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Review on Surface Texturing Method for Solar Cell Efficiency Enhancement

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ABSTRACT

Sun oriented cells are also known as Photoelectric (PE) cells, which labour to transform sunlight specifically into electricity, Photoelectric cells are attached electric powered and conveniently arranged within a wide outline known as sun based board. The efficiency of the sun-powered cell is turned on by the number of consumed photons that are absorbed in the consumer sheet of the sun-powered cell. However, the low absorption rate of the absorber material and light reflection in the surface of the material and the material interfaces of the glass absorbers will reduce the conversion of solar energy. The effect of the energy conversion can be upgraded by modifying the surface morphology of the solar cell. In this article review of Exterior by different Texturing Method to increase efficiency enhancement, minimum waste energy of light of the sun and to get maximum efficiency for the Sun Powered Cell Effective Upgrade has been investigated.

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1. Introduction

The development of technology depends on the basic materials and the energy which are used in it. Electricity has become important energy in today technology which there are more important sources to the generation of electrical energy such as hydropower, nuclear energy, geothermal, wind, fossil oil and solar energy. In the last decades, solar energy has more attention because it is free for everyone, it has minimal damage to the environment, and it needs to the low coast compared to. Every day we take a large amount of solar energy in the form of heat and radiation from the sun. Sun-powered energy is an unlimited source of energy and is no coast, also solar energy can be converted into electrical energy easily by using solar cells which is based on the photovoltaic effect of a semiconductor device [1]. The efficiency of the solar cell depends on the number of absorbed photons which are absorbed in the absorber layer of the solar cell. However, the low absorption rate of the absorber material and light reflection in the surface of the material and the material interfaces of the glass absorbers will reduce the conversion of solar energy. The efficiency of the energy conversion can be improved by modifying the surface morphology of the solar cell, interface the active layer, and back substrate of solar cells. Also the developing organic and hybrid solar cells are caused to increase the absorption rate of photons and the bandwidth of the absorption. The enhancement of the efficiency in the solar cell without changing the materials depends on two main optical principles: one of them is optical band gap improvement by anti-reflection effect and another is photon absorption enhancement of the absorber layer by the enhancement of optical path length. Increased transmission and photon absorption contribute to better current and quantum efficiency characteristics resulting in improved solar cell performance [2].

2. Literature Review

The principle work of photovoltaic (PV) is a photoelectric effect that converts the sunlight into electricity, and it was discovered firstly by A.E. Becquerel in 1839 which he is a French physicist, and Chapin, More full and Pearson of Chime labs in 1954 were generated the first solar power. Due to a conversion efficiency of about 4.5 %, in the early 1950s, the first p-n-conversion based form silicon chip was produced and cell efficiency has considerably improved since. The goal has been to reduce the reflection of the texture of the PV cell by front surface since 1960 [3]. The ruggedness of the textured surface increases the absorption coefficient by multiple reflections for oblique light incidence [4].

The surface texture is very efficient in orientation, mainly in monocrystalline si solar cells. Although chemical and physical etching techniques have been used to achieve various micro-pyramid structures earlier, in 2008 only scientists have tried nanostructured textured on the front side [5]. In photovoltaic systems, the use of pulsed lasers will boost performance. In the first instance, pulsed-laser hyperdoping will inject dopants at non-balance concentrations into a semiconductor, producing an intermediate band within the material bandgap and changing the absorption coefficient client. Secondly, laser pulses will improve the geometric trapping of light by increasing surface rudeness [6]. In contrast to a silicon semiconductor, a solar cell made of GaAs semiconductor presents better performance, which means that it is perfect for effective absorption and emission, and is almost optimal for single solar cells. GaAs is so absorbent that just a few microns of thickness are required for sunlight to absorb. The lack of reflection is a big challenge for progressing the proficiency of sun-powered cells. The photons used to produce electric charge should be absorbed by an ideal Solar Cell. The larger the absorption photons, the higher the efficiency [7]. Cell production was enhanced by the manufacture of doped wafers with different growth methods (float field, Czochralski, Multicristalline) with passive materials (SiNx, SiOx), with different standardized cellulars, etc. near the theoretical limit of about 29 per cent. Panasonic Co., Ltd. achieved the greatest efficacy to date with a thin-layer interdiscorded back contact (HIT-IBC) system with a cell area of 143.7 cm2 and is close to technically close to the theoretical maximum. The conversion efficiency of mc-Si is 2–3 % lower compared to a monocrystalline silicon solar cell. Its cost of production, however, is around 80% lower which is critical for the marketing of photovoltaic (PV) equipment. Satellites are powered by the first application of silicon solar cells. PV promotion was dramatically expanded in the 1990s. The PV industry has concentrated on reducing the cost of its goods per Wattspitch (Wp) as competition between suppliers has risen gradually. By 2008, the world PV industry averaged annual growth of 54.7%, owing to high demand for the unorthodox output of electricity. Si wafer-based photovoltaic systems accounted for around 90% of total production in 2013 and should be the leading technology by 2020 [3].

