Solid State Science and Technology, Vol. 27, No 1 & 2 (2019) 9-14
ISSN 0128-7389 | *http://myjms.moe.gov.my/index.php/masshp*

TRANSMISSION OF TEXTURED SiNW USING IR MEASUREMENT SYSTEM

Nurul Aqidah Mohd Sinin, Mohd Norizam Md Daud, Suhaila Sepeai and *Kamaruzzaman Sopian

Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

**Corresponding author*: ksopian@ukm.edu.my

ABSTRACT

Crystalline silicon (Si) based on pollution free photovoltaic (PV) electricity generation technology is expected to play a dominant role in this electricity generation transition from carbon to silicon. Silicon remains the material of choice for PV because of its abundance, high and stable cell efficiencies. Si wafer has to go through standard manufacturing process consist of damage removal, cleaning and texturing process. This study presents the various surface of p-type Si wafer; planar, textured and SiNW. Surface morphology, optical properties and the optical transmission near band gap is measured with custom-designed rear infra-red (IR) transmission measurement system. Si wafer with the SiNW surface have more light absorption than the planar and textured Si wafer.

INTRODUCTION

Silicon (Si) wafer-based photovoltaic module production has been growing over 30% since the last decade [1]. Generally, Si is an indirect band gap semiconductor and can be doped by impurities such as boron or phosphorus to form highly conductive positive or negative regions. It also absorbs light over a broad spectral range from ultra-violet (UV) to near infra-red (NIR) range [2]. Si PV technology is almost exclusive based on mono-facial solar cells in which light are incident from the front surface with the back surface completely metalized.

There are two basic steps in solar cell operation. First, an incoming particle of light, known as photon, enters and is absorbed by the material, rather than reflecting off its surface or passing right through. Second, electrons knocked loose from their atoms when that photon is absorbed, then need to make their way to a wire where they can be harnessed to produce an electrical current, rather than just being trapped by other atoms.

However, in order to absorb and capture more light, the silicon surface needs to be textured to reduce reflectance and to improve light trapping. Surface texturing aimed at enhanced absorption in silicon has been extensively investigated by geometrical optic [3]. Geometrical textures reduce reflection light into the semiconductor. For a good solar cell it is crucially important that all of the incident energy to be scattered into obliquely propagating transmitted orders in order to enhance optical path length hence increase absorption rate [4].

Basically, there are three different of texturing technique which are acid texturing, reactive ion texturing and mechanical texturing [5]. Usually, a mixture of $HF:HNO_3$ were used for acid texturing. However, this approach induces difficult reproducible results due to random distribution of grains of different crystallographic orientation on the surface [5]. Reactive ion etching creates needle-like surface, on which screen printing process become difficult and required an additional wet chemical etching step. Mechanical texturing technique may be effective but not suitable for thin, wrapped and fragile materials.

New approach has been investigated by using metal assisted etched texturing to trap more light on silicon surface [6]. In this paper, two different texturing techniques were used. In this contribution, we apply the metal assisted etched texturing on the pyramidal texturing surface to see the effect of reflection and absorption. Both technique will be compared with planar surface silicon wafer that act as baseline in IR transmission in (~800 – 1700) nm spectral range measurement.

EXPERIMENTAL DETAILS

Single crystalline silicon (c-Si) wafer with thickness about (~200 μm) is used. P-type Si wafers with resistivity ranging between (0.5-3.0) Ω.cm with doping density between 10^{10} to 10^{16} cm^{-3} were used. The Si wafer was divided into three types of surface which is planar, standard textured and textured SiNW surface. Firstly, all three types of surface need to go through damage removal process and this process called as planar surface. The Si wafer was initially cleaned by dipping into solution of hydrofluoric acid (HF) and nitric acid (HNO_3) in a ratio of 1:100 for 10 minutes. After rinsing with deionized water, it was then dipped into HF and water in a ratio of 1:50 for 1 minute. The wafer was immersed in 10% potassium hydroxide (KOH) at a temperature of 70 – 80 ℃ for 5 minutes. Subsequently, the wafer was repeatedly cleaned in $HF:H_2O$ for 1 minute. Then the wafers were rinsed with deionized water for about 2 minutes and dried with nitrogen gas.

