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Efficiency of Silver Nanoparticles in third Generation Solar Cells

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Abstract— Immense energy is required for the production of first generation solar cells and they also tend to be rigid. There are lower efficiencies of the second generation solar cells than the first generation solar cells. On the other hand, the durability and efficiency of the third generation solar cells is more than the first generation solart cells. Moreover, the third generation solar cells are not available commercially and this area of solar cells requires more research and development. The current research works makes use of silver nanoparticles to enhance the efficiency of third generation solar cells. Silver nanoparticles were first made and then the solar cells were fabricated. Titanium and platinum electrodes were used. The titanium electrode was immersed in the silver nanocluster solution for 12 hours after which the electrodes were then clipped together. Solar simulator was used in the research work for testing the efficiency of the solar cells. The efficiency was calculated to be 3.46%. The results of the research work suggest that silver nanoparticles can essentially enhance the efficiency of third generation solar cells.

***Keywords*—** Nanoparticles, solar cells, third generation, silver nanoparticles, dye sensitized solar cells.

I. Introduction

As there is economic growth, there is also an increase in the demand of energy. The world is highly dependent on the fossil fuels (86.4%) [1] and this has enhanced the emission of the greenhouse gases. Innovation and creativity is required for solving the problem of climate change. Renewable energy sources need to be developed to reduce the dependence on the fossil fuels.

There has been immense development of the environmental issues associated with the fossil fuels, therefore, there have been increased research and development in the alternative resources of power. One of this is to convert the sunlight into useable power source through the photovoltaic cells. The greatest potential in the renewable energy has been shown by solar energy [3]. In one hour, 6.12 x 10^17 KJ of solar energy hits the earth [3]. Therefore, we can see the abundance of this energy resource and it has gained the eyes of the researchers as a huge area of interest. The real challenge is to harness the solar energy to its full potential and then distributing the energy to the needed areas. Photovoltaic makes use of semiconductor materials and converts sunlight into electricity. For this purpose, usually silicon-based p-n junctions are used [4]. However, these tend to have high cost and the conversion efficiency is only 27% that too in ideal conditions [5]. On the other hand, these also have low operation cost and are highly reliable.

The photovoltaic technology of crystalline silicon constitutes the first-generation solar cells. The advance in the technology of thin film and amorphous silicon are classified under the second-generation solar cells. Lastly, organic solar cell, quantum dots, and organic dyes are classified as the third-generation solar cells. The efficiency of these cells has been increasing with time [6].

Third generation solar cells make use of small molecules, polymers or nanoparticles. Research is also undergoing on the perovskite solar cells and quantum dots. These have huge potential and have shown record efficiencies of 20% [2]. As a result, experiments are being performed on the third-generation solar cells and various materials are being used for testing their efficiency.

An emerging family of model compounds include monodisperse thiolate protected metal nanoclusters which are also known as the nanoclusters [2]. Researchers have been engaged in profound studies due to the discrete size and well-denned structures of the nanoclusters. This has enabled the researchers to study the physical and chemical properties of the nanoclusters in detail. Favorable properties of the silver nanoclusters can be used for the light harvesting applications. The current research work makes use of silver nanoclusters to test their efficiency in the third-generation solar cells. Silicon based solar cells are being used for commercial purposes as they have the characteristics of longevity and durability. The performance of the first-generation solar cells is usually 15-20% [2]. These solar cells have a good performance and the stability of these cells is also high. However, the first-generation solar cells require immense energy for their production and are also rigid. Moreover, third generation solar cells are more durable and efficient than the first-generation solar cells. On the other hand, the third-generation solar cells are not commercially available in the market as they are in the research and development phase and more research is required in this field. Moreover, third generation solar cells are currently expensive to be made commercially available. Furthermore, there is also a dire need to reduce the cost and test their efficiency to make them a viable option for the masses.

The objective of the research study is to produce Ag44(SR)30 and to test efficiency of silver nanoparticles in third generation solar cells.

II. Literature Review

The structural characterization in full have only been characterized for Silver thiolate nanoclusters [7]. There have been various reports of silver thiolate nanoclusters, however, these tend to be unstable and are polydisperse. Silver nanoclusters are of great importance as they have rare and attractive properties related to optical. These include various absorption peaks and a wide range of wavelengths are covered by these i.e. 350-950nm. These properties help in providing a material for light harvesting photovoltaics. However, the previous studies have reported nanoclusters that are prone to the oxidation which is a drawback of the previous studies [8]. The emerging model compounds include atomically monodisperse thiolate and they are considered one of the most important class of thiolates. These have well defined structures and the size is discrete which has enabled the researchers to envision a lot of researcher and engage then in studies. The advantageous physical properties include magnetism, nature of the interface of thiol-metal and chirality [9]. The most significant factor of the nanoclusters are the macroscopic sized crystals.

