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EXPERIMENTAL INVESTIGATION OF DIRECT PLASMA PECVD COATING ON THE ABSORPTIVITY OF MONO-CRYSTALLINE & SOLAR GRADE CRYSTALLINE SILICON WAFERS

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ABSTRACT
Advancements of technologies in today's world creates a need for resources alternative energy. Researchers are working continuously to tap various sources of renewable energy but still upgrading the efficiency of these resources is still a challenge. By varying the colors of coating, the effect of absorptivity of silicon wafers was studied. Silicon solar cells' efficiency is considerably affected by the absorption of light and charge collection area. Increase in absorption increases photocurrent and efficiency. To create various colors, silicon wafer were coated with different composition of silicon nitride. Coatings were done by Plasma Enhanced Chemical Vapour Deposition (PECVD) stage on the equipment manufactured by Schmid Gmbh, Germany.

KEYWORDS: anti-reflective coating; silicon nitride; Silicon wafers; plasma coating; absorption spectrum.

INTRODUCTION
Energy production through solar cell is growing worldwide nowadays. It is the most promising and affordable technique for alternative energy generation. Its working principle is PV effect, discovered by Becquerel in 1839. Later in 1883, Fritts created the first solar cell. But until recently solar cells has not been very successful. The reason for this are their low efficiency and high cost. Silicon solar cells possess a low efficiency of around 20% and even over the past decade, no improvement is made [1], [2]. One of the major loss that affects the efficiency of solar cell is incident light reflection which occur on the surface of the solar cell. Crystalline Si is used in the manufacturing of more than 90% of industrial solar cells [3]. On an average, 37% light gets reflected from the surface of a silicon solar cell. The reduction of reflection from the surface of solar cell has been a prime focus of researchers for many years [4-9]. Production of Solar cell comprises of processing of raw silicon wafers to complete solar cell in different steps. The major factor that affects the efficiency of a solar cell is the reflection of light from the upper surface. Anti-reflective coatings (ARC) help in reducing this loss. The reflection coefficient can be minimized by ARCs. ARCs are crucial for performance of solar cell as it provides more photocurrent by minimizing reflectance. Si_3N_4 films deposited with the help of Plasma Enhanced Chemical Vapor Deposition (PECVD) are widely used as standard ARCs for industrial silicon solar cells. Various other films have also been considered to be used as ARC for silicon solar cells, but Si_3N_4 has shown much potential. This is because of the fact that Si_3N_4 has good surface passivation and a refractive index that is tunable ranging from 1.9 to 2.9 due to which it can be easily optimized for its application. Also hydrogen provides bulk passivation and it reduces front side

optical reflection [10], [11]. In this work, monocrystalline and multicrystalline silicon wafers were used for the investigation. An infrared spectrometer was used for Spectral analysis of both coated and uncoated wafers of monocrystalline and multicrystalline silicon and results were compared. The wafer used here are the raw material for commercial grade solar cells which are made up of silicon. These wafers have dimensions of 156mm×156mm in area and 200µm thick with corners chamfered as shown in Figure 1.\

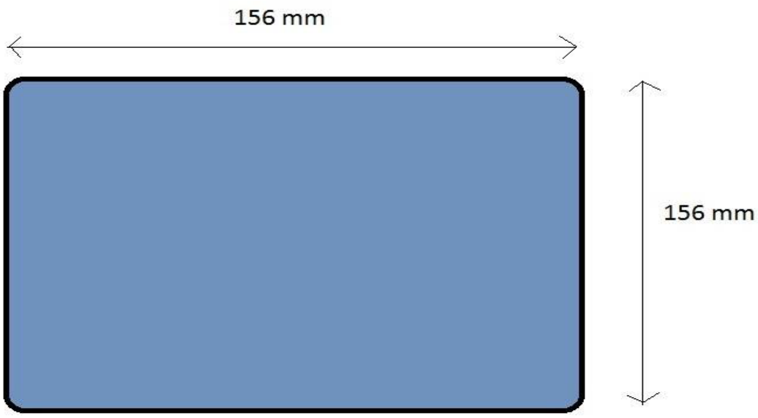


Figure 1. Raw Silicon wafer

EXPERIMENT

Direct plasma reactor technology is used here which achieves greater cell efficiency than the technology of remote plasma reactor. The PECVD system is runs on the technology developed by Shimadzu, a Japanese manufacturer.

