed worldwide capacity was projected to more than double or even triple to more than 500 GW between 2016 and 2020. By 2050, solar power was anticipated to become the world's largest source of electricity, with solar photovoltaic and Concentrated solar power contributing 16% and 11%, respectively. This would require PV capacity to grow to 4,600 GW, of which more than half was forecast to be deployed in China and India.

REFERENCE

[1.] Boehm H.P., Setton R., Stumpp E. Nomenclature and terminology of graphite intercalation compounds, Pure and Applied Chemistry 66 (1994), 1893-1901.

[2.] Science nr 324, Graphene: Status and prospects (2009), 1530-1534.

[3.] Kumar N.A., Dar M.A., Gul R. Jong-Beom Baek, Graphene and molybdenum disulfide hybrids: synthesis and applications; Materials Today 18(5) (2015).

[4.] Soldano C., Mahmood A., Dujardin E., Production, properties and potential of grapheme; Carbon 48 (2010), 2127-2150. Santanu Das, Pitchaimuthu Sudhagar and Yong Soo Kang, Wonbong Choia; Graphene synthesis and application for solar cells; J. Mater. Res.2013.

[5.] Gwamuri, J.; Güney, D. Ö.; Pearce, J. M. (2013-01-01). Tiwari, Atul; Boukherroub, Rabah; Sharon, heshwar, eds. Advances in Plasmonic Light Trapping in Thin-Film Solar Photovoltaic Devices. John Wiley & Sons.

[6.] Goetzberger, A., Hebling, C. & Schock, H. Photovoltaic materials, history, status and outlook. Mater. Sci. Eng. R 40, 1–46 (2003).

[7.] Kerr, M. J. & Cuevas, A. Very low bulk and surface recombination in oxidized silicon wafers. Semicond. Sci. Technol. 17, 35–38 (2002).

[8.] Yu, Z., Raman, A. & Fan, S. Nanophotonic light-trapping theory for solar cells. Appl. Phys. A 105, 329–339 (2011).

[9.] Zhang, Y. et al. Improved multicrystalline Si solar cells by light trapping from Al nanoparticle enhanced antireflection coating. Opt. Mat. Express 3, 489–495 (2013).

[10.] Yang, Y. et al. Enhanced light trapping for high efficiency crystalline solar cells by the application of rear surface plasmons. Sol. Energy Mater. Sol. Cells 101, 217–226 (2012).

[11.] Fahim, N., Jia, B., Shi, Z. & Gu, M. Simultaneous broadband light trapping and fill factor enhancement in crystalline silicon solar cells induced by Ag nanoparticles and nanoshells. Opt. Express 20, A694–A705 (2012).

[12.] Chen, X. et al. Broadband enhancement in thin-film amorphous silicon solar cells enabled by nucleated silver nanoparticles. Nano Lett. 12, 2187–2192 (2012).

[13.] Tiedle, T., Yablonovitch, E., Cody, G. & Brooks, B. Limiting efficiency of silicon solar cells. IEEE Trans. Electron Dev. ED-31, 711 (1984).

[14.] Willeke, G. Thin crystalline silicon solar cells. Sol. Energy Mater. Sol. Cells 72, 191 (2002).

[15.] Green M. A. Lambertian light trapping in textured solar cells and light-emitting diodes:

[16.] Analytical solutions. Prog. Photovolt. 2002; 10:235–41.

[17.] Pala R. A., White J., Barnard E., Liu J., Brongersma M. L. Design of plasmonic thin-film solar cells with broadband absorption enhancements. Adv. Mater. 2009;21:1–6.

[18.] Forster, S. & Plantenberg, T. From self-organizing polymers to nanohybrid and biomaterials. Angew.Chem. Int. Edn 41, 688–714 (2002).

[19.] 4. Klok, H.-A. & Lecommandoux, S. Supramolecular materials via block copolymer self-assembly. Adv. Mater.13, 1217–1229 (2001).

[20.] K.R. Catchpole and A. Polman. Plasmonic Solar Cells. Optics Express, Vol. 16, Issue 6, December 22, 2008

[21.] R.R. Lunt and V. Bulovic. “transparent, near-infrared organic photovoltaic solar cells for window and energy-scavenging applications.” Applied Physics Letters, vol. 98, no. 113305, 2011.

[22.] Michael E. A. warwick and Russell Binions. “Advancement in thermochromic vanadium dioxides films.” J. Mater. Chem. A, 2014, 2375-3292.