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INCREASING EFFICIENCY OF THIN FILM SOLAR CELLS BY USING METAL NANOPARTICLES

VIKAS PANT*
Research Scholar, TheGlocal University,Saharanpur, Uttar Pradesh

DR. SATENDRA SINGH**
Assistant Professor, TheGlocal University,Saharanpur, Uttar Pradesh

ABSTRACT

Thin-film silicon solar cells has the potential to greatly reduce the cost of producing electricity using photovoltaic means. It has been proposed that the conversion efficiency of thin film solar cells may be improved by including nano sized features, such as nanoparticle deposition at the front end. In the present study, the face of a silicon solar cell was coated with nanoparticles of metals like gold (Au) and silver (Ag). Absorption enhancement factor in thin film solar cells was investigated by using Lumerical Finite Difference Time Domain (FDTD) solutions. In an attempt to enhance light coupling into the active layer and boost light absorption, plasmonic nanostructures have been introduced into the active layers of both organic solar cells (OSCs) and perovskite solar cells (PSCs), although studies have revealed inconsistent outcomes in electrical properties. To build plasmonic nanoparticles (NPs) with a nanostructure consisting of a metal core surrounded by an inorganic semiconductor and an organic semiconductor, we provide a core-bishell method in this research.

Keywords: - Solar Cells, Metal, Nanoparticles, Plasmonic, Film

I. INTRODUCTION

The progress of solar cell research and development is lightning fast. Solar cells have the potential to render fossil fuels obsolete since they convert solar energy directly into electricity. Thin-film solar cells provide a promising avenue for reducing the cost of PV technology. However, increasing the solar cell's capacity to absorb light, and hence its effectiveness as a converter, becomes critical. It has been proposed that conversion efficiencies may be improved by the use of nano-sized characteristics, such as textured surfaces and the deposition of Nanoparticles on surfaces. The effectiveness of optical absorption and devices has been the subject of much study in recent years. The efficiency of thin film solar cells might be improved in several ways. To lessen surface reflection and increase light absorption, an antireflection coating composed of arrays of silicon nanowires is utilized. The best method is to deposit a nanostructure onto the front surface of the solar cell. Use of metal nanostructures may lead to the stimulation of Localized Surface Plasmons (LSPs). When surface plasmon resonance occurs in a solar cell, it dramatically improves the cell's ability to absorb light. Recent evidence suggests that adding metal nanostructures to solar cells may boost their field strength and absorption efficiency. Since only the light absorbed by the absorption layer of the thin film solar cell may contribute to the external power, it is vital to investigate the absorption improvement in this layer.

Lumerical FDTD Solutions was used to investigate the effect of doping a silicon solar panel with spherical metal (Ag and Au) nanoparticles. Increased absorption due to Ag nanoparticles in solar cells has been investigated, interpreted, and compared to that of Au nanoparticles in solar cells.

In this research, we provide a 3D FDTD simulation of a solar cell made from ultra-thin amorphous silicon. By enhancing the rate of optical generation and plasmonic resonance, silver nanoparticles implanted within the p-n junction depletion zone boost absorption in a thin film cell. In this article, we'll examine the inner workings of thin-film solar cells. The active layer of the p-n junction's depletion zone was modified by inserting metal nanoparticles. So far, we have achieved an efficiency of 5.27 percent with gold, 5.3 percent with silver, and 3.74 percent with aluminum.

