Texturing processes for reduction of front surface reflectivity in silicon solar cells

U. PTAK-MAŁYSIAK

Experimental Station of Solar Energy,
Mineral and Energy Economy Research Centre, Polish Academy of Sciences
ul. Krakowska 542, 43-340 Kozy/Bielsko-Biała, Poland

1. Introduction

In many cases the optical properties of materials with complex surface shapes are very important. For example, if at least one of the surfaces of the solar cell is textured then a trapping of light is observed due to the total internal reflection in semiconductor. Texturing solar cell surfaces to improve the cell performance has been attempted since 1960. First, in the textured cells the primary goal was to reduce the front surface reflectance by means of anti-reflection coating. Next, in the 1974 ÷ 1978, the texturing was used to produce double bounces on the front surface and to trap weakly-absorbable long-wavelength photons by means of total internal reflection. Recently, the texturing of the cell surface plays very important role in the process of solar cells manufacturing.

The texturing of silicon substrate with anisotropic etches leads to the surfaces covered by square-based pyramids which depend on the orientation of crystal axes. This yields to trapping the light and is widely used as a method of reflection control in silicon cells. The light trapping extends the length of optical path beyond the optical thickness of the device in case of weakly absorbable light. This influents on the current generation properties of the cell.

The improved texture etching using two kinds of texturing solutions is presented in this paper. The reflectivity of front surfaces are compared in two cases. In the first case the mirror-like surface using pre-etching has been obtained before general texturing, and in the second case only the usual cleaning process has been applied.

2. Experiment

The experiment was carried out on Czochralski silicon wafers with polished front surfaces. The texturization of silicon surface was done by means of aqueous sodium hydroxide (NaOH) with isopropyl alcohol (IPA) added as a complexing agent. The etching solution has been carefully stirred and then heated up to the temperature of 80°C.

In the first series of experiments the different times of etching were investigated. They were ranged from 50 to 90 minutes, with high concentration of NaOH (i.e. 10%) in the etching solution. In this case the large pyramids together with small ones on the top of side planes were observed, as it is shown on SEM photograph in Fig. 1.

In the second series of experiments the pre-etching with $HF:HNO_3:CH_3COOH$ solution (CP) was applied before texturing. Using this solution, the required etching time at the temperature of 80°C is relatively long (45 ÷ 50 min.) and some untextured areas between pyramids are left, even after the prolongated etching (see Fig. 2).

3. Results and conclusions

The total reflectivity of different samples was measured as the function of wavelength of the incident light. The measured values of the reflectivity of four samples etched in different solutions are given in Fig. 3. Curve *1* is represents reflection from monocrystalline surface after pre-texturization (5 min., CP solution) and 90 min. texturization in solution of NaOH and

