

CHEMICALLY CREATING TEXTURES AND OPTICAL
LAYERS ON THE SURFACE OF SOLAR CELLSRakhmonova Diyora Dilmurodjon qizi ¹Aliyev Sukhrob Rayimjonovich ²Alijonov Abbosbek Azizjon o'gli ³¹ Andijan State Technical Institute, student² Andijan State Technical Institute, Associate Professor,

Department of Alternative Energy Sources

³ Andijan State Technical Institute, Intern-Researcher,

Department of Alternative Energy Sources

+998931489804

Abstract: “PVLIGHTHOUSE” is mainly designed for modeling polycrystalline and monocrystalline silicon-based solar cells. Therefore, we can only calculate the resistivity, charge carrier mobility and similar material parameters of mono and polycrystalline silicon and the influence of the concentration of the input and temperature on them. However, the refractive index database contains a database of the dependence of the complex refractive index of more than 50 materials on the wavelength of light, determined experimentally. Using this database, the optical properties of multilayer solar cells can be calculated in the “Wafer Ray Tracer” module. However, in general, the electrical, thermal and optical properties of simple solar cells based on two types of multi- and monocrystalline silicon can be determined by modeling.

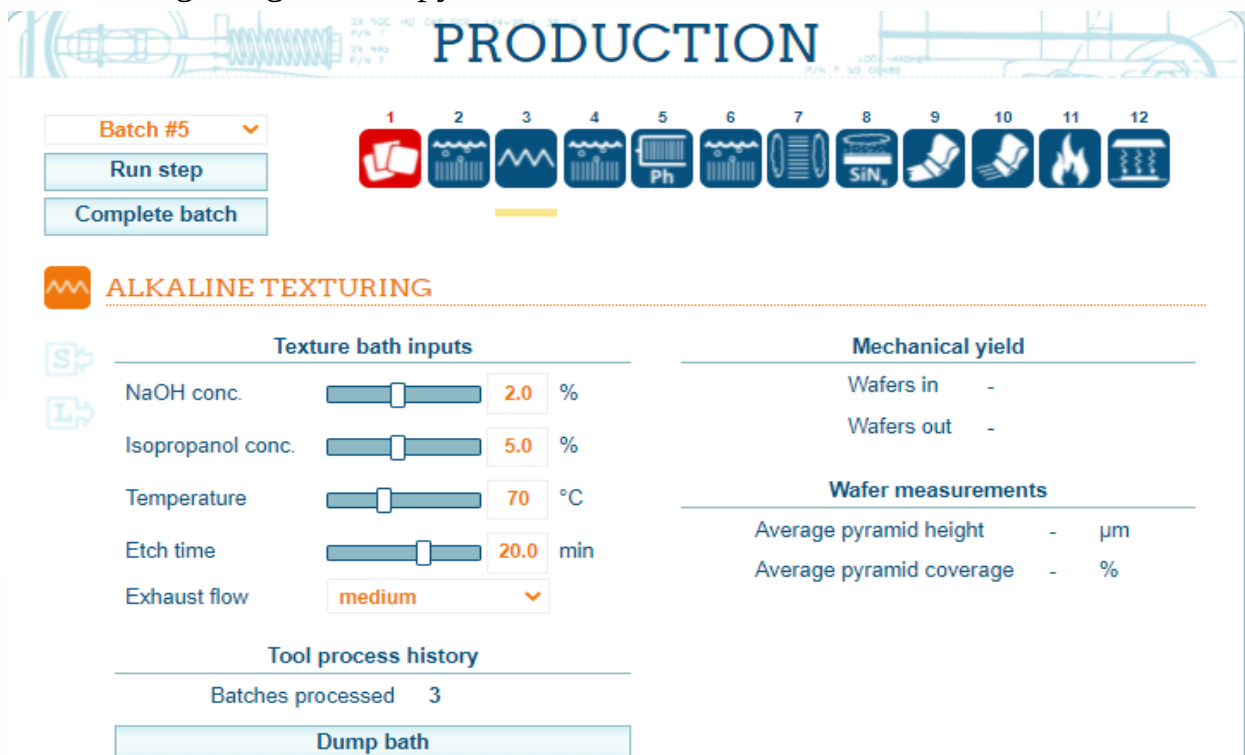
Keywords: PVLIGHTHOUSE, introduction, PV FACTORY, light, texture, virtual, equivalent, NaOH.