3. Fundamental Theory

3.1. Solar Cell

Solar cells are also known as Photovoltaic (PV) cells, which work to transform sunlight directly into electricity. This is different from the photovoltaic thermal cells (PVT) that act to supply heat to water in the house. Photovoltaic cells are attached electrically and conveniently arranged into a wide frame known as a solar panel. True solar cells are made of silicon semiconductors that absorb sunlight and transform it into electricity. Solar panels used in residential applications are typically only capable of absorbing around 20% of the sunlight and converting it into electrical energy. This is what is called solar processing. It is possible to use many other types of solar cells that are used for industrial and commercial purposes. They can have up to 40 % performance, but they tend to be more expensive than domestic models. One of the best aspects of solar energy is that there are constant advancements in the sector that improve overall efficiency and effectiveness. It is expected that this will only increase with further study and growth. Similarly, the price of solar panels is to continue to decrease as these factors increase, allowing them open to a much broader squad [8].

3.2. The Principle Work of Solar Cell.

The solar cell has two layers (as shown in Figure 1) which are the n-type layer (blue) and p-type layer (red) and its work is based on the photoelectric effect that it convert the sunlight into electricity by below steps.

- The surface of the upper layer of the solar cell will be bombarded by a photon that comes from the sun.
- 2. The photons carry their energy into the cell (yellow balls).
- In the lower, p-type layer, the photons give up their power to electrons (green blobs).
- The electrons are jumped to the upper layer (n-type) by using their energy and then they go out into the circuit.
- Flowing through the circuit, the electrons light up the torch [9].

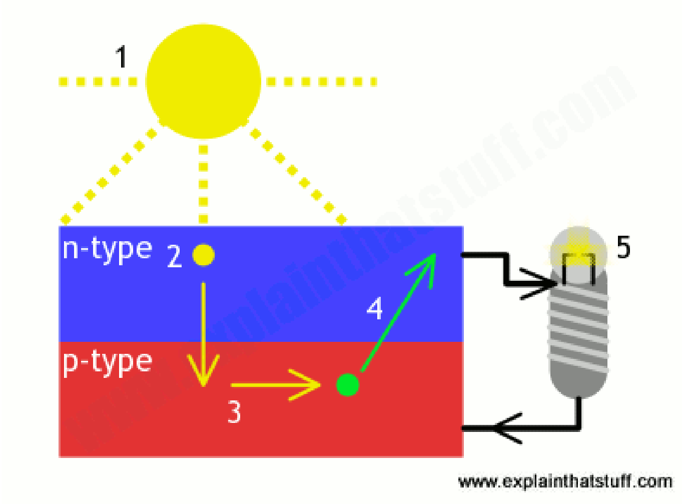

Figure 1. The principle work of the solar cell [9]

3.3. Surface Textured

This approach is used also to minimize reflection. The effect is a rough surface or a surface gravure [10]. The probability of reflection decrease as light falls on a structured surface and rebounds to the exterior. Regular and textured exterior is further successful apart from smooth surfaces as well as a certain algebra, as well as inverted, regular pyramid textures [11]. Not every form of substance can be suited to all these geometrical textured surfaces. It may be used for a specific solar cell type [12]. Geometric textures are usually less acceptable for solar cells with thin films due to the moo width of the lean film sun-powered oriented cell. Which induces decreased occupation, i.e. high mislaying as well as enhances the recombination of the majority courier. The figure indicates the textured exterior of the lean foil sun powered cell. Seventeen. Pyramid structures were just useful for monocrystalline solar cells and can also be used for high content absorption. These decrease solar cell width, reduce bulk replication and improve photon uptake and conversion efficiency. Light is mirrored correctly on the surface and this could raise the light direction of the substance until 4n2 with a surface connection on two sides of the cell (where n is the refractory record for the microelectronic). Compared to regular isotextures, the laser-flexibility cells average near to seventeenth % of their efficiency, an absolute 0.3% improvement in effectively was shown using laser textures on multicrystalline Silicon [13].

