SILICON SURFACE TEXTURING USING NH_4OH SOLUTION FOR SOLAR CELLS

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ABSTRACT

The efficiency of the solar cell increases with texturing of the silicon substrate with (100) crystallographic orientation. The texturing process consists in modify the substrate surface, making the more roughness. By this way, the surface absorption area of incident radiation is increased, which increases the efficient of solar cell. In this work, the silicon substrate texturing are carried out by an anisotropic wet etching, with an alkaline solution based on NH_4OH. With this solution, the <111> planes of silicon substrate with (100) crystallographic orientation are exposed and theses planes can form some pyramids on surface. Scanning Electron Microscopy analysis presents that these pyramids are observed all long on the surface, indicating that the wet etching was uniform on the substrate. Furthermore, the pyramid height values are between 3.5 and 7.2 µm, and the silicon etching wet rate was about 0.7 µm/minute. The reflectance measurements show that the surfaces with and without texturing present reflectance values of about 16% and 38%, respectively.

1. INTRODUCTION

The solar cell efficiency is hardly connected with device fabrication processes, such as texturing silicon surface, which increases the surface absorption area of incident radiation on the cell [1] and, consequently, reduces the substrate reflectance. Nowadays, solar cells based on silicon substrate are fabricated with texturing surfaces to increase the device efficiency. These surfaces are obtained by anisotropic wet etching in KOH and NaOH alkaline solutions [2]. The disadvantage of these solutions are K^+ and Na^+ ions from KOH and NaOH, which are mobile charges in Metal-Oxide-Silicon structures. Thus, these solutions are not compatible for CMOS technology, which is used for integration circuits and devices on silicon surface. As an advantage, using these alkaline solutions, the <111> planes of silicon substrate with (100) crystallographic orientation are exposed, resulting in groups of pyramid on silicon surface. The pyramids induce many reflections and scatterings of the incident radiation, which increase the light absorption on the surface. This effect is defined as light trapping [3].

In this work, NH_4OH as etching reagent has been used for silicon surface texturing process, because this solution can form pyramids on the surface, does not release alkaline products/reagents on the silicon surface and is fully compatible with the CMOS technology. Scanning Electron Microscopy analysis and reflectance measurements are carried out to verify the pyramid formation and light reflection/absorption on the silicon surfaces with and without texturing process, respectively. Furthermore, the surface roughness was measured by scan profiler after the texturing process, and, a micrometer was used to measure the thickness values of silicon substrates before and after the texturing process. Thus, with the process time and thickness values, the etching silicon rate for NH_4OH solution was obtained.

2. EXPERIMENTAL PROCEDURE

In this work, p-type Si (1 0 0) wafers with resistivity between 8 and 12 Ω.cm were used. The samples were cleaned by standard RCA method. After the cleaning process, the samples were immersed in a reactor with a solution based on NH_4OH to perform the silicon surface texturing during 30 minutes. The solution temperature was between 75 and 85 °C. These temperature values were measured by a thermometer. Four processes were carried out with different magnetic stirring speed. Figure 1 presents the schematic for texturing process. After the process, Scanning Electron Microscopy (SEM) analysis was used to verify the pyramid formation. Light reflection/absorption on the silicon surfaces with and without texturing process was measured by reflectance method with wave length between 300 and 800 nm.

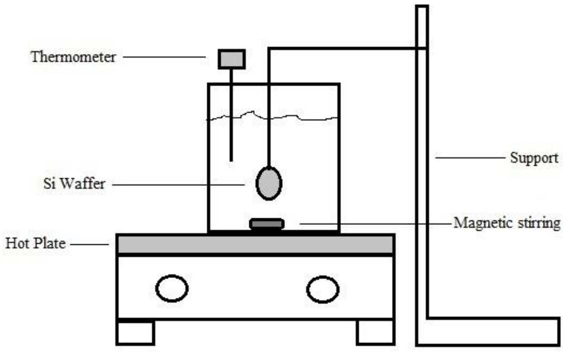

Figure 1- Schematic for texturing process

The thickness values of silicon substrates before and after the texturing process were measured using a micrometer. The etching silicon rate for NH_4OH solution was extracted by the ratio between the thickness values and the process time, which was fixed at 30 minutes. After the texturing process, the surface roughness was measured using a scan profiler.

3. RESULTS AND DISCUSSIONS

Four samples with different magnetic stirring velocities in NH_4OH solution were processed. Using a micrometer for the silicon substrate thickness measurements before and after the texturing processes, the etching rates were extracted and for four samples were about 0,7 µm per minute. Table 1 and Figure 2 present the mean roughness and standard deviation values of those four samples, after the texturing process in related to solution stirring velocity. The surface roughness values were measured using a scan profiler. It was observed that: sample mean roughness values are reduced when solution stirring velocity is increased, indicating that with higher solution stirring velocity, the etching reagent has higher mobility on surface, reducing the micro-masking effect and, consequently, the surface roughness. Furthermore, higher solution mobility on surface can lead to a pyramid uniform distribution on silicon surface. This is confirmed by SEM results in the Figures 3 (a) and (b), respectively, which present an overview and the pyramid details, such as pyramid height values, on silicon surface of sample 4. It was observed that: in (a), a pyramid uniform distribution on silicon surface occurs. In (b), the pyramid height values are between 3.5 and 7.2 µm.

