Silicon Nitride Surface Passivation in Silicon Solar Cells

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Abstract

One of the most important factors for achieving high efficiency solar cells is good quality surface passivation. Good quality surface passivation leads to reduced recombination rates and better cell performance. The use of silicon nitride (SiNx) as a material for surface passivation is investigated in this study. SiNx is deposited via PECVD and then put through a rapid thermal anneal to densify the SiNx layer and relieve stress acquired during the PECVD process. The film characteristics are investigated using spectroscopic ellipsometry and photoconductive decay (PCD). Ellipsometric characterization reveals SiNx film thickness between 50-60 nm and uniform film quality. PCD characterization reveals effective carrier lifetimes of around 800 µs, which is significantly larger than the original carrier lifetimes without surface passivation, around 70 µs. Open circuit voltage Voc was measured to be 670 mV. Inverse lifetime (Auger corrected) and carrier density show a linear relationship until carrier density of 1.5x1016 carriers per cm3, indicating good surface passivation.

Background

In recent decades, significant strides have been made in the pursuit of enhancing silicon solar cell efficiency, with a particular focus on refining surface passivation techniques to mitigate recombination losses. Surface passivation is a critical factor directly influencing the collection of photo-generated charge carriers, thereby playing a pivotal role in overall cell performance. Chemical passivation strategies aim to reduce surface defect states, while field effect passivation methods work on modifying carrier densities to minimize recombination rates.

This study endeavors to contribute to this ongoing optimization effort by depositing SiNx films via PECVD to achieve superior surface passivation. Leveraging insights from prior research endeavors, we aim to build upon existing knowledge and techniques. By advancing surface passivation methods, our ultimate objective is to bolster silicon solar cell efficiency, thereby advancing the feasibility and competitiveness of solar energy as a sustainable and cost-effective power source for the future.

References

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Methods and Materials

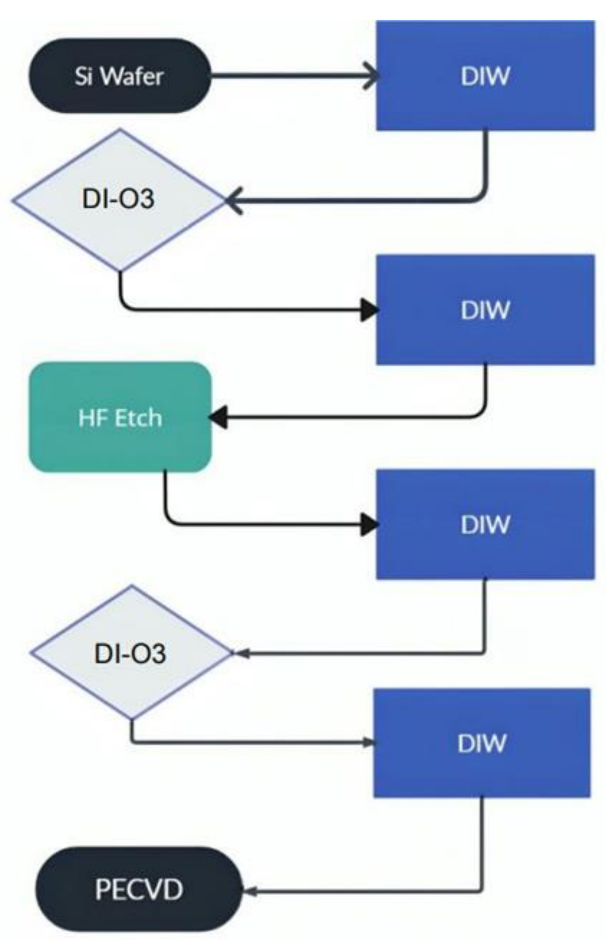

Figure 1: Fabrication Flow

The wafer sample is first rinsed in clean deionized water (DIW), known for its lack of charge carriers, making it ideal for silicon processing and as a solvent. It is then submerged in DIW with UV-ozone (DI-O3 water) for five minutes, creating a native oxide layer on the silicon surface. Afterward, it undergoes a five-minute immersion in hydrofluoric acid (HF) to remove contaminants. Subsequently, it is submerged again in DI-O3 water for another five minutes to grow a native silicon oxide layer approximately 2 nm thick, reducing the defect density. Finally, the sample is prepared for PECVD deposition. PECVD is used to deposit the SiNx layer on top of the Silicon oxide layer.