Second and third Si wafer with damage removal needs to go through the texturing process with ratio of 1:5:125 for $KOH:IPA:H_2O$. The texturing process is a combination of 4 g of KOH pallets, 20 ml of isopropanol and 90 ml of deionized (DI) water. Afterwards, third wafers were subsequently textured using a metal-assisted chemical etching (MACE) method. Therefore, SiNW will grow on the textured Si surface. SiNW was prepared following the method described by Jia et al. [7], using a mixture of $AgNO_3$ and HF at room temperature. A mixture of $AgNO_3$ (0.02M) and HF (5M) was added to the etching cell. The etching process was stopped after 20 min and the sample was rinsed thoroughly with deionized water. Here, porous silicon had grown on the silicon surface, but, the surface needed to be cleaned with several steps to remove the silver dendrite on the sample surface. The cleaning procedure started with a 2 min dipping in concentrated 65% of HNO_3. After that the sample was rinsed in deionized water several times, followed by with 8 min dipping in 5% HF to remove the oxide layer on the sample surface. The methods of preparing three different types of Si surface were shown in Figure 1.

Surface morphology and micro structural properties of planar, textured and SiNW textured surface were characterized using a field emission scanning electron microscope (FESEM). The topographical images of the three different surfaces were investigated using NanosurfeasyScan 2 atomic force microscopy (AFM). A simple experimental setup based on optical configuration has been developed for characterization of near IR transmission as a function of wavelength. This system is designed to measure optical transmission system in near and far infrared (IR) range specifically for the wavelength.

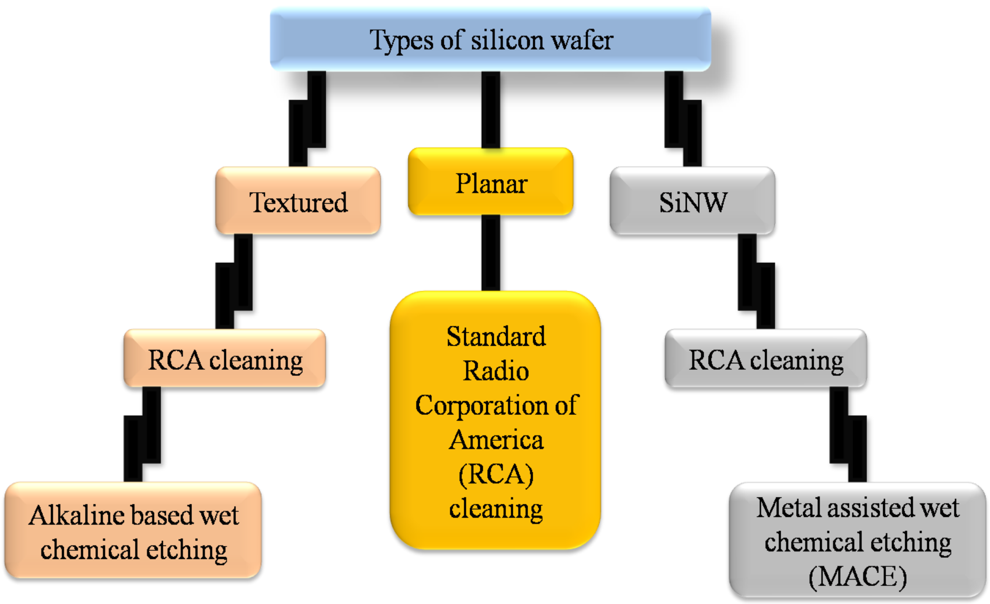

Figure 1: Method of preparing different types of Si wafer surface

RESULTS AND DISCUSSION

Figure 2 shows the field emission scanning electron microscopy (FESEM) images for different surface textured on Si wafer. The SEM image shows the top view of planar surface (a), the growth of pyramid textured on planar surface (b) and the growth of SiNW through MACE method on pyramid textured surface. Figure 2(a) was used as baseline for both textured and SiNW textured surface. Based on the Figure 2(b), the pyramid texture growth randomly on the surface. According to Ximello et. al, larger pyramid (more than 15 µm) lead to breaking during handling. However, small pyramid (less than 0.3 µm) result in an increase of reflection values because light

Solid State Science and Technology, Vol. 27, No 1 & 2 (2019) 9-14
ISSN 0128-7389 | *http://myjms.moe.gov.my/index.php/masshp*

diffraction becomes apparent in the long wavelength [8]. In this research, pyramid size was measured and the length is 3.289 µm. Figure 2 (c) shows the growth of SiNW with 20 mins time etching as mentioned and discussed in previous investigation by Ibrahim et. al. (2014). A slow process of charge detrapping was take place with etching time 20 min rather than higher etching time [9].

