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Numerical Simulation of Silicon HIT Solar Cell

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Abstract: This project presents a comprehensive and systematic approach to designing high-efficiency solar cells, with a specific focus on Hetero-junction with Intrinsic Thin layer (HIT) technology, using the advanced simulation capabilities of AFORS-HET software. The methodology outlined here in encompasses a series of critical steps that collectively guide the development of cutting-edge solar cell designs. At its core, this methodology emphasizes the importance of clearly defining objectives and requirements, setting efficiency targets, and considering material constraints and cost considerations. Material selection plays a pivotal role, where the choice of semiconductors and interfaces directly impacts the solar cell's performance. To translate these objectives into tangible designs, the project underscores the significance of becoming proficient with AFORS-HET software, a powerful tool for simulating and optimizing solar cell structures. Designing the HIT solar cell involves specifying layer properties, thicknesses, and interfaces, all finely tuned to achieve optimal performance.
Numerical simulations are central to this methodology, enabling the analysis of material properties, as well as the characterization of current-voltage (I-V) characteristics under varying conditions. Through iterative processes and optimization algorithms, the design is continually refined to maximize efficiency. Practical considerations related to fabrication and real-world manufacturing processes are not overlooked, ensuring that the design can be feasibly translated into physical solar cells. Validation through experimental test ing adds a layer of reliability to the simulated results. Comprehensive documentation throughout the project captures critical design choices, simulation settings, and results for future reference and reporting. Moreover, the project highlights the importance of continuous improvement, fostering an awareness of the ever-evolving landscape of perovskite HIT technology and encouraging the integration of the latest advancements into solar cell designs.
Keywords: Solar cells, HIT technology,AFORS-HET software,Simulation,Optimization

INTRODUCTION

As the world grapples with the pressing challenge of climate change, there is an urgent need to transition from fossil fuels to clean and renewable energy sources. HIT solar cells have the potential to significantly increase the efficiency of solar power generation, making them a critical component of this transition [1]. Solar energy is abundant and widely available, making it a key contributor to energy security Developing high-efficiency solar cells like HIT can reduce our reliance on finite fossil fuel resources and enhance energy independence for regions and nations. Advancements in HIT solar cell technology can drive down the cost of solar power generation This, in turn, can stimulate economic growth, create jobs in the renewable energy sector, and make clean energy more accessible to a broader population [2]. Research and development in HIT solar cell technology present exciting opportunities for innovation in materials science, nanotechnology, and semiconductor engineering. This can lead to breakthroughs with applications beyond solar energy. Gaining expertise in solar technology can open up career opportunities in the growing renewable energy sector. AFORS-HET (Automat for Simulation of Heterostructures) was developed specifically for heterojunction solar cell, which can simulate any type of semiconductor tandem materials with random combination [3]. Researchers investigated HIT solar cell performance using AFORS-HET simulation and obtained valuable results.

MATERIALS AND METHODS

Current Density – Current density is an important factor in any solar cell, and current density depends on the movement. Current density is a term used in physics to describe the amount of current in a conductor per unit cross-sectional area. Measured in amperes per square meter.

Band gap -The band gap of a semiconductor is an important photovoltaic cell that absorbs photon energy to form electron-hole pairs. The energy of the photons received by the photovoltaic cell is determined by the difference between the materials.

Open circuit voltage: Solar cells can receive maximum open circuit voltage (VOC) at zero current

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state. The open circuit voltage corresponds to the value of the forward bias of the solar cell caused by the bias of the solar junction with the light-producing current.

The HIT solar cell is a technology pioneered by SANYO, including an internal (i-type) amorphous silicon (a- Si) layer and a p-type a-Si layer laminated onto A p/ It adopts unique structure. The n heterojunction is made of textured n-type CZ crystalline silicon (c-Si) wafer. The background field (BSF) structure is created by adding i-type and n-type a-Si layers to the other side of the c-Si sheet. The transparent conductive oxide (TCO) layer and the gate metal electrode are then coated on both sides of the doped a-Si layer at low temperature.