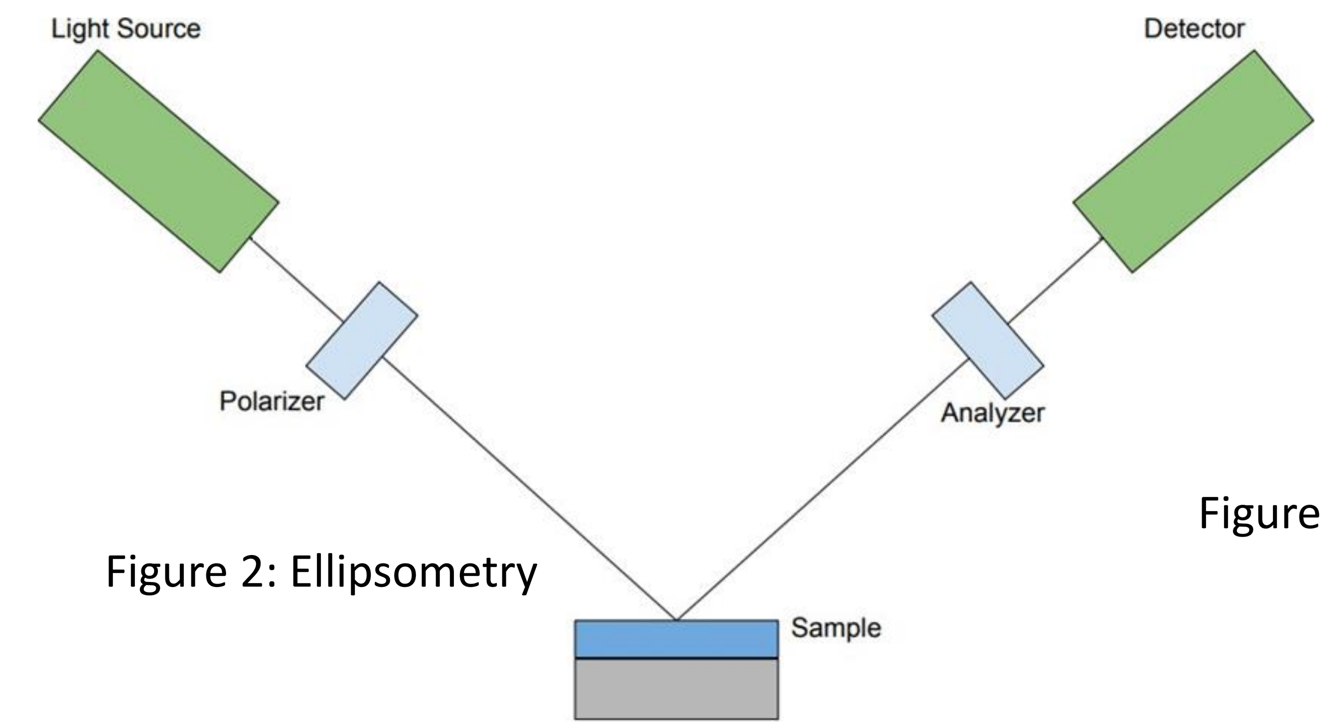

Figure 2: Ellipsometry

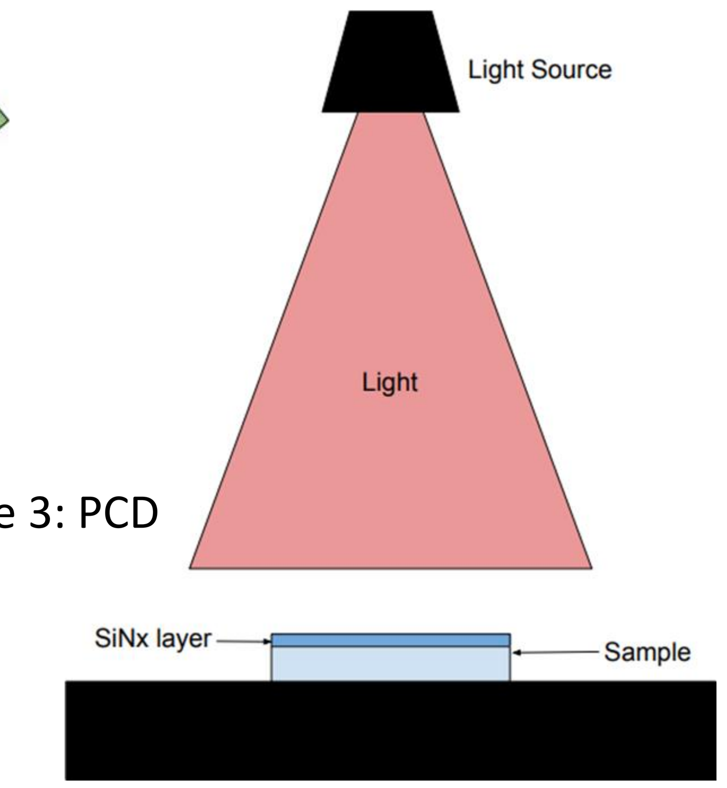

Figure 3: PCD

Spectroscopic Ellipsometry determines SiNx thin film thickness by directing polarized light at a set angle onto the sample, analyzing changes in polarization and intensity as the light reflects off the surface. Surface carrier lifetime for SiNx films is measured through photoconductive decay (PCD), where a brief light pulse generates excess carriers, whose recombination causes a decrease in photo-generated current. Analyzing this current decay provides insights into carrier lifetime.