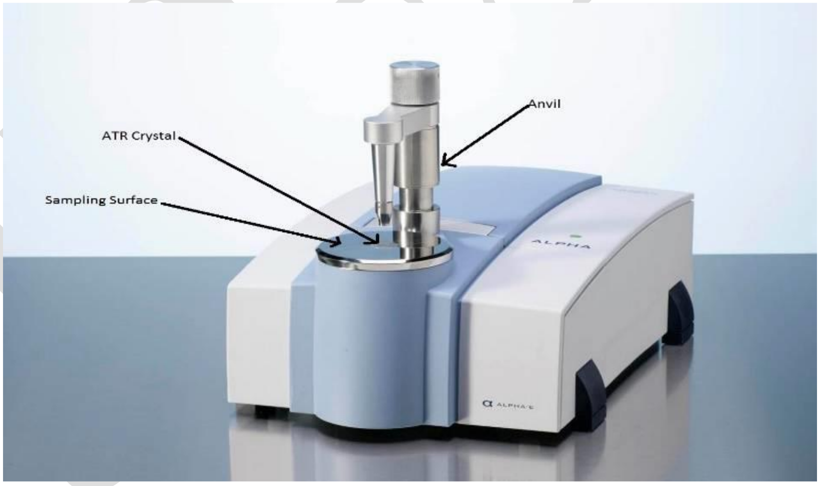


Figure 2. Bruker Alpha - E Spectrometer

Four samples each of mono-crystalline silicon wafers and commercial solar grade silicon wafers were obtained. First the absorbance of both monocrystalline and multicrystalline wafers is measured by Bruker Alpha - E Spectrometer. These samples are then passed through PECVD for silicon nitride deposition. In the PECVD coating system the wafer is coated with an antireflection layer comprising of silicon nitride. The samples were kept at the top of ATR (Attenuated Total Reflection) crystal at a proper position. It was made sure to clean the sampling surface, anvil and ATR crystal. Samples were placed at the center of the sampling surface. Sample size only big enough to cover the ATR crystal is used. The anvil is correctly pressed against the sample to make sure that the optimum contact pressure is applied against the ATR crystal. After acquiring the spectrum, the pressure applying device is moved up and the sample is removed.

RESULTS AND DISCUSSIONS

The graph absorptive versus wavelength is obtained as shown in the Figure 3(a) and Figure 3(b). Now this same process is repeated with all four samples of solar grade wafers. Their absorbance-wavelength graph is also plotted as shown in Figure 4(a) and Figure 4(b).