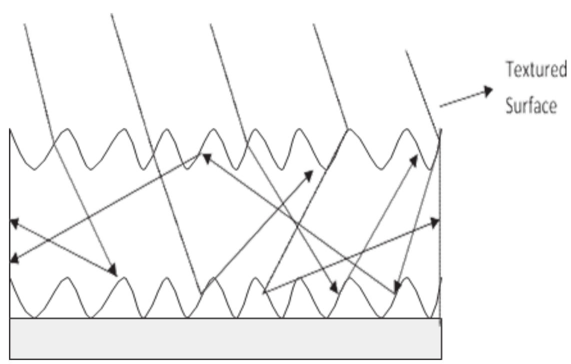

Fig. 2. Textured surface [41].

3.3.1. Physical Texturization Processing Techniques

Mazur et al [14]first implemented the femtosecond laser pulse into the texture of the C-Si surface. In recent years Iyengar et al have succeeded in developing modern, high-speed laser processing techniques for micro/nano organized texture on the front side, which decreased the reflection of all solar spectra by 5% [15]. The biggest technological challenge is to eliminate the materials stored in the laser and to minimize defects in the induction. The success of post-chemical cleaning has been achieved by both Nayak and others [16]. The key benefit of laser texture is its reproducibility, speed, process control, and uniformity that is more appropriate for industries than wet chemical etching. Sher et al used pulsed laser texture in their work and achieved a similar reflection near the unit [6]. However, it must again be a chemical procedure to eliminate laser errors. The method is less common with this counter-statement. If solar cell chemical etching is not the right option because of its grain orientation, since it is even in polycrystalline Si. The overall performance of Zolper et al has been reported to 16.7 percent by laser textured front surface Poly crystalline PV cell [17]. In experimental observation, MULTAK stated that the hillocks created by laser pulse femtosecond are more likely to be cylindrical, thus strengthening the light trap in the cell. The experiment also revealed a 10.8% variation in JSC, 12.9% in VOC, 8.8% in FF, and 25% in general quality following texture [18]. The possibility to shape various versions of a micro-sized structure on the surface are another significant benefit of the physical texture process over the wet chemical process. We can have upright, inverted pyramids and wet comb on the surface; anisotropical gravity normally only shapes upright pyramids in wet processes. We have upright pyramids. Hauser et al. also published their experimental report of lithography techniques for effective texture of the Honey Comb structure [19].

3.3.2. Pulsed-Laser Surface Texturization

The physics of texture by pulsed laser comes within the same mechanisms as those described in the Laser Melting and Doping section. The energy deposited on the irradiated surface by a single laser pulse differs from each other due to the interaction between the incident laser pulse and the auto spread of surface defects. The interfering effect, which is caused by intermittent shifts in the melt depth over distances equivalent to the laser wavelength occurrence. Capillary waves, randomly excited in melting, freeze into features known as laser-induced periodical surface structures during resolidification (LIPSS). The LIPS's periodicity has to do with the wavelength and polarization of the light incident [20]. Therefore, laser pulses consequently appear on a modulated surface and concentrate on the valleys of those characteristics. The molten silicon is super-heated and starts to melt if the energy stored in these valleys is enough to increase the temperature above boiling points. Additional changes in energy can mean that the rate of elimination, known as ablation, can be greatly increased [21]. Some material leaves the surface like superheated particles, a process that molecular dynamism simulations can imagine and understand. Therefore, LIPSS pulse laser irradiation provides positive feedback: the surface texture contributes to preferential focusing and leads to selective elimination leading to additional surface texture. Though pulsed laser textures have been observed for fs-, ps-, and ns-laser pulses following radiation, the requirement of fluency (energy for each area) and pulse numbers is the lowest for fs-lasers [22]. The atmospheric surroundings also have a major influence on the structure. A systematic analysis of the respective literature is also seen in the extensive evolution of the silicon spikes shown in Figure 3. The precise knowledge on the forming of the surface is based on several parameters, but the definition describes the consistency of the surface texture. Figure 4a displays the area of 600 fs-laser pulses at 8 kJ/m2 in an SF 6 atmosphere at a pressure of 6,7 € to 10 4 Pa that is the product of silicon irradiation. Figure 3 shows that We have researched thoroughly to what extent these surfaces may be produced and can produce all surface roughness of micrometre, and nanometer-scale 66.69. For eg, laser wavelength, fluence, number of laser pulses, pulse duration, and the environmental environment depend on the height and spacing of the spikes. The production of such spikes is also independent of the crystalline orientation of the substratum 68, which allows light trapping surfaces to be manufactured on small, amorphous or polycrystalline films. 70 Documents References [23] explain how irradiation parameters influence the increase of light absorption. Figures 1c and 1d demonstrate the absorption of fs-laser textured silicone. The laser-texture surface is poor in reflectance; hence the absorption is almost a unit from 0.24 μm to a minimum of 1.1 μm.