Table 1- Surface roughness values

Sample	Solution stirring velocity	Roughness (nm)
Sample 1	↓ Velocity is increased	1004 ± 198
Sample 2		800 ±99
Sample 3		651 ±143
Sample 4		641 ±72

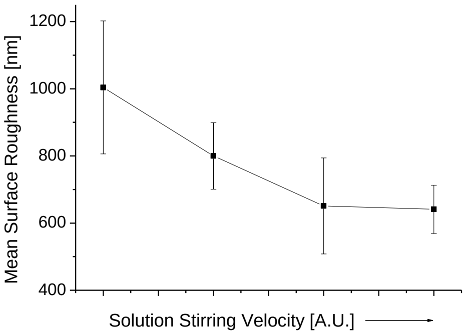

Figure 2 – Curves of the mean roughness values after the texturing process versus solution stirring velocity.

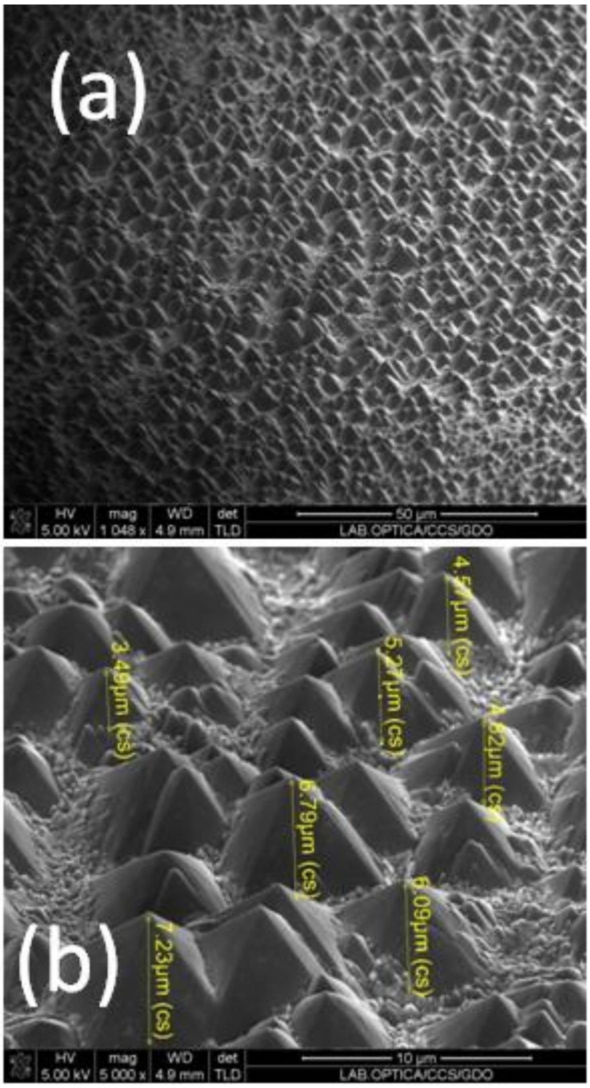

Figure 3 – SEM analysis presents the pyramid formation: In (a) and (b), respectively, an overview and the pyramid details, such as pyramid height values, on silicon surface of sample 4

Figure 4 presents light reflection on the silicon surfaces with and without (background) texturing process, which was measured by reflectance method with wavelength between 300 and 800 nm. Reference 5 presented that the photons solar intensity is maximum with wavelength nearby 600 nm and the solar cell efficiency was increased with a decrease on reflectance for this wavelength. So, in Figure 4, the reflectance values were extracted to wavelength at 600 nm. The reflectance of background sample was about 37.8%. Samples with texturing surface process exhibited reflectance between 14.7% and 18.1%. For the sample 4, which presented the best pyramid uniform distribution on silicon surface, the reflectance value was 15.7%. These reflectance values are very similar to obtained in the references 3 and 4, but the used texturing. Therefore, the silicon surface texturing process using NH_4OH solution presents a pyramid uniform distribution on silicon surface with reflectance of about 16%, which can increase the solar cell efficiency.

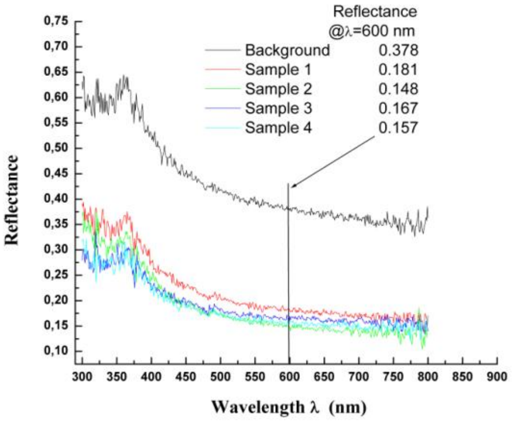

Figure 4 – Curve of light reflection on the silicon surfaces with and without (background) texturing process versus wavelength.

4.CONCLUSIONS

The preliminary results of texturing surface process using NH_4OH were presented in this work. This procedure is fully compatible with CMOS tecnology. This fact enables the integration and fabrication on the same layer solar cells and MOS devices.

The most important results are from SEM analysis and reflectance measurements that indicated that the silicon surface texturing process using NH_4OH solution presents a pyramid uniform distribution on silicon surface with reflectance of about 16%. Nevertheless, the efficiency of the solar cell can be increased by texturing surface process.

5.ACKNOWLEDGEMENTS

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