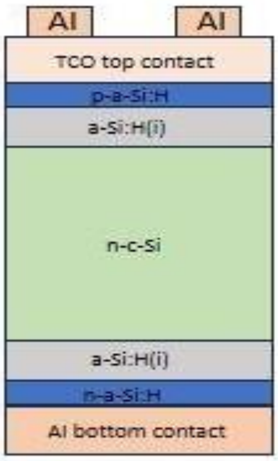

Figure 1: HIT solar cell structure

The main idea is to use the process of gradually depositing the quality of the c-Si wafer and using a doped - Si layer. The intrinsic a-Si layer effectively passivates the dangling bonds of c-Si on the surface. This passivation is achieved thanks to our expertise in manufacturing high-quality i-type a-Si products, resulting in HIT solar cells with lower Voc than conventional c-Si solar cells produced by thermal diffusion of approximately 900 °C. It not only improves the conversion but also increases the temperature coefficient.

The HIT The high thermal coefficient of the solar energy system can provide additional benefits to the customer because these cells produce more electricity each year than standard systems. Additionally, the symmetrical structure of HIT solar cells has two advantages. First, it helps create bifacial materials that can produce more energy than composite structures. Secondly, it keeps the structure free from stress, which is important for the good performance of thin sheets.

RESULTS

The I-V characteristics of HIT solar cells using 300µm thick c-Si sheets are shown in Figure 2. Using thin sheets we achieved a high conversion of 19.34%.

The best Voc of 965.2 mV was achieved. These results are recognized by AIST (Japan National Institute of Advanced Industrial Technology). The unique design and technology of HIT solar cells make them high- efficiency cells on a thinner silicon wafer. This proves that HIT solar cells are one of the best designs to achieve high efficiency when using thin c-Si wafers.

In order to improve the conversion efficiency, we estimated 22.8% of the total battery loss at this stage by analyzing the loss. Found to have 20% or more improvement margin with 22.8% battery. Excluding losses, the turnover of HIT solar cells can increase by about 10%. We will continue to work hard to achieve the goal of developing HIT solar cells with thinner silicon wafers to reduce silicon wafer costs.

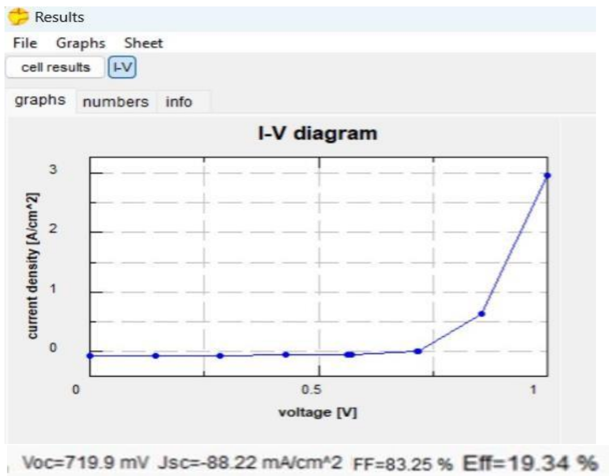

Figure 2: I-V graph of HIT solar

We also tried to make the HIT solar cell thinner than 300 µm to evaluate the possibility of thinner plates. As shown before, it was confirmed that there were no distortions in the 58 µm thick cells, so the reduction in the process could be avoided to some extent. Then, the relationship between Isc and Voc values of HIT solar cells and cell thickness is shown. Values for each cell thickness are normalized to the value of a 98 µm thick cell and measured by SANYO. An excellent Voc of 965.2 mV was achieved for HIT solar cells using 58 µm and 75 µm thick sheets. From this result, the surface recombination velocity of ~4 cm/s was estimated, which is a very low value. However, the tendency of the Quantum efficiency (QE) is a measure of a solar cell's ability to convert photons of light into electricity at different wavelengths.