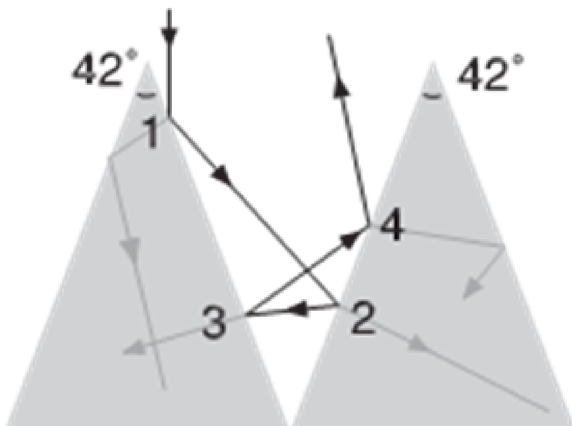

Figure 3. Illustration of the optical path of light incident on laser-textured silicon surfaces, with cones subtending 42° [24].

3.3.3. Texture-Etched Zinc Oxide

Films prepared by magnetron sputtering have been an alternative to SnO2:F with aluminium-doped zinc oxide (ZnO: Al). The mechanism of sputtering leads to very leading and clear yet smooth ZnO films. A simple step in the chemical grafting of diluted acid creates a textured surface that can be tuned to give maximum light distribution over a wide spectrum of wavelengths [25]. We investigated relations between ZnO film growth, structural characteristics, and surface morphology obtained following etching to establish optimized light trapping systems for different solar cell architectures (pin/nip) and absorber content (e.g. a-Si: H, mc-Si: H). The ZnO: Al films were developed using the ceramic or metal targets of RF or dc-magnetron sputtering [7], respectively. Centred on low target costs and high deposition speeds, reactive DC-sputtering from metallic Zn and Al targets is of considerable technical significance. During the sputtering phase, the deposition pressure and the substratum temperature affect the material properties of ZnO:Al. The highly conductive and transparent ZnO:Al films were produced for all deposition (rf, dc) techniques using low sputter pressures, while a characteristic rise in some resistance was observed when there was some value of a deposition pressure. The deposition pressure also influences structural film properties, as the surface morphologies obtained after etching (typically 10-50 s in the hydrochloric diluted acid of 0.5 per cent HCl in H2O) represent. The case of three reactively DC-sprayed films ZnO: Al stored in the low-pressure regime is demonstrated (ranging from 0.5 to 10 mTorr for this series). Both films are extremely translucent and exhibit low specific resistances (ro5 104 ° Cm), which are not affected by greying. The films exhibit different surface morphologies after printing whereas the Optical and electrical film characteristics are similar, as can be seen in the AFM micrographs. Craters with proper distribution, lateral scale, and depth occur on the surface due to anisotropic etching of all film deposits in the low-pressure regime. At 0,5 mTorr, even after a sustained etching, the craters are comparatively smooth, reducing the average root square area of the drum to 50 nm. Increased deposition pressure contributes to lower opening angles and greater crater depth [26].

