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ENHANCING THE EFFICIENCY OF SOLAR CELLS USING SILVER NANO PARTICLES

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ABSTRACT

Present day solar cell industry is completely dominated by the use of silicon as the active material. Silicon material is used to manufacture solar cells due to its low cost, abundance in nature, non-toxicity, long term stability, and well established technology. Enhancing the efficiency of silicon solar cells by nanoparticles has become a new trend in solar cell technology. Recently a new method for increasing the light absorption has emerged by the use of scattering from noble metal nanoparticles excited at their surface plasmon resonance. An effort is made to fabricate a photovoltaic device of high efficiency with the help of nanoparticles. The efficiency of silicon solar cells are enhanced by coating silver nanoparticles on them. Silver nanoparticles are synthesized by chemical reduction method. XRD, SEM, and FTIR, analyses are performed for the nanoparticles. The silver nanoparticles are coated on silicon solar cells by boil deposition method. The I-V& P-V characteristics, efficiency and the fill factor of solar cells are studied.

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INTRODUCTION

The development of photo electrochemical cells, also commonly known as photovoltaic cells or solar cells, emphasizes the need for a higher conversion efficiency of solar energy to electrical power. Photo electrochemical devices consisting of silicon based p-n junction materials and other hetero junction materials, most notably indium-gallium-phosphide/ gallium-arsenide and cadmium-telluride/cadmium-sulphide have been extensively studied for efficient light conversion and these materials have shown efficiency close to 20% as compared to cells based on other materials. Efforts to find other solar cell devices with various broad-band semiconducting oxide materials including ZnO and SnO_2 films have been made for possible improvement of the current state of TiO_2 based dye sensitized solar cell devices. Composite structures consisting of a combination of TiO_2 and SnO_2, ZnO or Nb_2O_5 materials or a combination of other oxides have also been examined in an attempt to enhance the overall light conversion efficiency.

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In addition, hybrid structures comprised of a blend of semiconducting oxide film and polymeric layers for solid state solar cell devices have been explored in an effort to eliminate the liquid electrolyte completely for increased electron transfer and electron regeneration in hopes of increasing the overall light conversion efficiency. So far, these devices have achieved an overall light conversion efficiency of upto 5% for ZnO devices, upto 1% for SnO_2 devices, upto 6% for composite devices, and upto 2% for hybrid devices, all of which are still less efficient than solar cell devices based on TiO_2 mesoporous film. But in this work we attempt to find the effect of silver nanoparticles on the efficiency of silicon solar cells. Silicon material is used to manufacture solar cells due to its low cost, abundance in nature, non-toxicity, long term stability, and well established technology. Enhancing the efficiency of silicon solar cells by nanoparticles has become a new trend in solar cell technology. Recently a new method for increasing the light absorption has emerged by the use of scattering from noble metal nanoparticles excited at their surface plasmon resonance (SPR). Decorating a material with the metal nanoparticles increases the interaction with light. When light falls on these structures it forces all electrons to dance back and forth in a collective way, generating a very large electric field nearby The surface plasmon resonance property of silver nanoparticles is very much useful for enhancing the efficiency of solar cells. Munir Nayfeh *et al.*, studied the enhancement in efficiency of silicon solar cells by integrating a high quality silver nanoparticles film onto them. They suggested that the coating process can be done easily in the manufacturing process with low cost. It will be expensive if we use vacuum systems for coating process. The highest efficiency solar cell can be achieved by coating effectively the nanoparticles onto the solar cells. The surface modification of solar cells can be done by coating a thin film of nanoparticles on solar cells. The silver nanoparticles are non-toxic and are easy to synthesize. Even though the silver nanoparticles are expensive, it is enough to use them in small concentration. Ralli Sangnoa *et al.,*reported that the plasmonic effect can reduce the reflectance of light in solar cells from 13% to 11%. Here, the interface between a metal and a semiconductor consisted of a good number of conducting electrons that were oscillating in both the metal and the semiconductor. On excitation with the light source, oscillating dipoles are created in the silver nanoparticles due to the surface electrons. These oscillating dipoles direct the electromagnetic waves toward the higher permittivity material where they would concentrate in the vicinity between the metal-semiconductor interface so that they can propagate and trap light at the interface . The reflectance decreases at the wavelengths ranging from 360-1100 nm and the absorption increases at these wavelengths close to the band gap for Si substrates. Silver nanoparticles can be used for the improvement of the conversion efficiency of waferbased silicon solar cells instead of usual anti reflection coating.