Main part: Another main module of “PVLIGHTHOUSE” is “PV FACTORY”. It is designed for virtual production of solar cells. After modeling of solar cells, the production process is organized using the solar cell database. That is, the structure of the experimentally produced solar cell is determined on the basis of the “Solar cell library” corresponding to and equivalent to the solar cell created in the virtual production process, and the photoelectric parameters of the virtually produced solar cells are automatically calculated using other modules of “PVLIGHTHOUSE” depending on the structure, dimensions, dopant concentration, type and size of this solar cell, as well as the type and thickness of the optical layers. This ensures that the obtained result is close to the experimental result. The production of solar cells in “PV FACTORY” is carried out in 12 stages.

Texturing is a chemical process designed to reduce the amount of light reflected from the wafer surface and thus increase the photocurrent produced by the solar cell [1]. Monocrystalline wafers are etched more slowly in dilute alkaline solutions than in the direction in which the silicon crystal is oriented, thus creating a texture. On the surface of the silicon [2] with crystal orientation, regular pyramids are formed in the direction. Light incident perpendicular to the wafer is refracted between the two pyramids, causing more light to be absorbed. This double refraction reduces the net light reflectance of the silicon surface. The formation of these pyramids over the entire surface of the silicon wafer reduces the reflectance from ~36% to 11–12% in the wavelength range 400 to 1100 nm. This anisotropic etching process is known as hydroxide texturing or random pyramid texturing.

The process of creating textures using alkali is similar to the stage of removing defects formed during the cutting process, except for the concentration of NaOH. Typically, 2% NaOH is used in a chemical bath at 80-

90 0 °C to ensure the speed [1] of pyramidal textures. As in the previous step, the plates are immersed in a plate holder with a capacity of 100 plates and a chemical bath for texturing. The baths are ventilated to remove vapors from the hot alkaline solution, as well as hydrogen gas formed as a result of the chemical reaction during etching. After the texturing process is complete, the wafers are rinsed in purified water. Additives such as isopropanol are required to achieve a uniform texture across the entire wafer surface. Due to the high temperature of the bath, a large part of the isopropanol evaporates, which increases the cost of the process. In a good texturing process, the wafer surface is almost 100% covered with pyramidal textures with an average height of 5 μm . For this, the concentration of NaOH and isopropanol, the wafer temperature, the immersion time and the flow rate are given as input parameters. Figure 1 depicts the step of creating textures on the surface of a silicon wafer using NaOH and isopropanol. Based on these values, the percentage coverage of the silicon wafer surface with pyramidal textures and the average height of the pyramids are calculated.



PRODUCTION

Batch #5

1 2 3 4 5 6 7 8 9 10 11 12

ALKALINE TEXTURING

Texture bath inputs		Mechanical yield	
NaOH conc.	<input type="text" value="2.0"/> %	Wafers in	-
Isopropanol conc.	<input type="text" value="5.0"/> %	Wafers out	-
Temperature	<input type="text" value="70"/> °C	Wafer measurements	
Etch time	<input type="text" value="20.0"/> min	Average pyramid height	- μm
Exhaust flow	<input type="text" value="medium"/>	Average pyramid coverage	- %

Tool process history

Batches processed 3

Figure 1. The texture generation stage of the PV Factory module of the PVLigh House online platform

Before the wafers are transferred to the high-temperature diffusion furnace, their surfaces must be cleaned of all impurities. Texturing can leave silicate residues on the surface, and metal impurities can become sticky and adhere to the native oxide that grows on the surface of the silicon wafer. According to the data, the wafers are first immersed in 1 to 5% HF acid solutions at room temperature, then rinsed in deionized water, and then immersed in 2% HCl before a final rinse in deionized water. An alternative, inexpensive cleaning process commonly used in the industry today involves immersing the wafers in a room temperature solution containing 2% each of HF and HCl. Figure 2 illustrates the process of removing foreign atoms generated during the texturing process. The main parameters are the HF and HCl concentrations, the cleaning time, and the rinsing time.