3.4. Antireflection Coating (ARC).

To decrease the reflection from the front surface, ARC is used. This reduction is based on device disruptive interference [27, 28]. It consists of a film of dielectric material deposited on the active solar cell material's unique thickness surface. The wavelength thickness of the fourth layer should be translucent (d1⁄4μ/4n thickness, where n is a refractive index) In 1801, the wave of light transmitted from the semiconductor surface of the reflected wave is out-of-phase. This leads to disruptive interference, with zero net energy reflected [29]. Between the materials on either side should be the refraction index of the ARC. Glass and Si have a 1.5 and 3.7 refractive index and can have a refractive index with a refractive index of 2.4 reduced reflections. Figure 4 is shown the arrangement of ARC. Six [30, 31]. In specific, MgF2 [32], Si_3N_4, and ITO are used for anti-reflective coatings. MgF_2 is a robust, durable, reflection minimizing, and absorbing coating. ITO is often used as an ARC for collecting the carrier. As a counter-reflection layer in Salman et al. used the ZnO/Pores Silicon layer with the minimum effective reflective effect for ZnO/PS sheets (PS). These sheets are an efficient ARC to enhance and increasing the effectiveness of the light transfer of sun cells (18.15%), which is equal to the efficiency of commercial sun cells with standard alkaline-textured pyramids and single-ARC cell layers of SiN_x [33, 34].

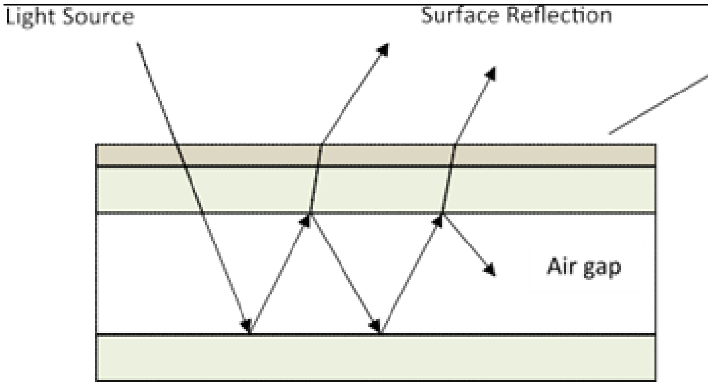

Fig 5. Antireflection coating [33].

3.4.1. Strengthening Quality of Gaas Based Solar that Use the Si3n4 Absorber Layer Covering

Various techniques were used to mitigate solar cell reflectance. Light trapping and anti-reflection (ARC) are among the commonly used means of increasing the performance of photovoltaic cells [2]. Anti-reflexive coatings on solar cells consist of a thin film of the dielectric material of special thickness to induce a wave transmitted by the top surface with the anti-reflection wave mirrored by the semiconductor on the surface. The wave has a specially selected thickness. The Si3N4 material is an electric isolator that is not moistured with non-ferrous alloys. Silicon nitride is a very costly material, but its cost-effectiveness is excellent where it is used in applications where the normal materials can be superior to long service life and with rather durable low maintenance. Silicium nitride has a low density, high-temperature tolerance, high toughness against cracks, and high stiffness [3]. The thickness of emissions and simple layers has a direct influence on the performance of the solar cells. Figure 3 shows the effect, for different values of the basis layer thickness, of the spark layer thickness, tE, on the solar efficiency. The maximum efficiency of GaAs without ARC is 17.46 %t and is 0.4 µm and 2 µm respectively at the emitter and the base thickness. The solar efficiency is, as predicted, very sensitive to the thickness of the emission sheet. As the thickness of the radiation is elevated from 1µm to 5 µm, the solar efficiency will decline from 16.5% to 7.5%. It is also obvious that if the emitter thickness reaches 1,5 µm, solar performance would be diminished with the same pitch irrespective of the base thickness size. Increasing doping in the emitter layer increases the combined electric field leading to higher voice and lower resistance, but greater doping contributes to crystal degradation. The effects of emission and base doping on solar performance are seen in Figures 5 and 6. The emitter and base layers differ in the concentration of doping between 1015 cm̄3 and 1020 cm̄3. The performance is expected to decrease due to the rise in the rehabilitation rate at extremely high emission and base doping. The effect on solar efficiency is presented in Fig. by ARC materials such as Si3N4 and MgO. 4 and Fig. 5 and Fig. 6. The Si3N4 ARC content is more effective in the entire spectrum of doping materials. Maximum performance during the use of Si3N4 ARC and the concentration of emitter and base doping is 1017 c.

