Ultimate Efficiency Enhancement in Solar Cell Employing Plasmonic Nanowire (Au) as the Core of C-Si Nanowire

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Abstract **— Integrating plasmonic metal nanoparticles of gold or silver as the core of nanowire solar cells can enhance their ultimate efficiency. We propose a simple crystalline silicon plasmonic nanowire structure by integrating a gold core and a crown glass anti-reflector which resulted in 49.8% improved efficiency to conventional nanowire structure and an ultimate efficiency as high as 35.24% for fixed filling ratio and length of nanowire.**

Index Terms **— crystalline silicon, cylinder, hemisphere, nanowire, photovoltaics, plasmonic nanowire, thin films.**

I. Introduction

Silicon nanostructures aligned vertically offers low cost alternatives to bulk silicon wafers and thin film photovoltaics for next generation photovoltaic application due to its promising light harvesting capabilities. An array of Si nanowire (NW) shows interesting optical characteristics such as low reflection, low transmission, wavelength selective absorption [1,2], light trapping, resonant mode between neighbouring nanowires by controlling the period, filling ratio and spatial arrangement [3]. Application of plasmonic metal nanoparticles, however, can reduce the physical thickness of the photovoltaic absorber layer while keeping the optical thickness constant [4]. In this paper, we propose a simple plasmonic nanowire (PNW) structure that employs the gold core inside the conventional crystalline silicon nanowire [5] and a crown glass antireflector (40nm thick) to increase the absorption efficiency and as a result the ultimate efficiency of the overall photovoltaic. We also added extra hemispherical shaped regions of crystalline silicon at the bases of the cylindrical NW to further increase efficiency. By varying the lattice constant from 100-250nm, we were able to find the absorption and ultimate efficiency of plasmonic nanowire model and compare the results with conventional nanowire model. We verified our results through 3D electromagnetic simulation with finite integral technique (FIT) and found this plasmonic nanowire model can increase efficiency without increasing the length of the nanowire.

II. Results

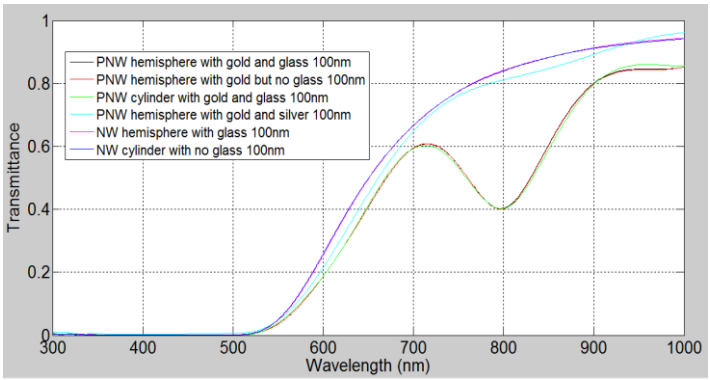

Fig 1, Transmittance comparisons between our model and other Si PNW and NW structures with fixed lattice constant 100nm

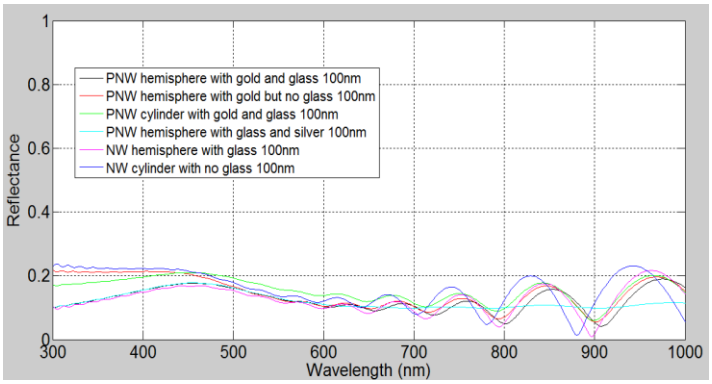

Fig 2, Reflectance comparisons between our model and other Si PNW and NW structures with fixed lattice constant 100nm

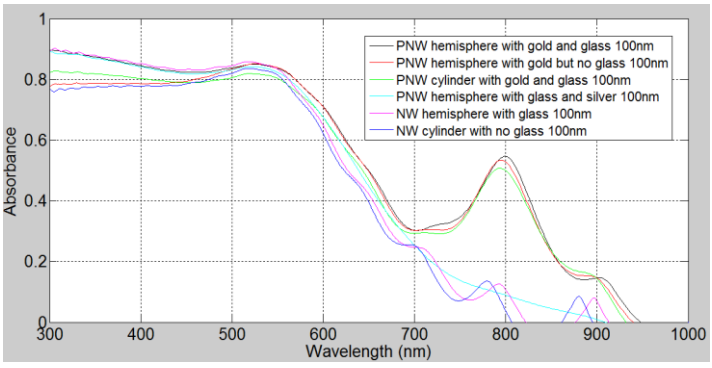

Fig 3, Absorbance comparisons between our model and other Si PNW and NW structures with fixed lattice constant 100nm