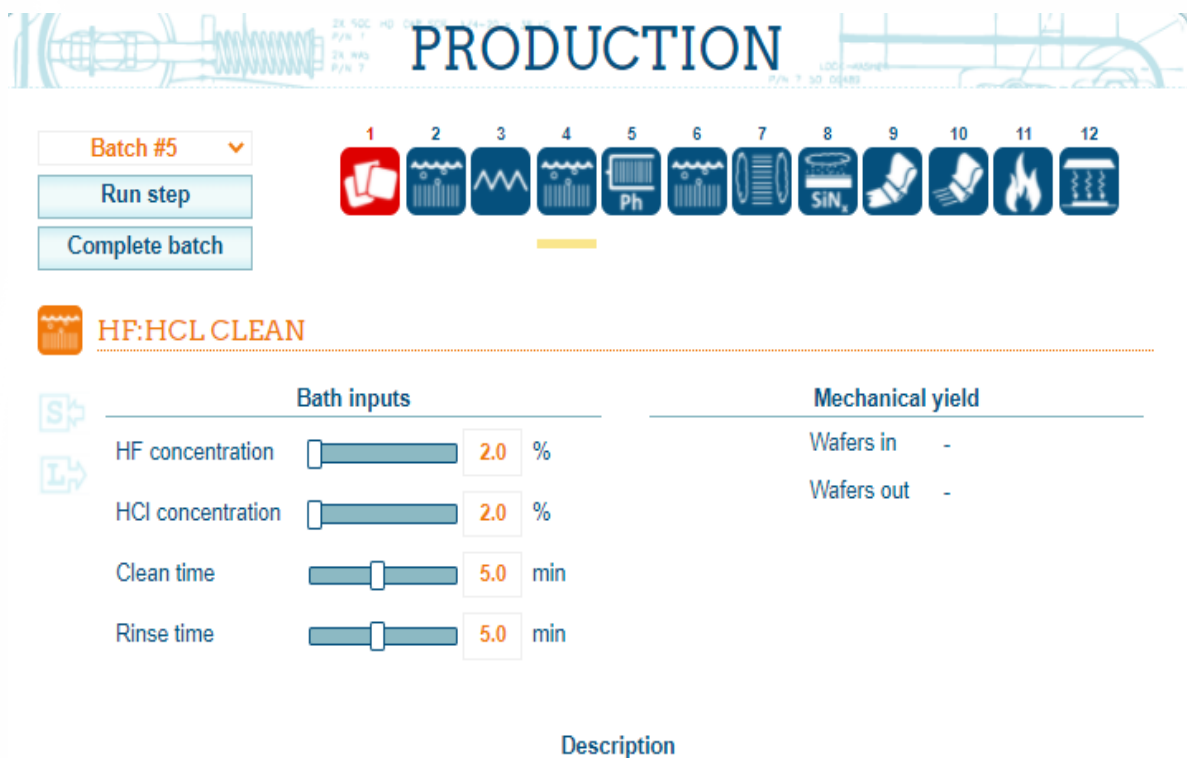


Figure 2. The cleaning stage of the PV Factory module of the PVLigh House online platform after texture generation

produced by HCl are effective chelators of metal ions. They tend to form complexes with metal ions , thereby preventing them from adhering to the surfaces of silicon wafers. In addition to chelating metal ion impurities such as iron and copper that may be released from the wafer surface during the cutting process , chloride ions are also very effective in reducing the concentration of potassium and sodium ions that may remain after texturing. If metal impurities are not removed from the surface before the diffusion process, they can also diffuse into the wafer, where they affect the residence time of the non-dominant charge carriers in the solar cell . If a long time is left between cleaning and diffusion processes, it is necessary to store the wafers in a clean place or to repeat the cleaning process before diffusion.

