Renewable Energy Research Center

Broad band light trapping in Si (thickness <100 µm) by making nanoholes on micro pyramids

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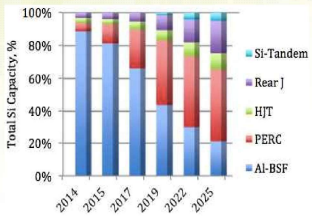
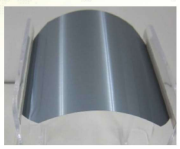
Research Objectives

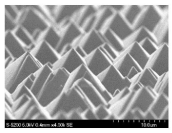
Si solar cells market share upto 90%



Ref.: Martin Green, Renew. Economy

Developing technology for Si (<100 µm) PERC and IBC solar cells





Purpose

1. To reduce the production cost
2. To enhance the efficiency (by controlling optical and electrical losses)

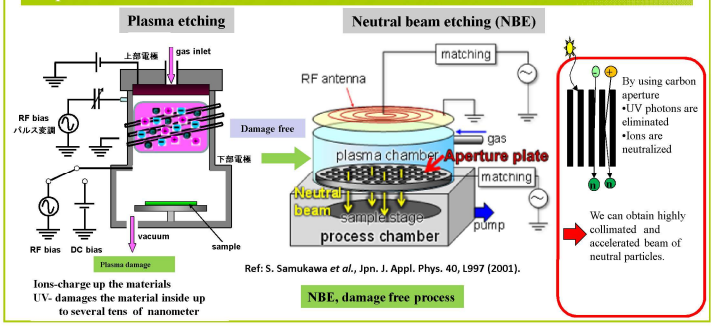
We control optical loss by light trapping in industrial scale

Surface texturing
Wet etching

Reflectance minimum – 9%

Needs to reduce surface reflections below 3%

Experimental Details



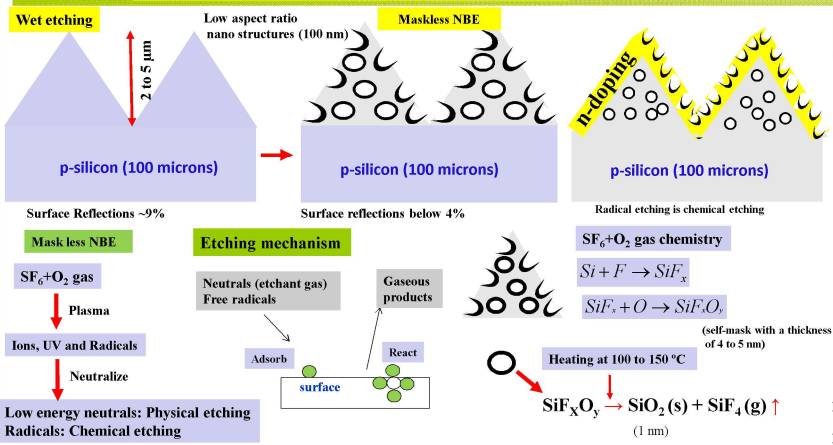
Ref: S. Samukawa *et al.*, Jpn. J. Appl. Phys. 40, L997 (2001).

Ions-charge up the materials
UV- damages the material inside up to several tens of nanometer

NBE, damage free process

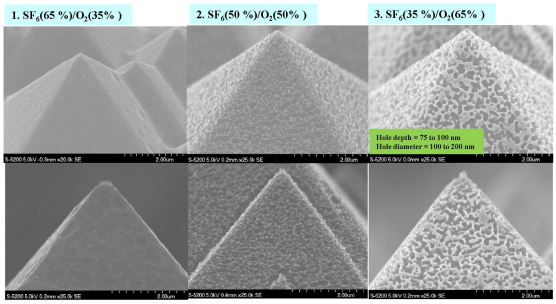
Results

Maskless neutral beam etching (NBE) to make nanoholes



Etch recipe: ICP=1000 watts, Stage temperature = 20°C, Vpp=50 volts, Etch time = 4 min

Vpp=50 volts means neutral particles have very low energy which will participate in making nanoholes.

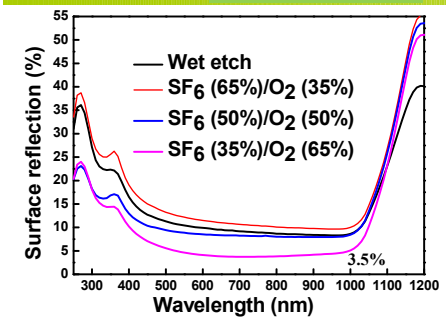


- Optimized NBE recipe (SF_6 (35%)/O_2 (65%) and bias (Vpp=50 V)) to generate low aspect ratio nano structures (with hole depth = 75 to 100 nm and hole diameter = 100 to 200 nm) on micro pyramids.
- Surface reflections are decreased to below 4% in broad wavelength range.

Self passivation layer, the interface defect density between Si and SiO_2 is very small

Discussion

Reflection Spectrum



H. Sekhar et.al, "Nano holes on micro pyramids; broadband optical light trapping in thin wafer based Si (< 100 µm) solar cells" Proc. 16th Int. Conf. Nanotechnology, 415-418, (2016)

NBE texturing of honeycomb pattern for broadband optical light trapping

Si etching chemistry

Si wafer thickness = 180 micron

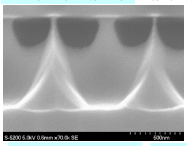
Chlorine (Cl_2) - Less radicals
-Physical etching
-Anisotropic etching

Florine (F) - Large number of radicals
- Physical and chemical etching
- Isotropic etching

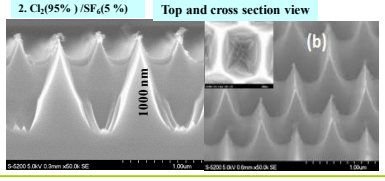
$Si(s) + 4Cl(g) \rightarrow SiCl_4(g)$
$Si(s) + 4F(g) \rightarrow SiF_4(g)$

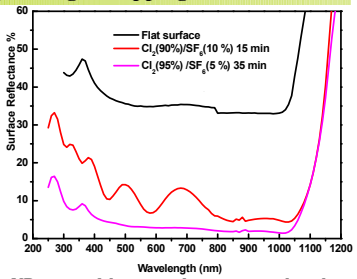
ICP Power= 2000 Watts, Vpp= 500 Volts

1. Cl_2(90%) /SF_6(10 %) Etch time= 15 minutes



2. Cl_2(95%) /SF_6(5 %) Top and cross section view





NB textured honeycomb structures show broad band optical light trapping with low surface reflections (5% to 1%) in the wavelength from 400 to 1040 nm.

Summary

- Introducing new innovative damage free (NBE) technology to trap the light in thin wafer based Si (<100 µm) solar cells.
- Nano holes with optimum etch depths (100 nm) on micro pyramids decrease surface reflections below 4% in broad wavelength range compare to their micro pyramids (9%).
- NBE applied to texture honeycomb pattern.
- Using NBE, we achieve very low surface reflections, 5% to 1% in the spectral range from 400 nm to 1040 nm.

Reference

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