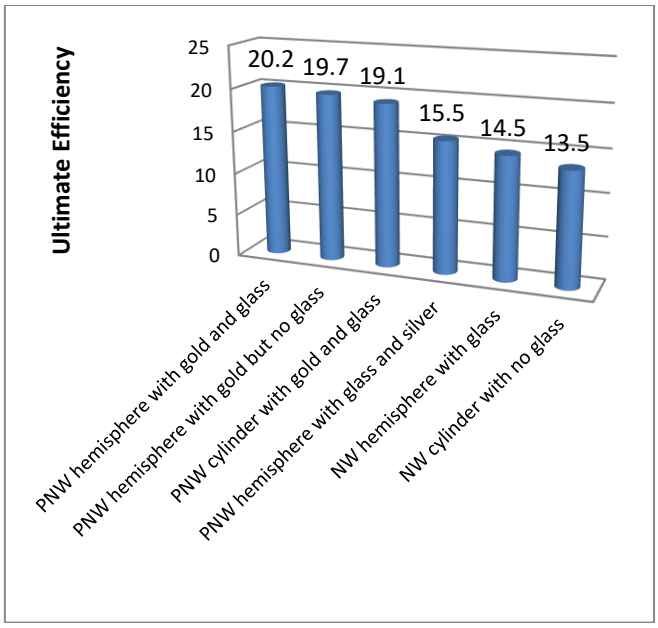

Fig 4, Ultimate Efficiency comparisons between our model and other Si PNW and NW structures with fixed lattice constant 100nm