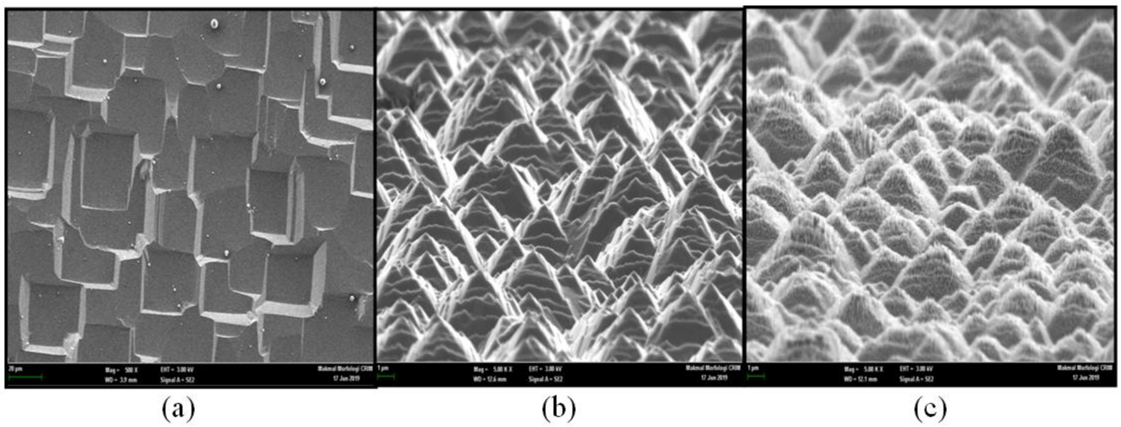

Figure 2: (FESEM) images for different surface textured on Si wafer. a) planar, b) texture and c) textured SiNW

The topography images of each silicon surface were investigated by using AFM is depicted in Figure 3. AFM images show differences among samples according to their texturing technique. The surface roughness for each samples were measured automatically after scanning by clicking the calculate line roughness in the software. The detailed roughness parameters of each silicon surface are summarized in Table 1. It is clearly observed from Table 1, the roughness of the surface increase from planar to SiNW textured. The increasing of surface roughness will reduces the reflection of light and increasing the chances of reflected light bouncing back onto the surface, rather than out to the surrounding air.

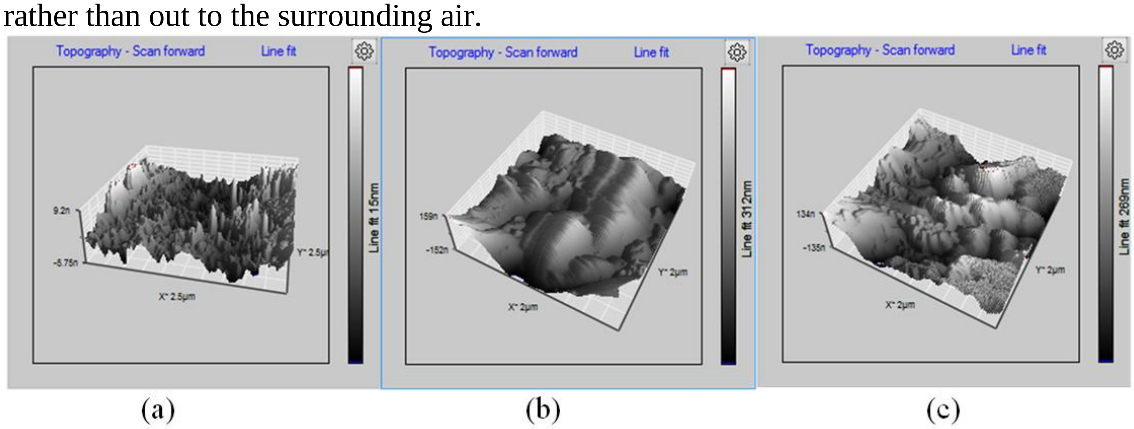

Figure 3: 3D image profile of (a) planar surface (b) texture surface (c) texture SiNW surface

Table 1: Comparison of roughness parameters for different silicon surface

Surface	Line Roughness	Area Roughness
Planar	2371.6 pm	2982.2 pm
Textured	44.589 nm	51.138 nm
Textured SiNW	65.205 nm	56.535 nm

Figure 4 shows recorded transmission data as a function of wavelength for planar surface, textured surface and SiNW textured surface. The data was recorded under light absorption near IR wavelength range between 850 to 1750 nm. Based on the figure, SiNW textured surface shows the lowest transmission value (red line). This is due to the size form of nanopillars in Si substrate is higher than textured surface. From the figure, it shows that the light starts to transmit at 1050 nm compared to textured surface. The planar surface shows the highest transmission value (orange line) due to its surface and roughness. More light will transmitted and reflected when it near to Si surface and reduces the optical path-length and cause of less absorption of light [10].