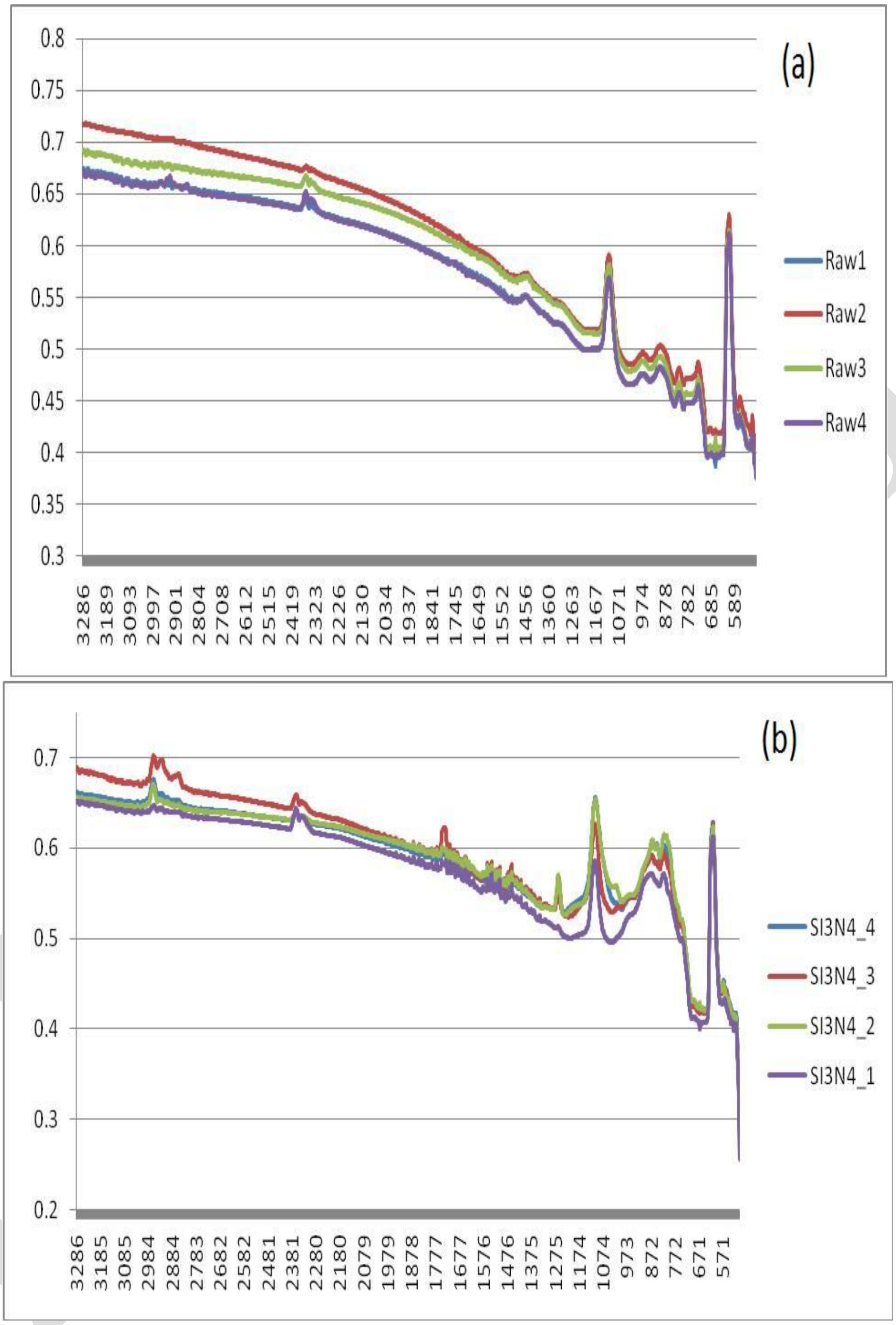
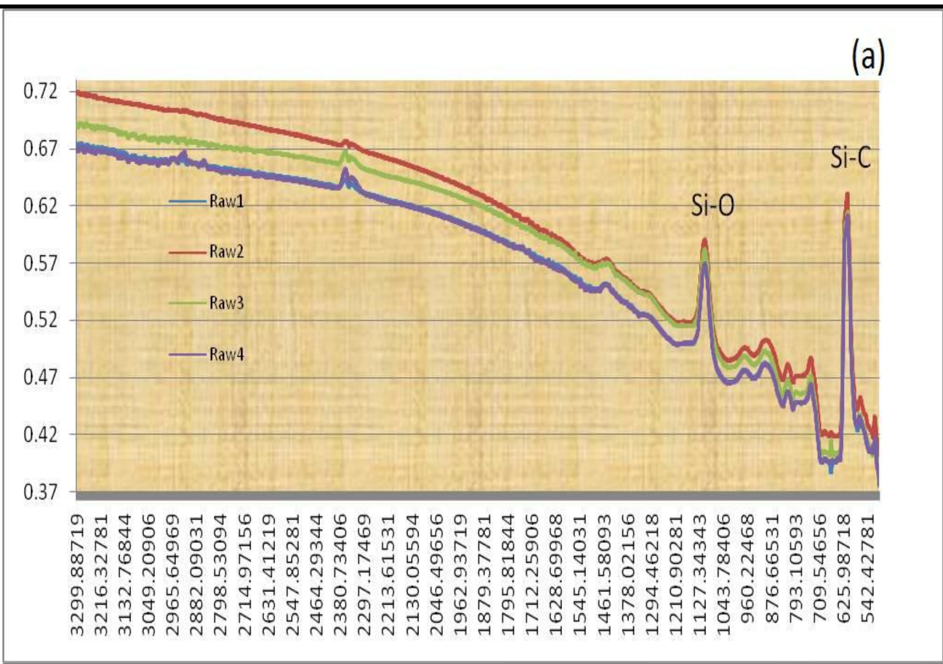