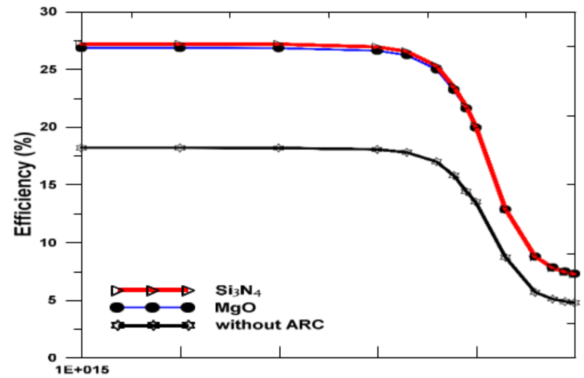

Fig 5. Efficiency versus Emitter with and without ARC at NA= 1015 cm-3, tE = 0.4 µm, and tB= 2µm

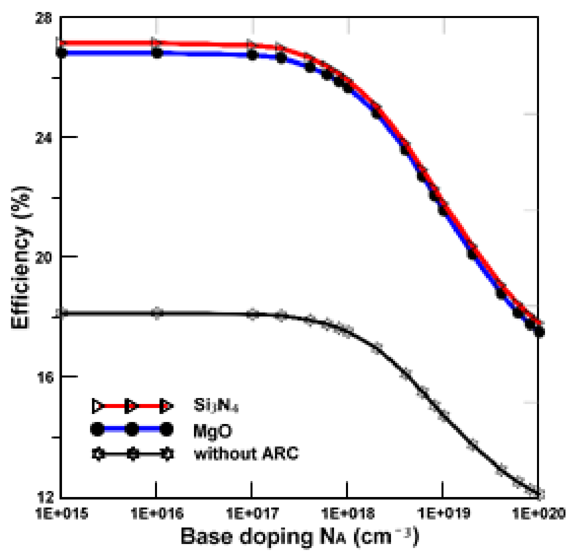

Fig 6. Effect of the solar efficiency with and without ARC at ND= 10^{15} cm̄ ^{3}, tE = 0.4 µm, and tB= 2µm

3.5. The Plasmonic Approach

The efficiency of the process of light absorption produced by electron-hole combinations and subsequent extraction of these charging carriers are key factors that decide the output of the solar cells. Many industrial cells for PV are silicon wafer on oriented based The use of surface texture, which allows the scattering of light into the solar cell over a broad angular spectrum, is traditional for the increase in the productive distance into the cell [28, 35-39]. Slotted and inverted layers of silica structured by a prism (SiO_2) were taken as an example in perovskite cells [38]. Besides, a different front and rear touch textures optimization will enhance light capture and photon control of thin-silicon solar foil cells. The wider region could, however, increase the recombination of minority carriers and thereby reduce solar cell efficiency. Another limiting factor in solar cell efficiency is the difference between the brainstem of the active material and the total range of the electromagnetic light, which is liable for the failure of a significant proportion of inbound radiation. The use of up and down-conversion layers that are capable of transforming solar spectrum frequencies int from near-middle IR and UV regions to resolve this problem UV region in the visible range, respectively, of highest cell concentration. The use of plasmatic nanoparticles can also improve this aspect, as the spectral range of the quantum dots depends on the wavelength of the waves. The optimum choice of scale, form, distribution and properties of the surrounding medium can be correctly described. Plasmonic nanostructures at least 3 distinct conditions are used (Fig. 7): on the exterior of the membrane (Fig. 7.a) or on the lower layer between both the semi-conductor and the active layer of steel (Fig. 7.c) [31-34].

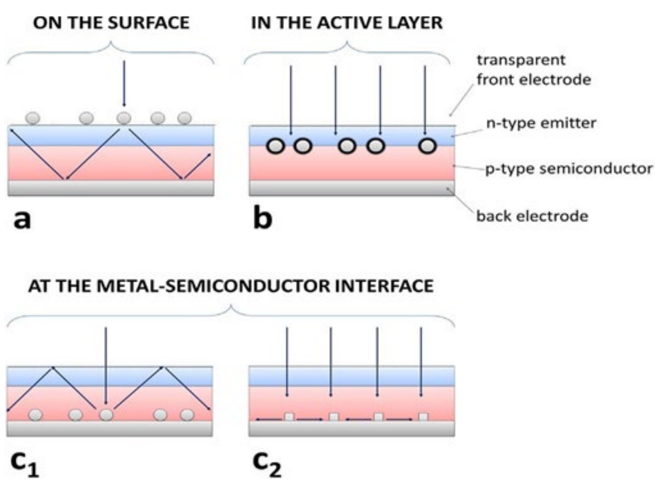

Fig. 7. Plasmonic light-trapping configurations for thin-film solar cells. (a) Metal nanoparticles on the surface of the solar cell. (b) Metal nanoparticles embedded in the semi-conductor. (c) Metal nanoparticles or periodic arrays at the metal/semiconductor interface.