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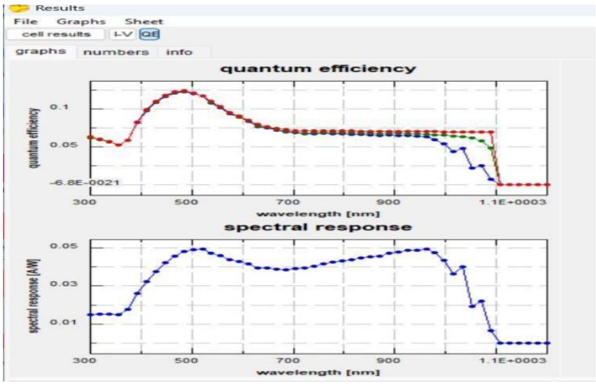

Figure 3: Quantum Efficiency & Spectral response graphs

DISCUSSION

The intrinsic a-Si:H acts as a layer-by-layer structure. In many studies, the hydrogen content in the a-Si:H film is thought to play an important role by enabling the hydrogenation of silicon overhanging bonds [2, 6]. It has been reported that for sputtered a-Si:H film, increasing the H2 concentration in plasma leads to better reflectivity. However, in this study we found that hydrogen content is not the only thing that reduces fast- state couplings and couplings.

The reduction in plate thickness is perfect for reducing the production cost of solar panels. However, thinner silicon wafers are often problematic. The first problem is the weakness of the technology. Thin silicon wafers are prone not only to cracking but also to deformation due to mechanical and thermal stress. Bending the cellswill reduce efficiency during the solar module assembly process. The second is to reduce the photocurrent. Since Si has low magnetic absorption in the near-infrared region, incident photons at near-infrared wavelengths can penetrate the wafer without being absorbed by Si. This leads to a decrease in Isc. The third is Voc loss. When the minority of carrier recombination on the Si surface is larger than that on Si, as the thickness of the silicon layer decreases, the carrier recombination rate on the Si surface increases. In this case, the open circuit voltage of thinner cells decreases. By controlling the properties of HIT solar cells and improving their optical parameters, we demonstrate an efficient HIT solar cell using thin silicon wafers.

Quantum efficiency (QE) is a measure of a solar cell's ability to convert photons of light into electricity at different wavelengths. The x-axis represents the wavelength of light, ranging from shorter wavelengths on the left to longer wavelengths on the right. The y-axis represents the quantum efficiency, which is the ratio of the number of charge carriers generated by the solar cell to the number of incident photons. The graph shows how the quantum efficiency of the solar cell varies across different wavelengths of light.

The peak of the curve indicates the wavelength at which the solar cell has the highest efficiency in converting light to electricity. The shape of the curve illustrates how efficiently the solar cell converts photons into electrons at different wavelengths. It might have higher efficiency in certain parts of the spectrum and lower efficiency in others. This example demonstrates how a quantum efficiency graph provides insight into the performance of a solar cell across different wavelengths of light. The x-axis represents the wavelength of light, ranging from shorter wavelengths on the left to longer wavelengths on theright. The y-axis represents the spectral response, which is a measure of the solar cell's sensitivity to light at each wavelength. The graph shows how the spectral response of the HIT solar cell varies across different wavelengths of light. The peak of the curve indicates the wavelength at which the HIT solar cell has the highest sensitivity .The shape of the curve illustrates how effectively the HIT solar cell absorbs light across the spectrum. It might have higher response in certain parts of the spectrum and lower response in others. This example illustrates how a spectral response graph provides insight into the sensitivity of a HIT solar cell to light at different wavelengths.

CONCLUSION

We have demonstrated that a high-performance HIT solar cell for thinner Si wafers is one of the best c-Si based solar cells because it has high mechanical resistance, good a-Si/c-Si interface characteristics, and a high conversion efficiency. In addition, by reducing the optical loss, we succeeded in obtaining a high conversion efficiency of 19.36% in HIT solar cells with a 98-μm-thick c Si wafer. In addition, we reachedan excellent Voc of 965.2mV with 300 μm-thick cells. In order to further cut the cost of HIT solar cells, we will continue to aim for higher-performance HIT solar cells with thinner silicon wafers. We will also set our sights on a HIT solar cell with a higher conversion efficiency at the R&D stage in the near future.

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