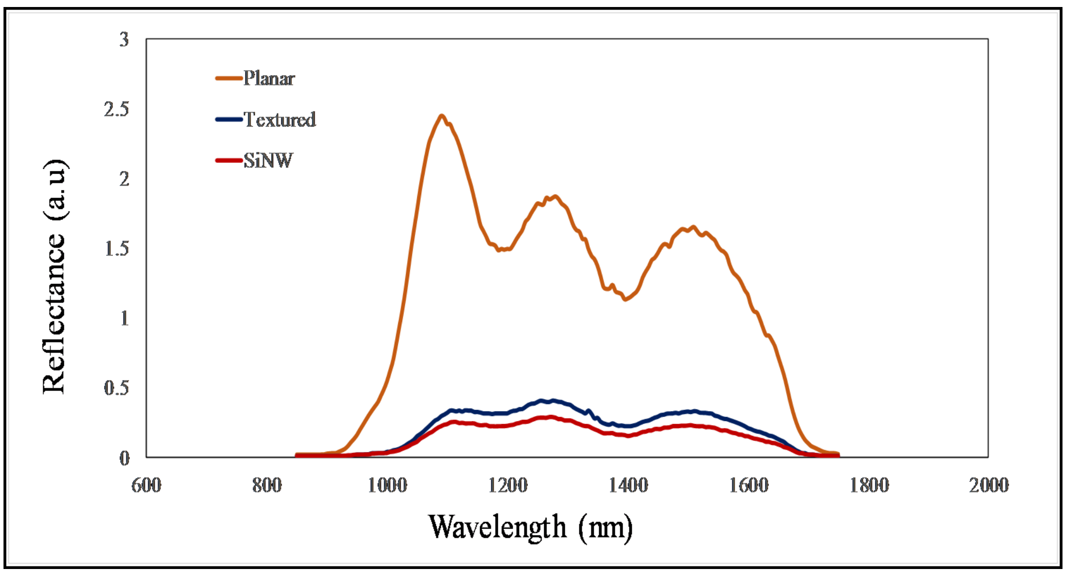

Figure 4: Optical transmission data as a function of wavelength for different silicon surface

CONCLUSION

In this experiment, we investigate the relationship of different silicon surface which is planar surface as baseline, textured surface by using alkaline solution and SiNW textured surface by suing metal assisted chemical etching (MACE) method. A simple IR spectral transmission system based on InGaAs photo detector and monochromator was successfully developed for spectral optical measurement. Based on feature dimensions, incident light interaction can be described in terms of geometrical, diffractive and physical optics. The high reflectance shown by planar wafer indicates that the light is highly reflected compare to texture and SiNW wafer. The reflectance measurement proves that SiNW wafer can potentially produce a good performance output of solar cell compared to commercial solar cell.

ACKNOWLEDGEMENT

The authors would like to express appreciation for the support of the sponsor from Universiti Kebangsaan Malaysia under grant of AP-2017-006/2.

REFERENCES

[1] Maycock, P. *Renewable Energy World*, 6(4): 84 (2003)

[2] Zulhafizhazuan, W., Sepeai, S., Leong, C. S., K. Sopian and Zaidi S. H. *Malaysian Journal of Analytical Sciences,* **21**, 1127 – 1133 (2017)

[3] Green, M. A. and Keevers, M. J. *Progress in Photovoltaics: Research and Applications.* **3**, 189 – 192 (1995)

[4] Nasir, N. S., Sepeai, S., Leong, C. S., Sopian, K. and Zaidi S. H. *Malaysian Journal of Analytical Sciences.* **21**, 1134 – 1142 (2017)

[5] Dobrzanski, L. A. and Drygala, A. *Journal of Achievements in Materials and Manufacturing Engineering.* **31**, 77-82 (2008)

[6] Barugkin, C., Aleen, T., Chong, T. K., White, T. P., Weber, K. J. and Catchpole, K. R. *Optic Express.* **23**, A391-A400. (2017)

[7] Jia, G., Steglich, M., Sill, I. and Falk, F. *Solar Energy Materials & Solar Cells.* **96**, 226-230 (2012)

[8] Ximello, N., Dastgeheib-Shirazi, A., Scholz, S. and Hahn, G. 25^{th} EU PVSEC. 1761-1764 (2010).

[9] Ibrahim, M. A., Sinin, N. A. M., Azhari, A. W., Sepeai, S., Daud, M. N. M., Teridi, M. A. M., Ludin, N. A. and Sopian, K. *Computer Applications in Environmental Science and Renewable Energy.* 104-109. (2014)

[10] Nasir, N. S. M., Sinin, N. A. M., Sepeai, S., Leong, C. S., Sopian, K. and Zaidi, S. H. (2017). **1838**, 020005-1-020005-8.