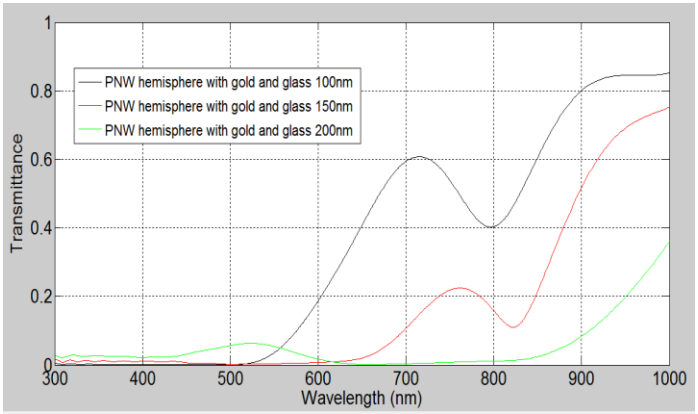

Fig 5, Transmittance for different lattice constants (100-200nm) of our model

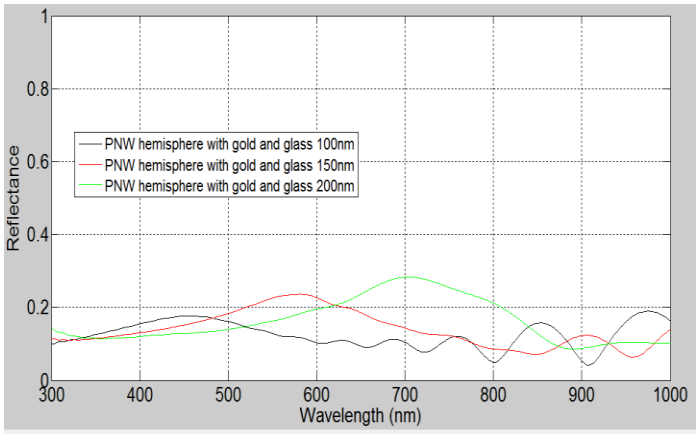

Fig 6, Reflectance for different lattice constants (100-200nm) of our model

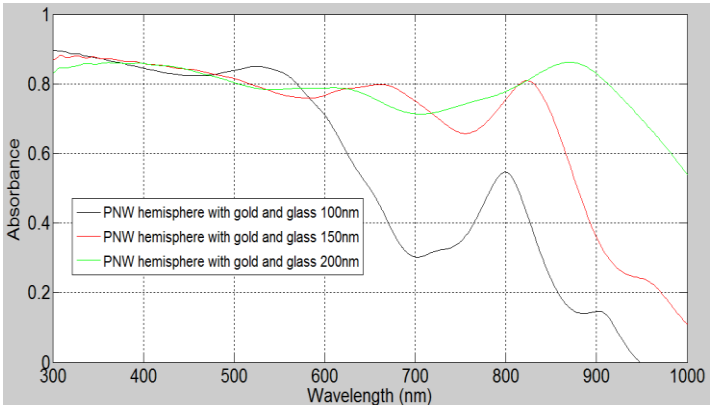

Fig 7, Absorbance for different lattice constants (100-200nm) of our model

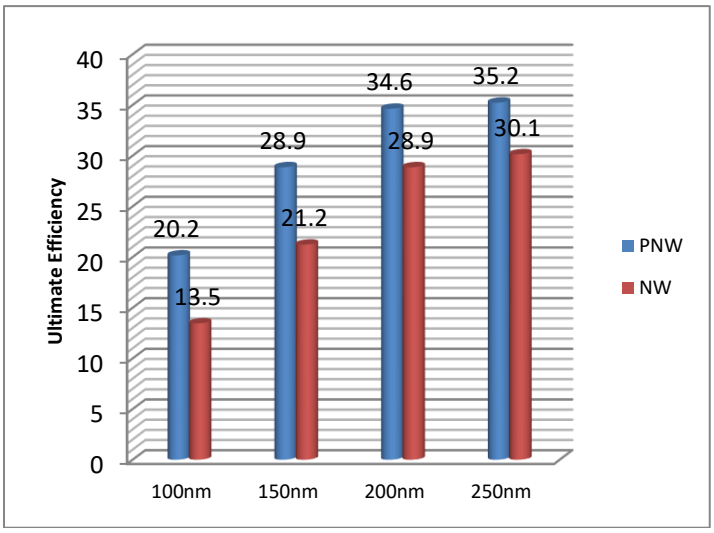

Fig 8, Ultimate Efficiency comparisons of our model with conventional NW structures for lattice constant range 100-250nm

III. Discussion

From Fig (1-3), we can see the Transmittance, Reflectance and Absorbance of Si NW array, PNW array with gold, PNW with silver and our PNW model with fixed filling ratio of 0.25, length 2.33 micrometer and lattice constant 100nm similar to [5] in order to observe the overall improvement. In our proposed structure, we have considered the inner gold radius is 1/5th of the outer radius. As shown in Fig 3, Si NW with gold core, hemispherical shaped regions at the bases of the NW and a glass reflector has the widest absorption compared to other structures for fixed lattice constant. From Fig 4, we can see that our model is therefore the most efficient when compared to other NW and PNW structures.

From Fig 5-7, we can see the Transmittance, Reflectance and Absorbance of our model for a range of lattice constants (100-200nm). The bigger the lattice constant, the higher the absorption and ultimate efficiency and we were successful in

finding a peak ultimate efficiency of 35.24% for 250 nm lattice constant in Fig 8 where it also shows the ultimate efficiency comparisons between our model and conventional NW structure.

IV. Summary of Work

From Fig (1-3), we can see that by introducing plasmonic nanowire in the form of gold core, crown glass antireflector and hemispherical edges, we have widened the absorption bandwidth which leads to overall ultimate efficiency improvement. After measuring ultimate efficiency we have found our model has improved efficiencies particularly for 100nm, 150nm, 200nm and 250nm as shown in Fig 8. The improvement is 49.80%, 35.98%, 20% and 16.90% respectively.

V. PROPOSED MODEL

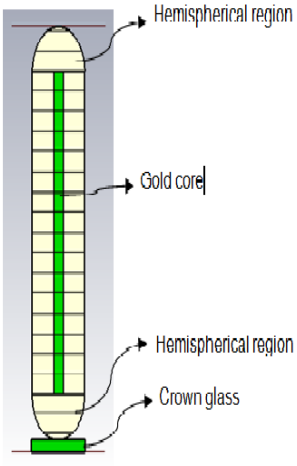

Fig 9, Internal view of our model

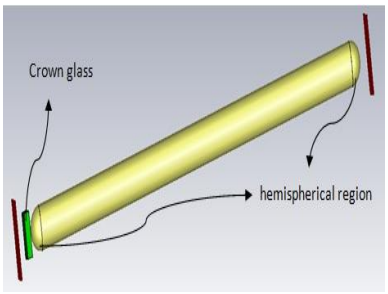

Fig 10, Side view of our model

Fig 9 and 10 shows the internal and side view of our proposed model (PNW hemisphere with gold and glass) which yielded the best results of ultimate efficiency and it is shown above in the earlier section.

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