A great number of gold nanoclusters have been reported so far [10]. However, silver nanoclusters have not been explored greatly. [11] reports nitro group as the anchoring groups for organic dyes. The nitro group was designed, and synthesized in the research work. Furthermore, the research study also applies nitro group in the dye sensitized solar cells. As the voltage was reversed, an unusual change in the color was reported.

Thiolate-protected noble metal molecular nanoparticles have been used in the research study of [12]. These are a promising class for the nanomaterials. However, the different applications have not been materialized to the full extent. Thiolate protected noble nanoparticles have not been materialized to the full extent as the ligand exchange strategies do not widely exist. Thiolate had been used in the research study for preserving the nature of the particles and the native ligands have been replaced which contain various functional groups. Therefore, smooth thin films were created with the help of the research study and therefore creating pathway for the solution processed devices and their integration.

[12] report synthesis of the thiol-protected silver nanoclusters as well. The nanoclusters tend to be highly stable in this manner and the research reports highly stable nanoclusters as compared to the previous studies. Such nanoclusters are produced that are stable for at least 9 months under the room temperature and the degradation in these 9 months is very less. Mass spectrometry was used and ultracentrifugation was used in the research work. Spectrum charge state nanoclusters were produced in the research study and there are various unique features in the absorption spectrum. The research study also identifies the protocol to transfer the nanoclusters. Solid state films were fabricated in the research work of [Ag44(SR)30]m. The distinct features were retained in the research study. X-ray diffraction was used in the research work to study the films and photoelectron spectroscopy was also used for the investigation of the atomic composition, structure of the valance band and crystallinity. The pathway to the crystallization of [Ag44(SR)30]m is paved in the research study.

III. Fabrication of Silver Nanoparticle Based Solar Cell

5,5’ -dithiobis (2-nitrobenzoic acid) (DTNBA) was stirred with Sodium hydroxide (NaOH) aqueous solution. DTNBA amount taken for the experiment was 9.91mg and 25mmol. Amount of NaOH used in the experiment was 20mL and 1 M of NaOH aqueous solution. The solution was stirred, the orangish solution turned to dark yellow which indicated the disulfide bond yielding cleavage to MNBA i.e. 5 mercapto-2-nitrobenzoic. The MNBA solution was then added with AgNO3. 8.5mg, 50mmol and 5mL of AgNO3 was taken. As they were mixed, the color turned to greenish yellow which indicated that Ag-S complex was formed. For reduction of the complex, NaBH4 solutions was taken. The amount of NaBH4 was 1mg, 2mL. The color changed to dark brown and slowly and gradually it further changed to dark red. The color changed to dark red after 6 hours of stirring. Precipitation was performed to purify the clusters with methanol. Centrifugation was performed at 9000 rpm. The process was repeated 4 times till the supernatant turned colorless. Fig. 1 shows the spectrophotometer plot of the silver nanoparticles. The figure presents the absorbance (Y-axis) and wavelength (x-axis). The four peaks in the graph shows the presence of silver nanoparticles.

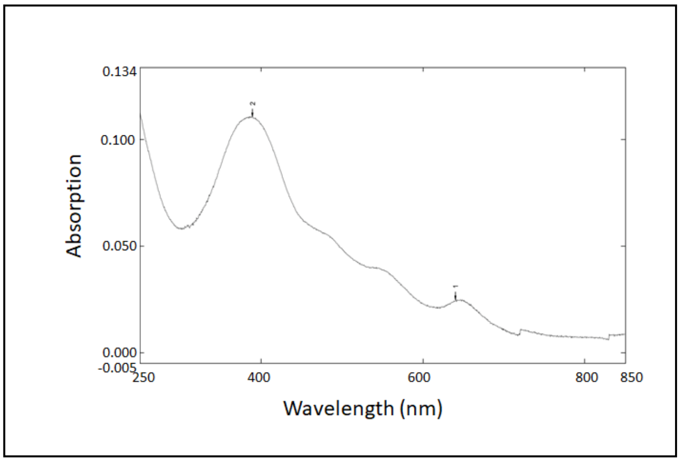

Figure 1. Spectrophotometer plot

Fig. 2 represents the solar cell area used in the research. It is necessary to sensitize titanium dioxide as it does not absorb visible light which is needed for the solar cells. The titanium dioxide was sensitized by immersing it in silver nanoclusters for 12 hours. The titania electrode, after taking it out from the silver nanoclusters, was dried with the help of a blowdryer.

Multimeter was used to identify the conductive side of the TCO glass plates. TCO glass plates tend to be conductive only on one side. By placing the probes of the multimeter on the glass plates helped to determine the conductive side. Pre-made

Titania electrodes were ordered. Firing process was run before the usage of the electrodes. This ensured to remove any moisture from the ambient air.

