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Texturisation Effect On Reflectivity

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Abstract

Renewable resources are clean or green energy sources that give much lower environmental impact than conventional energy sources. Renewable resources are attractive because they are replenished naturally – which means that they will never run out. Solar cells use the sun, a free and inexhaustible source of fuel, to produce emissionfree electricity. Photovoltaics are the foremost and most extensively studied among sustainable energy systems and among them silicon photovoltaics play a significant role in market share due to its ease of processing. Silicon solar cell researchers continuous approach has brought the silicon solar cell efficiency closer to the theoretical efficiency and continuously on-going refinement of the manufacturing process aims to improve the efficiency of the cell while bringing down the cost.

Texturisation of Silicon wafers is key process in solar cell manufacturing process as its instrumental in minimizing the reflectivity and hence increase the open circuit current. The studies were carried out on 156 x 156 mm mono-crystalline silicon (C-Si) wafers. The wafer reflectivity and texture uniformity were studied.

The most prevalent bulk material for solar cells is crystalline silicon (c-Si), also known as "solar grade silicon".Bulk silicon is separated into multiple categories according to crystallinity and crystal size in the resulting ingot, ribbon or wafer. These cells are entirely based around the concept of a p-n junction. Solar cells made of c-Si are made from wafers between 160 and 240 micrometers thick. Thickness of silicon wafers as per the current industry standard is 180±20 microns.

1. Introduction

Achieving higher efficiency in solar cells is the one of most important issues for the solar cells as power produced is in direct proportion to the area available for installation. Surface texturing of solar cells is used to reduce incident light reflection and, consequently, increase solar cell efficiency. Wet etching is commonly used to produce texturization on surface of solar cells. Due to the texturisation , pyramidal structure gets formed on the surface of silicon solar cells by alkaline solutions etching. This pyramidal surface shape occurs because alkaline solutions etch silicon along crystallographic orientations. The pryramidal structures can be seen with a Scanning Electron Microscope and the Pyramids dimensions can be measured and a direct relationship between the Pyramids dimension and the reflectivity can be established.

The reflectivity of a Silicon wafer after texturisation gets reduced and hence more Incident light can be absorbed and hence a higher short circuit current is obtained.

If the cells are binned only on the basis of power the mismatch possibility is high as same bin may contain cells with different current.

The conventional processes involved in manufacturing of Mono-crystalline solar cells (standard p-type process) are –

- Texturisation
- Diffusion
- Edge Isolation
- PSG Removal
- PECVD – ARC
- Metallization
- Testing

Texturisation:
To absorb maximum amount of sunlight, surface of sillicon wafer is made rough as flat surfaced wafer reflects one third of light falling on it. Texturisation is a chemical process which uses NaOH as etching agent in addition to a special additive for texturisation.

Diffusion:
It form a p-n junction using phosphorous as adopant.

Edge isolation:
It removes the n-type material from the edges of the cell & hence improves the Rshunt (Shunt Resistance) of the solar cell. It may be Laser based/ RF Plasma based.

PSG Removal:
It uses a HF chemical bath to remove the phosphosilicate glass layer formed on the Si wafer during the diffusion process.

ARC:
It further reduces the reflectivity of the Si wafer to upto 4% .It uses PECVD based deposition technique.

Metallization:
It uses screen printing for forming the front and the rear contact. Which uses the Al back metallization for forming BSF & Silver front paste for front grid.

Testing:
Testing is done under STC, and based on the outputs the cells can be sorted.

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Among this, surface texturization, a first step in the process, plays an important role because it etches the wafers while also removing some portion of the surface impurities.Improved light harvesting is strongly correlated to both short circuit current (Isc) and open circuit voltage (Voc) and thus impacts the cell efficiency.

2. BACKGROUND

Here we are going to discuss the texturisation process for mono-crystalline Silicon wafer solar grade. Boron doped mono-crystalline silicon wafers (p-type) of thickness 180 ± 20 microns with bulk resistivity of 0.5-3 ohm-cm and bulkcarrier life time in the range of 10 microns (for ingot) were used for fabricating silicon solar cells. The wafers were subjected for saw damage removal (SDR) and alkali texturization processes by using the required composition of Sodium hydroxide (NaOH) and special additive with deionized water.
Saw Damage Removal (SDE) and texturization is important because it removes surface damages and unevenness of the silicon wafer. Saw Damage Etching (SDE) is carried out to reduce the surface roughness of the wafer.

The texturisation process reduces the reflection from 35% to less than 12%, which is the largest drop in reflectance in the entire process flow and hence it is critical to the solar cell efficiency. Mono-crystalline silicon wafers undergo Alkali texturization which is an anisotropic texturization process using NaOH. The rate of texturization depends on the number of bonds and the strength of the bonds holding the surface silicon atoms.