Results

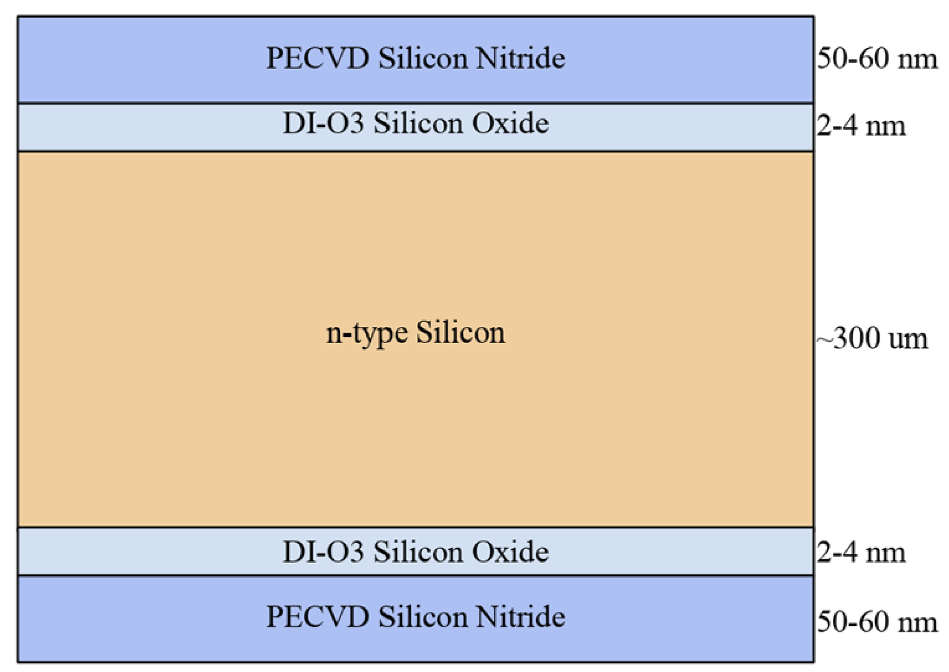

Figure 4: Final Fabricated Stack

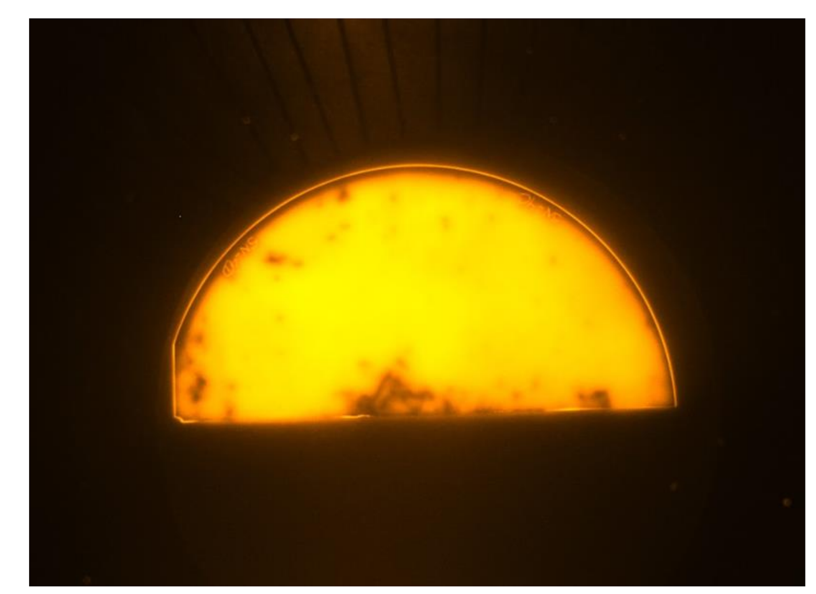

Figure 6: PL Image of Sample

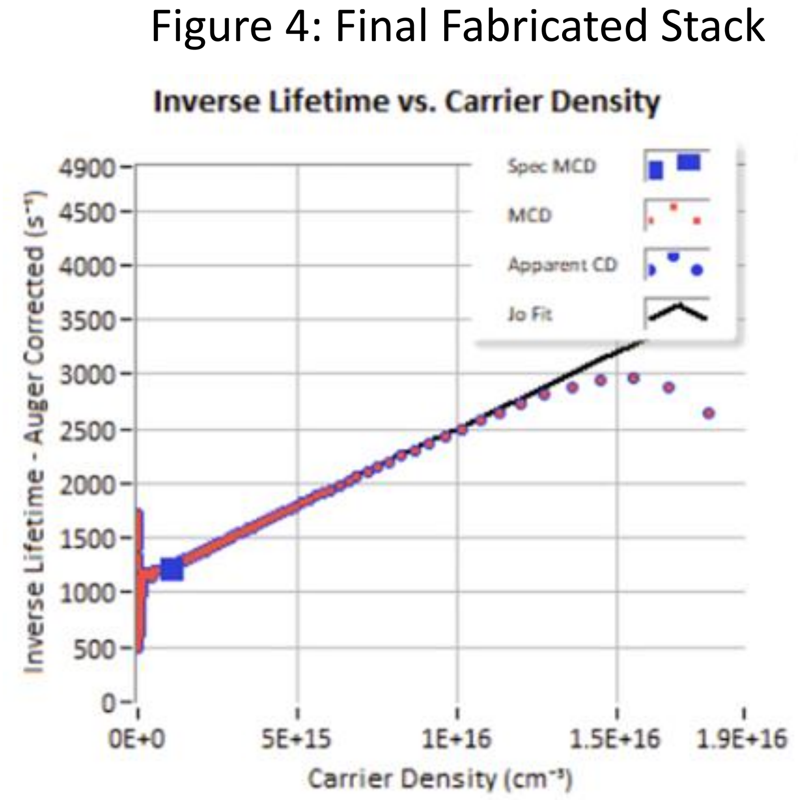

Figure 5: Carrier Lifetime Inverse

We explored silicon nitride as a surface passivation layer for silicon solar cells, crucial for enhancing carrier lifetimes and overall efficiency. Silicon nitride effectively reduces recombination rates by minimizing defect states and excess carriers. SiNx thin film deposition was carried out using PECVD reactors, followed by rapid thermal annealing for film densification and stress release.

Spectroscopic ellipsometry revealed the thickness of the front and back deposited layers as 58 nm and 51 nm, respectively. This SiNx layer reduces surface defect states and excess carrier density. Carrier lifetime measurements using PCD techniques showed an increase from 70 µs before SiNx deposition to around 800 µs afterward, indicating highly effective surface passivation.

Future Direction

In future directions, our focus remains on refining silicon nitride (SiNx) passivation techniques for silicon solar cells. We aim to explore novel approaches in SiNx film deposition, optimizing its effectiveness in reducing surface recombination. Additionally, we plan to investigate the impact of SiNx passivation on the long-term stability and reliability of solar cell performance. Through these efforts, we aim to contribute to the continual advancement of SiNx-based surface passivation, ultimately enhancing the efficiency and durability of silicon solar cells for widespread renewable energy adoption.

The more efficiently we can engineer solar cells to be able to convert light into electricity, the more competitive they will become as an energy source. To that extent, this is a small step in the quest to create high-efficiency silicon solar cells.

Acknowledgements

Thank you to Dr. Ngwe Zin, Dr. Henry Wang and Dr. Vibhor Kumar for all the guidance and help during this research endeavor.

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