Two main types of textures are formed on the surface of the solar cell. These are straight and inverted pyramidal textures. Straight pyramids are formed using high concentrations of NaOH alkali. Inverted pyramids are formed using acids. Figure 3 shows the straight and inverted pyramidal textures obtained in the experiment.

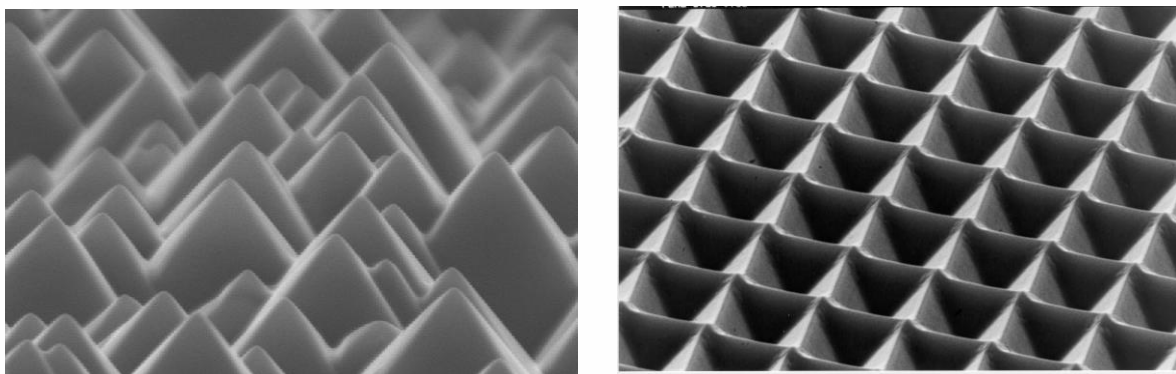


Figure 3. SEM image of straight and inverted pyramidal textures formed on the surface of a monocrystalline silicon-based solar cell

the regular pyramidal textures formed on the surface of the solar cell directly depend on the concentration of NaOH. NaOH with a maximum concentration of 3% is usually used for texture formation. Table 1 shows the dependence of the height and coverage of the regular pyramidal textures formed on the surface of silicon-based solar cells on the concentration of NaOH.

presents the surface coverage of textured silicon-based solar cells at different NaOH concentrations and the height of the textures.

Table 1

NaOH, %	Average pyramid height, μm	Average pyramid coverage, %
1	1.3	11.3
1.5	2	25.4
2	2.6	45.4
2.5	3.2	70.1
3	3.5	83.9

and coverage of the textures increased as the concentration of NaOH increased. The most important aspect in texturing is therefore the ability to choose the time for the application of alkali [3] and isopropanol concentrations.

Conclusion: The surface reflectance of a typical pure silicon wafer is very high, over 30% [4]. Texturing the wafer surface with alkali can reduce the reflectance to a maximum of 11%. However, the use of a thin dielectric coating can further reduce the reflectance if the thickness of the coating is designed so that the phase difference between the light reflected from the silicon-dielectric surface and the light reflected from the dielectric-air surface is exactly 180° . As a result of interference, the reflectance at a specific wavelength is minimized (600 nm in industrial solar cells). This dielectric layer is called the anti-reflection layer. SiN_x is used as the anti-reflection layer in almost all



industrially manufactured solar cells [5]. Because, in addition to its property of reducing the reflectance, it also has the property of passivating the surface, i.e. reducing the rate of surface recombination. The main method of depositing SiN_x on the wafer surface is plasma-enhanced chemical vapor deposition. In this process, a plasma is generated between two radiofrequency or microwave electrodes, where the space between the electrodes is filled with a subatmospheric mixture of reactive gases, including silane and ammonia gases. Figure 4 illustrates the process of plasma deposition of SiN_x onto a silicon wafer. The plasma deposition time, temperature, and flow rates of silane and ammonia gases are given.