USE OF SILVER NANO PARTICLE COATED ON SOLARCELL

The propagation of light through a material can be studied by measuring the refractive index of the material. If the refractive index of the material coated on the solar cell is higher, then more incident light gets reflected and is not converted into photocurrent. Antireflection coatings can reduce the unwanted reflective losses. The nanoparticles coated on solar cells can act as optical thin films. In this work a very simple and cost effective process is adopted for coating process. A thin layer of nanoparticles can be considered as an optical thin film with the effective refractive index. This technique minimizes the reflectance of light which in turn increases the efficiency of the solar cells. The nanoparticles are like tiny lenses and they concentrate light more strongly at the interface. This is due to the plasmonic effect i.e. the collective oscillations of electrons at the nanoparticles surface that intensify the incoming light and focus it into the silicon layer, which significantly improves the light absorption. Since the SPR peak of silver nanoparticles is around 450 nm, all the light in the visible region can be captured. In a conventional silicon solar cell, when light is incident on it, a single photon is capable of producing only one electron hole pair. Our aim is to produce multiple electron hole pairs from a single photon with the help of nanoparticles by the effect called quantum confinement. It has been shown that the silver nanoparticles prevent the recombination of electron hole pairs. So, the surface modification of silicon solar cells with the silver nanoparticles can enhance the electron transfer by providing electron pathways thereby increasing the efficiency.

This can be achieved with the help of surface plasmons resonance. In this plasmonic light trapping with the help of metallic nanoparticles like silver or gold (Ag/Au), we enhance the efficiency of thin film solar cells. Although some other metals also support surface plasmons but silver and gold are popularly used for experimental research in this field. The performance parameters of SPs largely depend on shape and size of the particles, properties of material and dielectric property of surrounding environments. Apart from utilizing it as light absorber layer to improve the solar cell efficiency by trapping or concentrating light at the absorber layer it can also be used as a back contact or a cheap anti-reflective electrode.

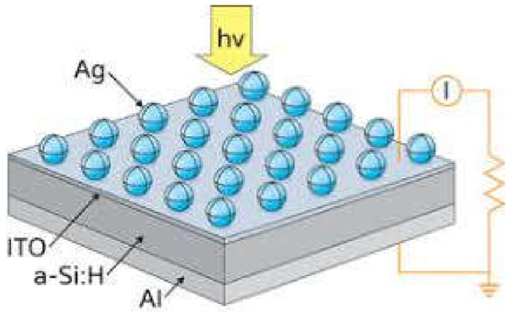

Figure 1. 1 Plasmonic effect

EXPERIMENTAL METHODS

PREPARATION OF SILVER NANO PARTICLE

Chemical method is adopted for the synthesis of silver nanoparticles. Silver nitrate is used as the precursor which is dissolved in distilled water. Poly (vinylpyrrolidone) (PVP) is added to this aqueous $AgNO_3$ solution as capping agent to prevent agglomeration of nanoparticles. Sodium boro hydride is used as reducing agent. $NaBH_4$ is dissolved in water and is added to $AgNO_3$ solution drop by drop. A change in colour indicates the formation of silver nanoparticles. The solution is centrifuged, and the precipitate obtained is washed and dried. The size of the silver nanoparticles is estimated by X-ray diffraction analysis.

Boil deposition method

Silver nanoparticles are deposited on silicon solar cells by boil deposition method. The silicon solar cell is preheated to 100^0C. The silver Nano powder of about 1.4 mg is dispersed in 2 ml of ethanol. Using a micropipette, this solution is applied onto the preheated silicon solar cell. The solar cell is allowed to dry. Thus a very thin layer of silver nanoparticles is deposited on the silicon solar cell.

Characterization Techniques

XRD analysis was performed using a X' Pert PRO PAN analytical diffractometer, and Cu-Kα X-rays of wavelength (λ)=1.54056 Å was used and data was taken for the 2θ values ranging from 10° to 90° with a step size of 0.02° The surface morphology was analyzed by using SEM model S-3000H of HITACHI. Functional groups were analyzed by SHIMADZU FTIR spectrometer. ESSEL solar cell kit was used to study the I-V& P-V characteristics, efficiency and the fill factor.

RESULTS

Here we characterize the size of the silver nanoparticles by XRD and SEM morphology. Also I-V & P-V, characteristics, fill factor and efficiencies are obtained for the solar cell with and without silver nanoparticle coating.