Thus the different orientations <100>, <110> and <111> have different etch rate and for <100> it is highest.The chain of reactions goes as follows:

Fig 1

3. EXPERIMENTS

For our experiment Boron doped mono-crystalline silicon wafers (156x156 mm) (p-type) of thickness 180 ± 20 microns with bulk resistivity of 0.5-3 ohm-cm and bulkcarrier life time in the range of 10 microns (for ingot) are used. The orientation of wafers is <100>.The Alkali based texturisation process used for mono crystalline Silicon wafer is carried out.
The texturisation bath is prepared using Sodium Hydroxide (NaOH), DM Water and special additive in defined ratio.The texturisation /Etching pyramids formed on the surface of silicon wafers gets affected by the time and the temperature at which the process is carried out.
Here in our experiment we will vary the texturisation time while all other variables are kept constant. Different texturisation time leads to difference in dimension of pyramids formed.
For three different times the texturisation process is carried out and the pyramids dimensions & corresponding reflectivity are recorded.
The pyramids dimensions are measured using the Scanning Electron Microscope of Zeiss Make and the corresponding reflectivity is measured using the reflectivity meter (with integrating sphere) of Perkin Elmer make. Reflectance studies on texturized Si were carried out in a wavelength range from 400- 1100 nm
The results are obtained and recorded for three different timings of texturisation process.

4. RESULTS

Surface morphology & reflectance of textured samples are shown in figure. The sample 2 shows the least reflectivity.

S.No	Sample	Texturisation Time (min)
1	Sample 1	10
2	Sample 2	15
3	Sample 3	20

The sample 1 has the pyramid height of 4 microns but the surface uniformity is not found as a result of which reflectivity found to be 13%.

The sample 2 has the pyramid height of 5.7 microns and the reflectivity found to be 11%.

The sample 3 has the pyramid height of 3 microns and the reflectivity is deteriorated.

Morphology for the sample 2 is shown in fig 2 and fig 3.

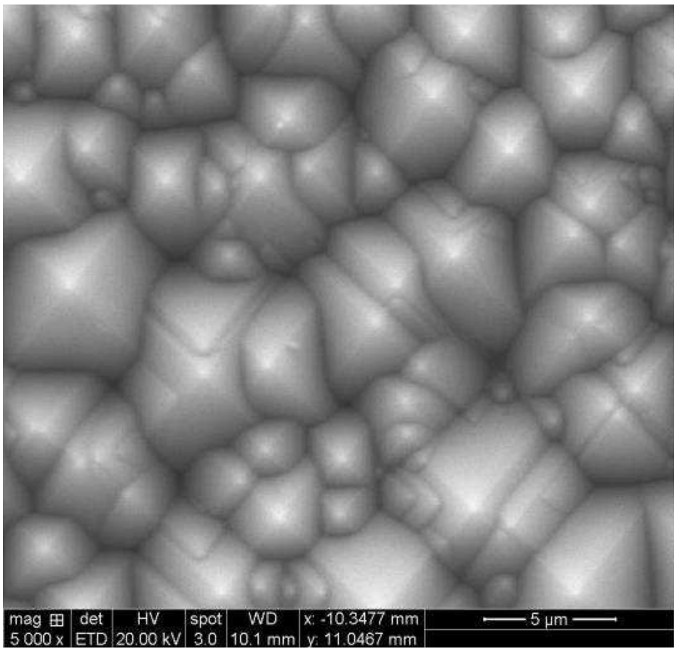

Fig 2 shows the height of pyramid

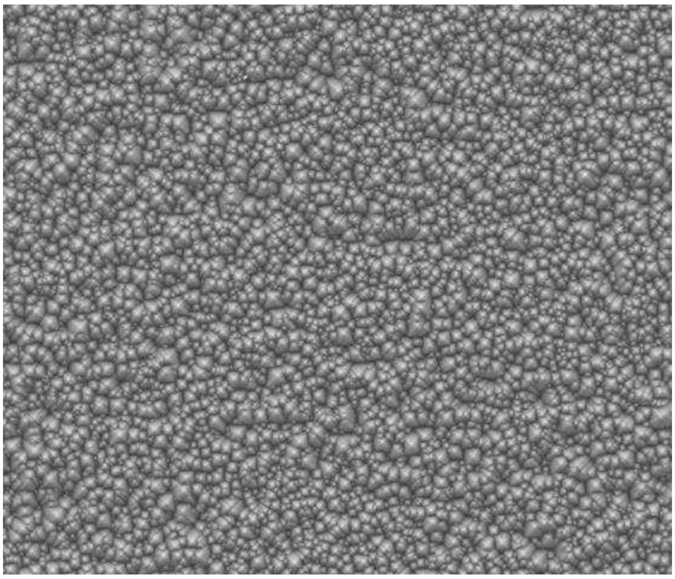

Fig 3. Shows uniformity over the surface, using SIMS

3 Results Discussion

For the sample 1 the texture time was 10 minutes and it could be inferred that the samples were not textured properly and it can be seen from the reflectivity measurements also. The sample 2 was textured for 15 minutes and it can be said that it was optimized times as can be seen through the results. The sample 3 was textured for 20 minutes but as seen through the results the pyramids got damage due to over texturisation and the reflectivity is more than 15%.

The texture process was optimized to get a uniform texture and reflectance and morphology studies were carried out. Also further three surface texturization shapes can be simulated with various angles of incident light. This methodology can easily determine the absorptance differences of various surface texturizations and suggest better texturization shapes. To consider the effect of incident angle, a range of high efficiency exists due to the increasing probability of second reflection. Furthermore, the azimuth angle of incident light also affects the efficiency of solar cells.

4. Conclusions

Reduction of optical losses in both mono and multicrystalline silicon solar cells by surface texturing is one of the important issues of modern silicon photovoltaics. Texturing of the front surface of silicon solar cells has been modeled and analyzed with reference to the reduction in reflection co-efficient and increase in optical trapping. Significant enhancement in open circuit voltage and short circuit current has been achieved through such texturing of the front surface of mono-silicon solar cells.

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