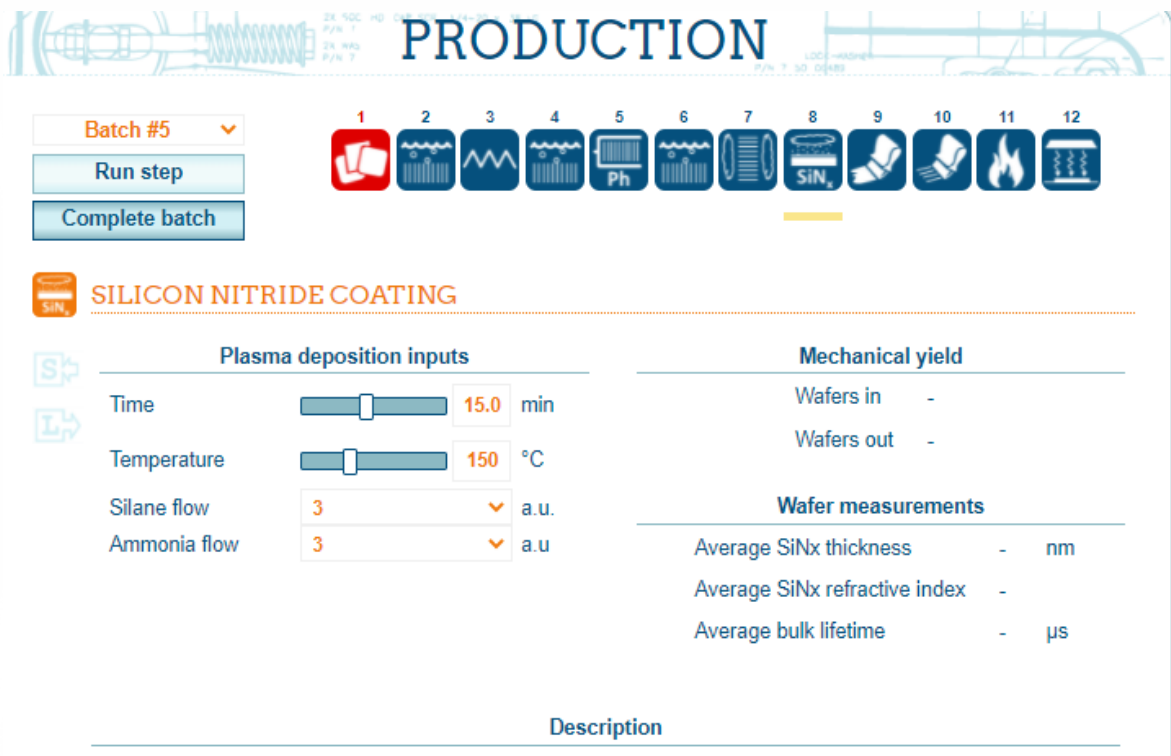


Figure 4. The stage of creating an anti-reflective layer of the PV Factory module of the PVLIGHT House online platform

If we look at the surface of solar cells, they glow in all colors. We know that pure silicon has only one color, silver. So, its glow in different colors



depends on the anti-reflective layer coated on it. Depending on the thickness of the anti-reflective layer, the solar cell glows in different colors. Figure 5 shows solar cells with a SiN_x anti-reflective layer on their surface and their color depending on the thickness of the SiN_x .