II. THIN-FILM SILICON SOLAR CELLS

The case for solar cell technology

With a growing global population and more people taking part in modernization efforts, it's clear that reliable energy sources are essential. Due to the depleting supply of fossil fuels and the destructive impacts of their usage, a clean and sustainable alternative is urgently required. As the demand for fossil fuels increases, so does the amount of carbon dioxide in the air. The global population expanded by 5% between 2004 and 2008, while energy production and carbon dioxide emissions both climbed by 10% in the same time period. Power consumption throughout the world increased by more than 40 percent, from 15,400 terawatt-hours in 2000 to more than 21,330 terawatt-hours in 2010. Because of this, finding a sustainable solution to meet this rapidly increasing need is of the utmost importance. Despite the fact that renewable energy resources accounted for only 7% of total energy production in 2008, according to the U.S. Energy Information Administration, solar manufacturing capacity has increased from less than 2 GW in 2006 to over 12 GW annually in 2010. The quantity of solar power capacity that has been installed has increased by 40% in the previous decade alone.

III. PROPOSED MODEL

Amorphous silicon, indium tin oxide, and aluminum, each at 50 nm in thickness, make up the active layer of the proposed solar cell architecture. For incident plane waves, the AM1.5 irradiance is used. The FDTD method was employed for this optical study. In order to reproduce the solar cell's structure, a unit cell was developed, and periodic boundary conditions were applied along the x and y axes, while the perfectly-matched-layer (PML) technique was used along the z axis. For a certain incident wave, this calculation will provide the electric field intensity distribution |E(x,y,z,)|2. The rate of volume absorption may be calculated using

$$Q_{abs}(\mathrm{r},\lambda) = \frac{\omega\varepsilon_0}{2}\,\mathrm{Im}[\varepsilon(\mathrm{r},\lambda)]\,|\,\mathrm{E}(\mathrm{r},\lambda)\,|^2$$

Qabs is the power absorbed in a given volume at a given wavelength, is the relative permittivity that varies with frequency, 0 is the permittivity of empty space, is the angular frequency, and E is the electric field. The following equation is used to determine the rate of generation:

$$G(r) = \int Q(r,\lambda)\left(\frac{\lambda}{hc}\right)d\lambda$$

The Planck constant, h, is related to the speed of light, c. The ideal short circuit current density may be stated as, where I is the number of electron holes pairs (EHPs) gathered at the contacts and P is the number of photons absorbed in the active layer.

$$J_{sc} = \frac{q\int G(r)dV}{S}$$

Where q is the electron charge, dV the atomic volume, and S the solar cell's surface area. After importing the optical stimuli from the optical FDTD simulation, these results are used to do the electrical modeling of the device and solve the related Poisson and charge carrier continuity equations. Doping concentration in silicon is modeled using the Poisson equation. For bulk silicon, we take into account both radiative and Auger recombination modes. The rear and front contact regions are p-type and n-type diffusion doped, respectively, with a surface doping concentration of 1x1019cm-3. We estimate surface recombination at the silicon/Silver/Aluminum/ITO interface, assuming a carrier recombination velocity of 107 cm/s.

IV. RESULT & DISCUSSION

As was previously said, the form of the particle determines the plasmon resonance wavelength. Therefore, it is essential to precisely engineer the particle density and size. Previous research has shown that applying gold nanoparticles to a cell's surface may increase its efficiency by 4.4%. However, it is reasonable to assume that nanoparticles would have the greatest impact on the cell's active layer. These nanoparticles are positioned in the depletion zone between the p-n junctions to make advantage of the inherent potential and reduce the recombination rate. Figure 1 Shows a spatial representation of the electric field intensity at a wavelength of 901 nm on the y = 0 plane when silver nanoparticles are present in the p-n junction depletion region. Nanoparticle in the active region, surrounded by an electric field magnified by a factor of up to three (electric field normalized, color bar on a logarithmic scale). Because of this, more energy is absorbed during the conversion process, which is a good thing. Depicts the absorption rates of the five different solar cell varieties. Silver nanoparticles used in the active layer of solar cells exhibit maximum absorption between 400 and 820 nm and again between 850 and 1000 nm. Absorption is lowest at wavelengths below 650 nm in the cell that has been coated with nanoparticles. This phenomenon may be explained by the reflection of incoming light from the cell surface, which is caused by nanoparticles. However, cells with nanoparticles in their active layer are an exception to this rule since they behave as light traps.