X-RAY DIFFRACTION (XRD) RESULTS

Table 1. 1 X-ray diffraction parameters of silver nanoparticles

2 θ (deg.)	h k l	FWHM	d spacing (nm)	Lattice parameter (A^0)
38.05	(111)	0.314	0.236	4.09
44.23	(200)	0.409	0.205	4.1
64.38	(220)	0.408	0.145	4.1
77.32	(311)	0.485	0.123	4.07
81.46	(222)	0.302	0.118	4.09

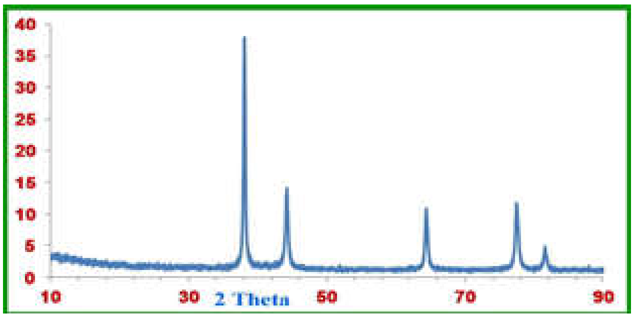

Figure 1. 2 XRD pattern of silver nanoparticles

From the table 1.1 and figure 1.2 the crystalline nature of silver nanoparticles was confirmed by X-ray diffraction. The diffracted intensities were observed from 2θ = 38° to 82°. Five strong Bragg reflections at 2θ = 38.05°, 44.23°, 64.38°, 77.32° and 81.47° correspond to the planes of (111), (200), (220), (311) and (222) respectively which can be indexed according to the facets of face centered cubic crystal structure of silver. The inter planar spacing ($d_{calculated}$) values are 0.236, 0.205, 0.145, 0.123 and 0.118 Å for (111), (200), (220), (311) and (222) planes respectively and agree with the JCPDS standard silver values. The average particle size is calculated using Debye-Scherer formula

$$D = K\lambda/\beta COS\theta$$

Where D is the average size of the nanoparticles, K is the geometric factor (0.9), λ is the wavelength of X-ray radiation source and β is the angular FWHM (full-width at half maximum) of the XRD peaks at the diffraction angle 2θ. The average particle is estimated to be 28.3nm.

SEM RESULTS OF SILVER NANOPARTICLES

SEM micrograph of silver nanoparticles

The above SEM micrograph shows the spherical nature of particles synthesized from silver nitrate.

FTIR RESULTS

Fourier Transform Infrared Spectroscopy (FTIR) is a useful tool for the study of identification of functional groups of molecules.