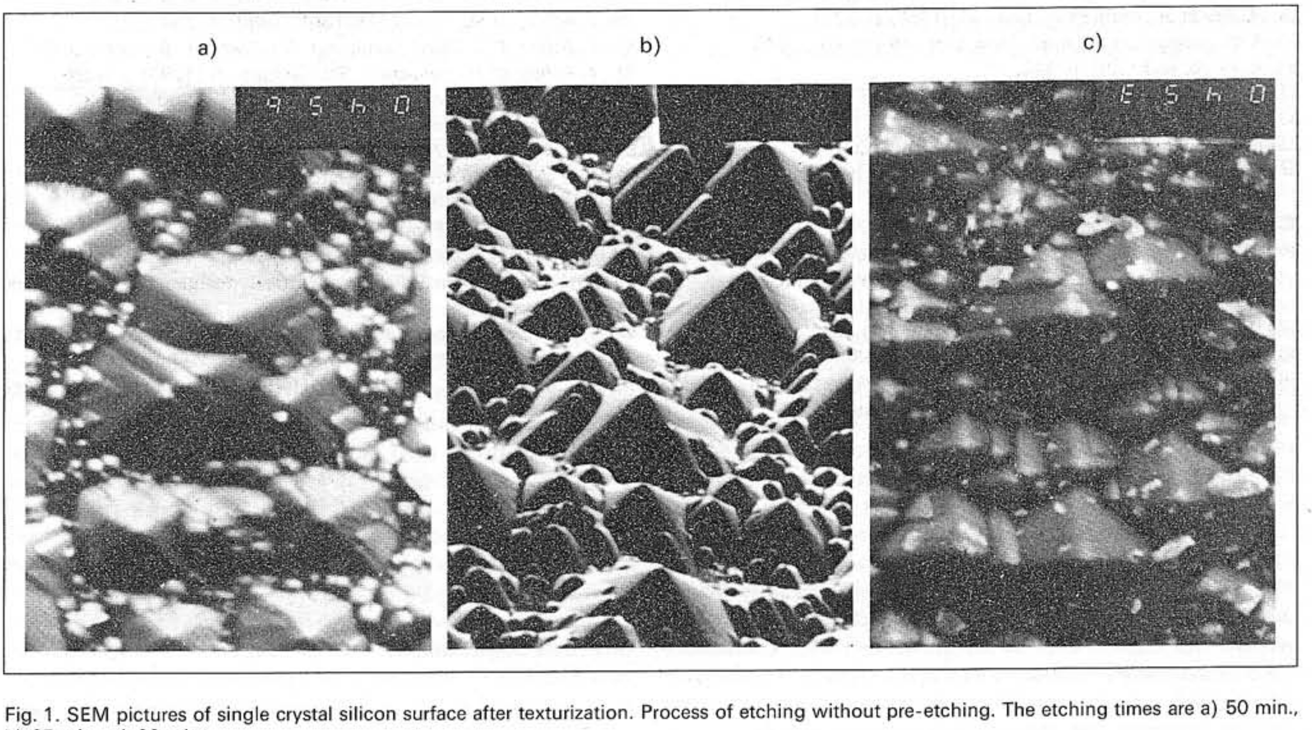

Fig. 1. SEM pictures of single crystal silicon surface after texturization. Process of etching without pre-etching. The etching times are a) 50 min., b) 65 min., c) 90 min.

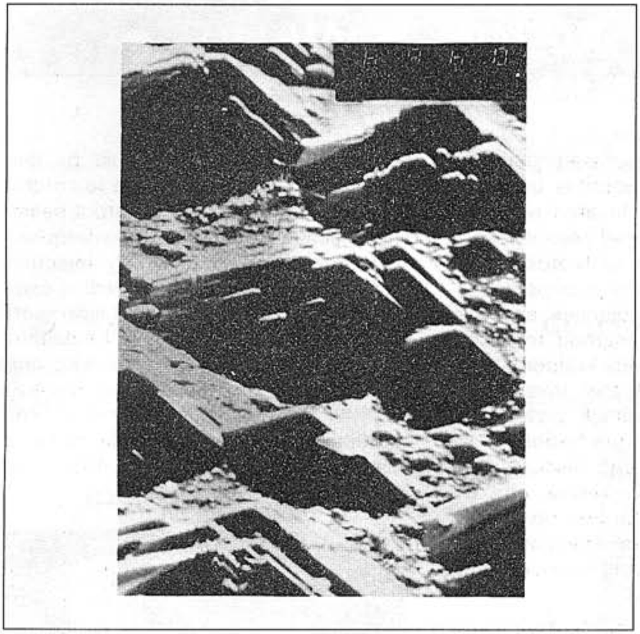

Fig. 2. SEM picture of single crystal silicon surface after two-steps texturization with pre-etching time of 5 min. and general etching time of 90 min.

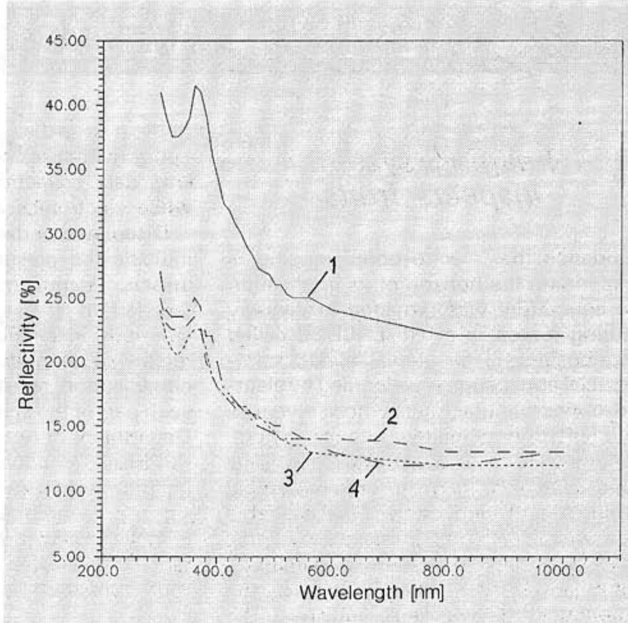

Fig. 3. Reflectivity of the front surface versus wavelength of incident light

IPA. Curves *2, 3* and *4* are the reflection in the case of texturization in NaOH and IPA without pre-etching, at 50, 65 and 90 minutes, respectively.

Considering the Fig. 3 we can note that the best results in reducing the light reflection are observed if no pre-etching has been applied. Moreover, the dependence of the reflectivity reduction on the etching time is straightforward.

The best obtained results are represented by the curve 1, which is slowly varied over a wide range of wavelengths. In average, the reflectivity value within the range of $500 \div 1050$ nm is below 15%. More complicated structure of the cell surface gives the light more chances to be trapped in the cell.

The proposed one-step texturing process provides superior reduction in the reflectivity of the front surface, comparing to the usually used two-steps techniques. Additionally, it has been demonstrated that the cost of solar cells production may be reduced due to the elimination of the first etching process.

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