Titanium dioxide does not absorb the visible light therefore, it is necessary to sensitize the titanium dioxide which is a white semiconductor. The titania electrode was stained in silver nanoclusters for 12 hours. The titania electrode had titania paste deposited on the electrode. After that, the electrode was removed and rinsed with the help of ethanol. The rinsing process was not mixed with the stained solution so that the solution can be used again. Gasket is put on both the electrodes. Iron is applied on the gasket sealing so it melts.

The platinum electrode and the titania electrode's active sides are put together. The stained titania face the platinum side. The electrodes were sealed together and the electrolyte was injected via the hole that is drilled in the cathode. This approach gives linger lasting solar cells than the open cell approach. The electrodes are sealed together with the help of a gasket. The electrodes were put in such a manner that there is room for electrical contacts. The gap between the electrodes is filled with an electrolyte. The electrolyte used is Spirometal. Complete filling is performed with the help of observation and examination. Most of the cavity is filled with electrolyte. Excess electrolyte is wiped off and the glass is cleaned. After filling the electrolyte, the hole is sealed with the help of a sealing cap. Iron is applied on the sealing cap so it melts and tightly fits.

IV. Characterization of Silver Nanoparticle Based Solar Cell

Solar simulator was used for the purpose of finding the efficiency of the cells. The solar simulator of Kethlink company has been used. Solar simulator was set under 1 sun conditions (1000 W/square m). Kickstart software was used for the purpose of finding the efficiency and the I-V curve. Fig. 3 shows the I-V curve obtained form the solar simulator.

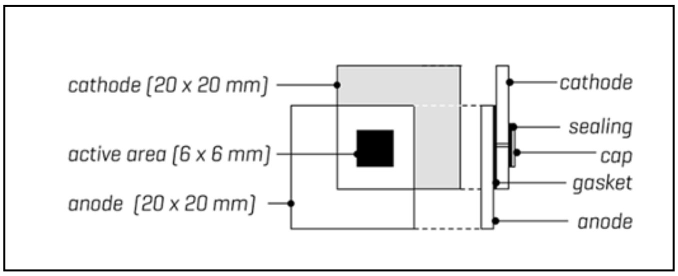

Figure 2. Solar cell area

The fill factor refers to the maximum power that is obtainable and is calculated using the product of I(sc) and V(oc). It represents the overall behavior of the solar cell. The fill factor represents the quality of the solar cell. The I-V curve also represents the fill factor. Fill factor is impacted due to the losses of the diode, resistances. The fill factor is calculated from the following formula:

$$FF = P_m/(V_{oc} x I_{sc}) \quad (1)$$

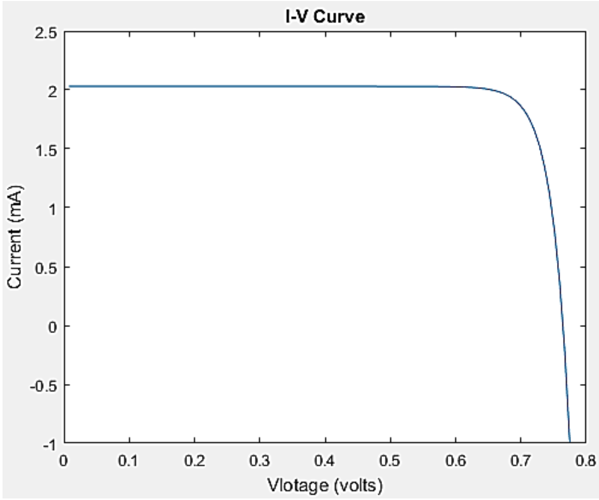

Figure 3. I-V curve

FF= 88%

The efficiency of the solar cell is calculated from the following formula:

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{in}} \quad (2)$$

Efficiency = 3.46%

Concuslion

The results indicate that silver nanoclusters can be used in third generation solar cells. The efficiency obtained from the results in 3.46%, however, the efficiency can be further improved. Normal PV cells that are operating in the market (first generation solar cells) have typically efficiency of 20%. Measures can be taken to improve the efficiency of the third-generation solar cells making use of silver nanoclusters. There were a few limitations in the research study. Firstly, the nanoclusters were made in the city of Lahore and then they were taken to Peshawar for development of the solar cell. This might have resulted in some degradation of the nanoclusters. Moreover, another limitation is that there might have been some influence of unintended impure particles when transferring the solution in beakers and during the experiment which might have hindered the results.

The current research work has provided the researchers more insights regarding the efficiency of silver nanoparticles. Future work can be carried out on both silver nanoparticles and gold nanoclusters and under the same conditions, the performance of both can be compared. Different electrolytes can be used and the efficiency of both the nanoparticles can be compared under the same conditions. Dye sensitized solar cells can also be made and the performance of dye sensitized and nanoclusters can be compared which will give detailed insight regarding the phenomenon.

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