Figure 3. FTIR GRAPH of IC Grade Mono crystalline Wafers: (a) Raw Wafers & (b) Silicon Nitride coated Wafers

By comparison of the two graphs, the effect of silicon nitride coating on the absorbance of the wafer can be clearly seen. In FTIR spectrum of raw wafer, at near Infrared rays, absorption coefficient of 0.47 is obtained. After the coating the FTIR spectrum indicates a rise in absorption coefficient at around 860nm from 0.47 to 0.62. This is corresponding wavelength to the vibrational frequency of Silicon nitride and maximum energy is absorbed at this point. 30% increase in the absorptivity is obtained.



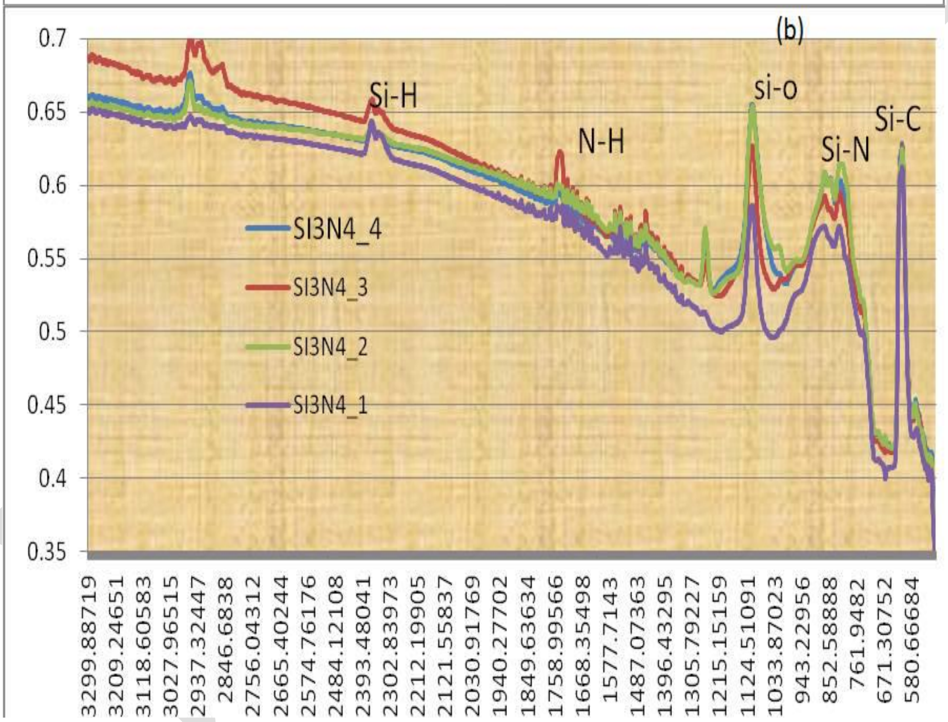


Figure 4. FTIR GRAPH of SIN Solar Grade Wafers: (a) Raw Wafers & (b) Silicon Nitride coated Wafers As can be inferred from the above graphs, the coating of silicon nitride increase the absorptivity around 853 nm from 0.45 to 0.58. It can be inferred that the above process can bring about 28% increase in absorptivity.

CONCLUSION

Investigation of optical properties of Si_3N_4 films deposited by direct plasma reactor PECVD onto monocrystalline and solar grade silicon wafers were conducted. It was evident that the absorptivity of these films enhanced and it can be considered for optimisation of solar cells. By the results obtained above it can inferred that by using Si_3N_4 PECVD coating by direct plasma reactor technology, there is an enhancement in the absorptivity of 30% in mono-crystalline silicon wafers and increase in absorptivity of 28% in solar grade silicon wafers.

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