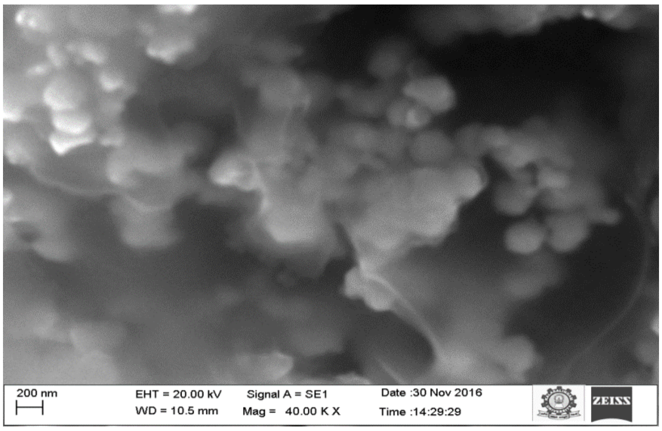

Figure: 1.3 SEM micrograph of silver nanoparticles

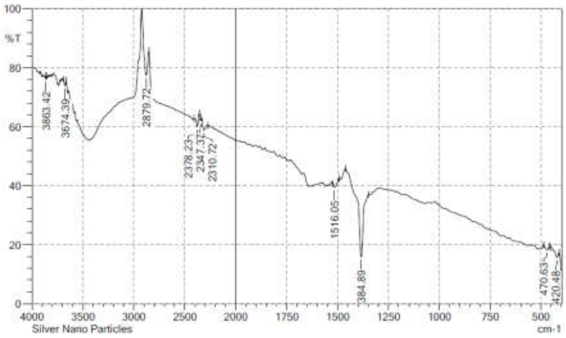

Figure: 1.4 FTIR spectrum for silver nanoparticles

It is a very weak signal from the environmental technique to resolve a complex wave into its frequency components. In this present work the observed intense bands were compared with standard values to identify the functional groups. The FTIR spectrum from figure 1.4 shows absorption bands at 420.48, 470.63, 1384.89, 1516.05 and 2879.72 cm^{-1} respectively. 420.48 and 470.63 cm^{-1} are the absorption peaks which indicate the presence of an inorganic metal, silver. The peak at 1384.89 cm^{-1} indicates the O-H bending vibration. This may be from water which was used during the silver nanoparticle synthesis process. It may also represent the NO_2 which may be from $AgNo_3$ solution the metal precursor involved in the Ag nanoparticle synthesis process. The 1516.05 cm^{-1}peak indicates the N-H amide. It shows that the nitrogen may come from silver nitrate. The peak at 2879.72 cm^{-1} is an O-H stretching vibration which shows the strong interaction of water with the surface of silver nanoparticle.

I-V CHARACTERISTICS OF SILICON SOLAR CELL BEFORE SILVER NANOPARTICLES COATING

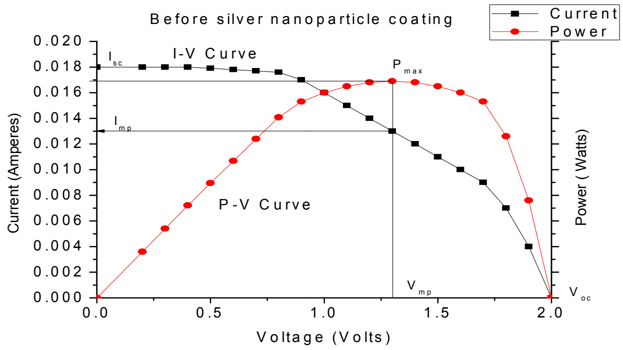

Figure 1. 5 I-V characteristics of the silicon solar cell before silver nanoparticles coating

The Figure 1.5 shows the I-V characteristic curve of solar cell coated without silver nanoparticles. The measured value of the short circuit current, (I_{sc}), is 18 mA and the open circuit voltage is 2.0V. The calculated maximum efficiency of the solar cell before silver nanoparticles coating is 23.47% and the fill factor is 0.46944.

I-V CHARACTERISTICS OF SILICON SOLAR CELL AFTER SILVER NANOPARTICLES COATING

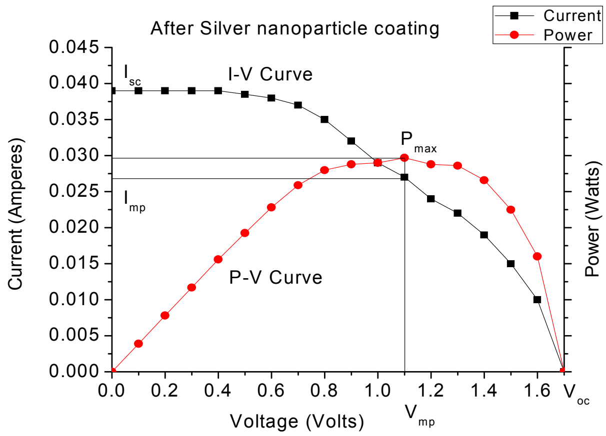

Figure 1. 6 I-V characteristics of the silver nanoparticle coated silicon solar cell

The Figure 1.6 shows the I-V&P-V characteristic curves of solar cell coated with silver nanoparticles. The measured value of the short circuit current, (I_{sc}), is 39 mA and the open circuit voltage is 1.7V. The calculated maximum efficiency of the solar cell after silver nanoparticles coating is 41.25% and the fill factor is 0.44796.

Summary and Conclusion

An effort is made to increase the efficiency of the silicon solar cell with the help of silver nanoparticles. Silver nanoparticles are synthesized by chemical reduction method. XRD, SEM and FTIR analysis are performed for the nanoparticles. The silver nanoparticles are coated on the silicon solar cells by boil deposition method. The enhancement in efficiency of solar cells is studied. The powder form of the synthesised silver nanoparticles was subjected to XRD studies. From the XRD studies the size of the silver nanoparticles was determined to be 28.3 nm. The SEM study determines that the shape of the synthesized silver nanoparticles is of spherical in nature. From FTIR, the representative spectrum of silver nanoparticles functional groups corresponding to the absorption peaks are enumerated.

The I-V&P-V characteristics, efficiency and fill factors are obtained for the solar cell with and without silver nanoparticle coatings. The efficiency of the silver nanoparticle coated solar cell is increased when compared with the same cell not coated with silver nanoparticles.

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