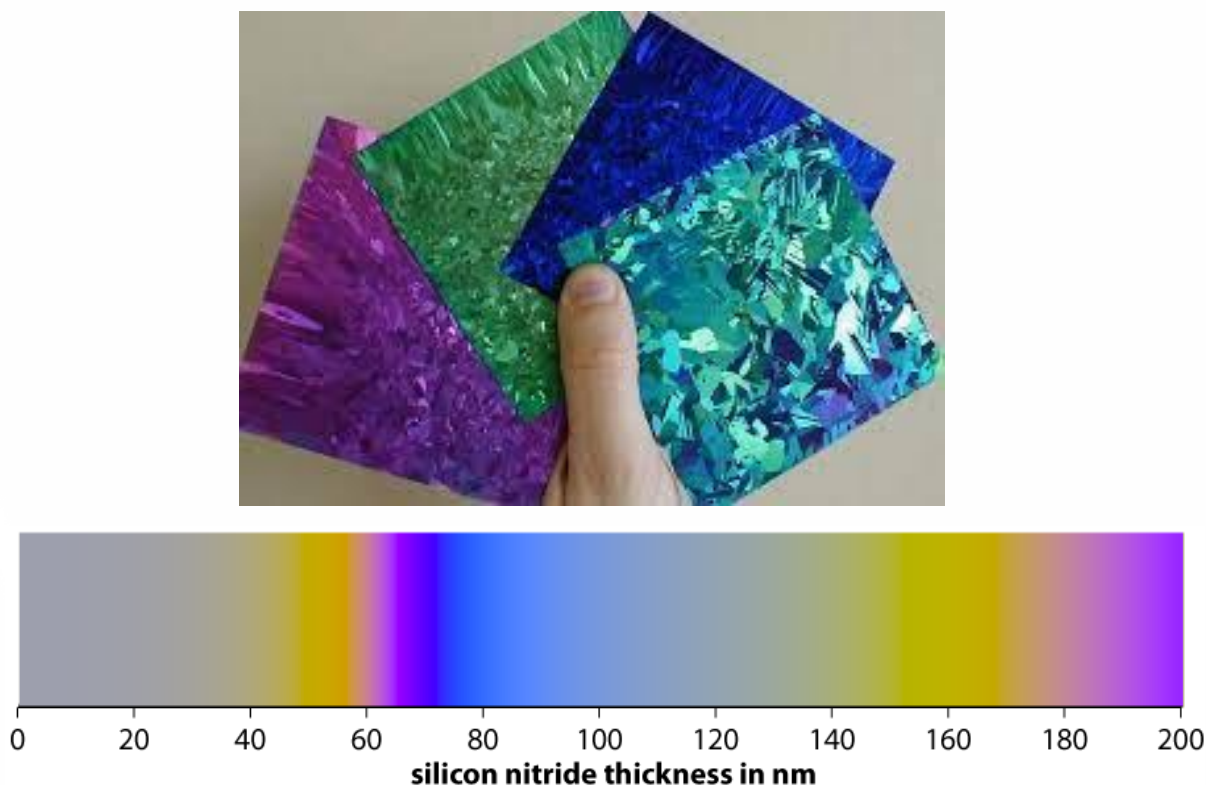


Figure 5. Solar cells with SiN_x anti-reflection layer on their surface and their color dependence on SiN_x thickness

Depending on the thickness of the anti-reflection layer, light of wavelength λ is interfered within the anti-reflection layer, and the solar cell is not illuminated by light of this wavelength.

REFERENCES USED

[1] Scheul T, Khorani E, Rahman T, Charlton M, Boden S. " Wavelength and angle resolved reflectance measurements of pyramidal textures for crystalline

silicon photovoltaics" *Progress in Photovoltaics: Research and Applications* (2020) 28(12) 1248-1257 DOI: [10.1002/pip.3319](https://doi.org/10.1002/pip.3319)

[2] Igor Sobkowicz, Martin Foldyna, Kamil Postava, Ileana Florea, „Optical properties and performance of pyramidal texture silicon heterojunction solar cells: Key role of vertex angles" *Progress in Photovoltaics: Research and Applications* · February 2018. DOI: [10.1002/pip.2994](https://doi.org/10.1002/pip.2994)

[3] YT Cheng et al. , "Efficiency improved by acid texturization for multi-crystalline silicon solar cells," *Solar Energy* , vol. 85, no. 1, pp. 87–94, Jan. 2011, doi:10.1016/J.SOLENER.2010.10.020.

[4] Kumaragurubaran, B. and Anandhi, S. (2014) Reduction of Reflection Losses in Solar Cells Using Anti Reflective Coating. *Proceedings of 2014 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC)*, Chennai, 16-17 April 2014, 155-157. <https://doi.org/10.1109/ICCPEIC.2014.6915357>

[5] Renwei Feng , Chaoyang Wei, Shuxin Tu, Yongzhen Ding, Ruigang Wang, Junkang Guo ,. "The uptake and detoxification of antimony by plants: A review" *Environmental and Experimental Botany* Volume 96, December 2013, Pages 28-34 <https://doi.org/10.1016/j.envexpbot.2013.08.006>