Different physical rules are responsible for increasing cell efficiency. Light is distributed and stuck through a semiconductor thin film in (a) and (c1) configurations because of numerous and high-angle spreads, creating an increase in the effective path length within a cell. The (b) arrangement allows the formation of extra gap sets of electrons inside the microelectronics equipment to be closely located and strengthened close fields in the vicinity of the particles. Finally, a steel irritating consists of a regular range of nanomaterials on the rear of the (c2) configuration that can pair light to polariton photon absorption (SPP), which propagate in the microelectronics layer plane. Via numerical simulations by Catchpole and Polman [31], a thorough analysis of the best design for increasing power efficiency by surface nanostructuring is being carried out. The cylindrical ones in particular, spherical and wedge-shaped particles led to major structural directional changes relative to microspheres, with a maximum increase of 28 times to 800 particles. nm for hemispheres of 100 nm silver diameter (Ag), and just a 9-fold increase in the Ag spheres in contrast, which is still important in either case. For optimal performance, the size of the nanoparticles (NPS) is also very important: increasing the size from 100 nm to 150 nm would greatly decrease the path lines from 28-5 times the limit. In inclusion, the addition of a spacer layer would provide an extra tuning capability when developing the final system, which will boost the upgrade further. The choice of golden (Au) nanostructures rather than Ag led to a decrease in overall plasmonic layer efficiency. It should be remembered that dielectric nanoparticles can also disperse light. Matheu et al [32]. analysis of the effect on the absorption and photocurrent generation of Au or SiO2 NPS imposed on a silicon solar cell. In their studies aided by numerical simulations, the conversion rate of 100 nm Au NP's and 150 nm SiO2 NP's increased 2.8 %, as well as an 8.8 % rise. The greater oxide quality NPS is due to the large absorption of Au NPs beneath the wavelength of resonance. However, this improvement is less than that accomplished by using a regular anti-reflection (ARC) coater on the cell surface. The efficiency is smaller. This technique is not, therefore, absorbing for traditional cells, however, they can be used for the sun industrial cells, where typical ARC Systems can be daunting or not consistent with their architecture [40].

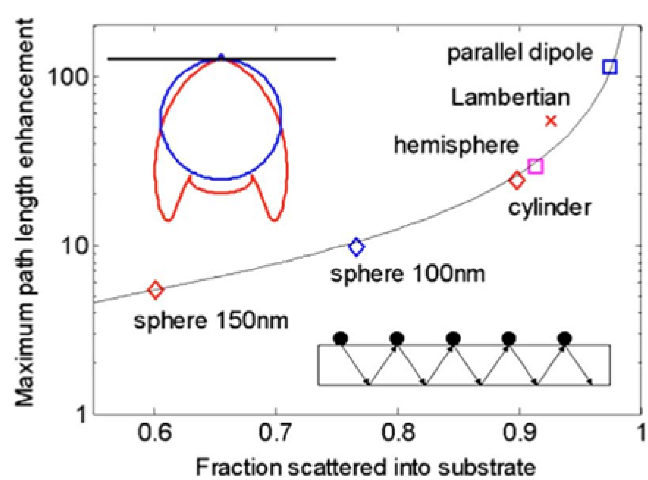

Fig. 8. Maximum path length enhancements for different geometries at a wavelength of 800 nm. Absorption within the particles is neglected for these calculations, and an ideal rear reflector is assumed. The line is a guide for the eyes. Insets: top-left: angular distribution of scattered power for a parallel electric dipole that is 10 nm above a-Si surface and a Lambertian scatterer; bottom-right: geometry

4. Conclusion

In this article review, we can conclude that:

- The solar cell has two layers which are the n-type layer and p-type layer and its work is based on the photoelectric effect that it converts the sunlight into electricity
- The efficiency of the solar cell depends on the number of absorbed photons that are absorbed in the absorber layer of the solar cell.
- The enhancement of the efficiency in the solar cell without changing the materials depends on two main optical principles: one of them is optical band gap improvement by anti-reflection effect and another is photon absorption enhancement of the absorber layer by the enhancement of optical path length.
- Surface texture is an efficient and more robust method for minimizing reflexes and enhancing light trapping relative to anti-reflective coatings.

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