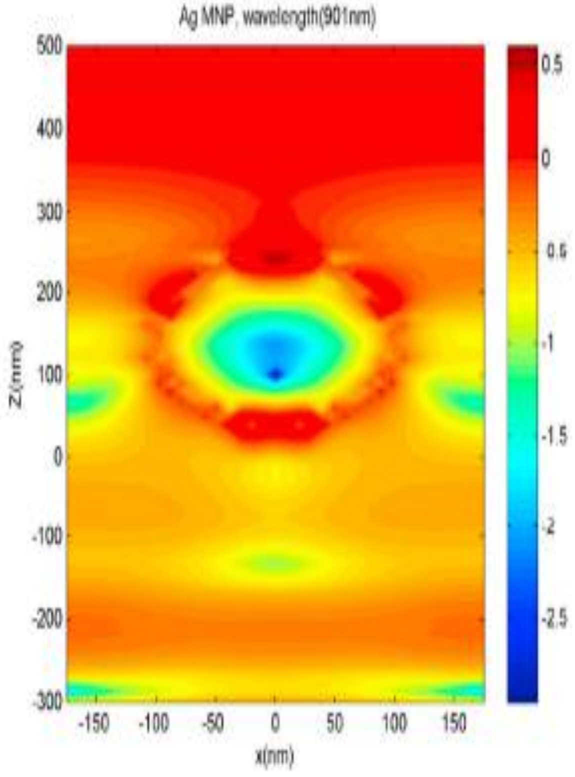

Figure 1. The spatial distribution of the electric field intensity at a wavelength of 901 nm and at y = 0, with the presence of silver nanoparticles within the depletion region. (The electric field has been normalized and the color bar is in logarithmic scale).

The reflection of the five types of solar cells, which have been studied in this study, are illustrated.

It can be seen that the cell with silver nanoparticles have the least amount of reflection. In the following we will study the electrical parameters of solar cells.

AM1.5 solar radiation has an integral power of pin=100mW/cm2 , so using the η=pmax/pin the power conversion efficiency is achieved. Voltage- efficiency characteristics of five types of solar cells are presented. Proposed solar cell with silver nanoparticles within the depletion region of p-n junction has the highest efficiency.

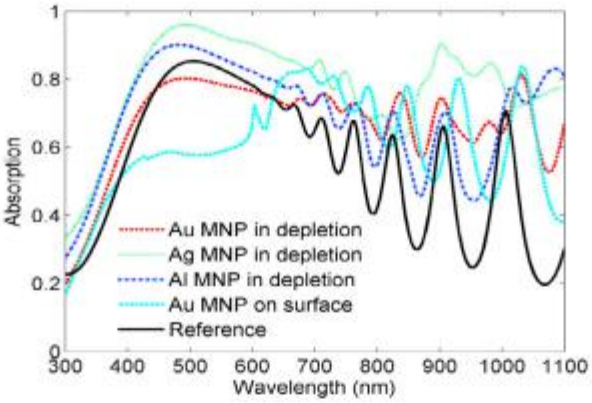

Figure 2. The absorption of five types of solar cells with gold, silver and aluminum nanoparticles within the active layer and gold nanoparticles on the surface of solar cell and the reference cell without nanoparticles.

V. CONCLUSION

Plasmonic thin film amorphous silicon solar cells are suggested in this research, with metal nanoparticles of varying compositions inserted inside the p-n junction's depletion area. The depletion zone was created by placing metal nanoparticles 10 nm below the ITO layer, directly under the n+ layer. When compared to the standard reference cell, the efficiency gains from using silver nanoparticles in this study are 20.45 percent, from using gold nanoparticles in this study are 19.77 percent, and from using aluminum nanoparticles in this study are 15 percent. Therefore, silver nanoparticles embedded inside the depletion area are introduced as promising new components for solar cells in this work.

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