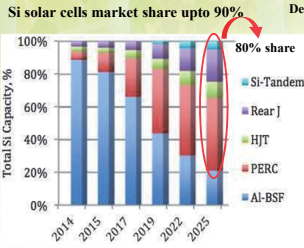


Advanced damage free neutral beam etching technology for the application of broad band optical light trapping in thin Si (<100 μm) wafer based Solar cells

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研究の目的

Si solar cells market share upto 90%

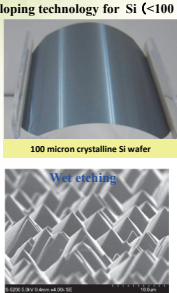


80% share

- Si-Tandem
- Rear J
- HJT
- PERC
- Al-BSF

Ref: Martin Green, Renew Economy

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



100 micron crystalline Si wafer

Wet etching

Purpose

- To reduce the production cost
- To enhance the efficiency (by controlling optical and electrical losses)

We control optical loss by light trapping in industrial scale

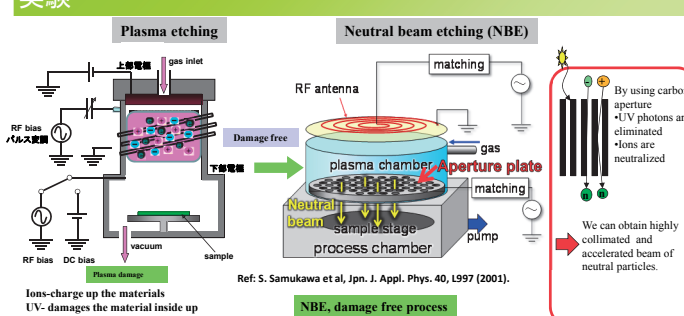
Surface texturing

Wet etching

Reflectance minimum ~ 9%

Needs to reduce surface reflections below 3%

実験



By using carbon aperture

- UV photons are eliminated
- Ions are neutralized

We can obtain highly collimated and accelerated beam of neutral particles.

結果

Our proposal

Wet etching

Mask less NBE

Low aspect ratio nano structures

(p-silicon (100 microns))

2 to 5 μm

Reflectance ~9%

Reflectance below 4%

Etching mechanism

SF₆+O₂ gas

Plasma

Ions, UV and Radicals

Neutralization

Low energy neutral: Physical etching

Radicals: Chemical etching

Neutrals (etchant gas) Free radicals

adsorb

react

gaseous products

surface

Si + F → SiF_x

SiF_x + O → SiF_xO

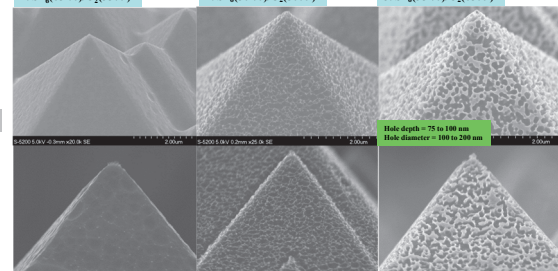
Self mask

Passivating layer

NBE with different gas composition

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

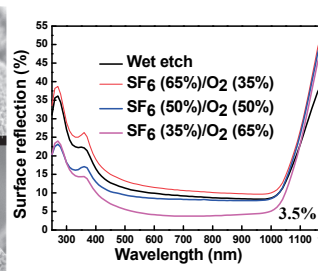
- SF₆(65 %)/O₂(35%)
- SF₆(50 %)/O₂(50%)
- SF₆(35 %)/O₂(65%)



Hole depth = 75 to 100 nm

Hole diameter = 100 to 200 nm

Reflection Spectrum



Surface reflection (%)

Wavelength (nm)

3.5%

Optimized NBE recipe (SF₆ (35%), O₂ (65%) and bias (Vpp=50V)) 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 decreases to below 4% in broad wavelength range broad wavelength

考察

Bias dependent etching

ICP=1000 watts, SF₆(35%)/O₂(65%)

Vpp=50 volts

Etch time = 4 min

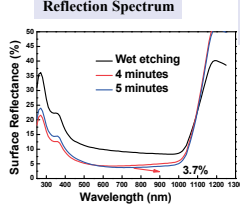
Etch time = 5 min

Vpp=100 volts

Etch time = 4 min

Etch time = 5 min

Reflection Spectrum



Surface Reflectance (%)

Wavelength (nm)

3.7%

3.5%

5%

Honey comb pattern with a period of 1 μm with a hole opening of 500nm was generated on the front surface of Si substrate using photolithography.

Si Etching chemistry

Chlorine (Cl₂) - Less radicals

- Physical etching
- Anisotropic etching

Fluorine (F₂) - Large number of radicals

- Physical and chemical etching
- Isotropic etching

Si(s) + 4Cl(g) → SiCl₄(g)

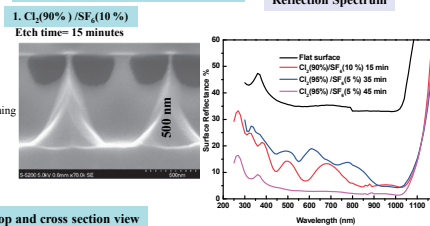
Si(s) + 4F(g) → SiF₄(g)

ICP Power= 2000 Watts, Vpp= 500 Volts

1. Cl₂(90%)/SF₆(10%)

Etch time= 15 minutes

Reflection Spectrum

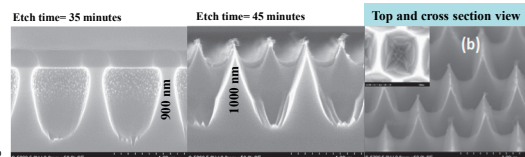


Surface Reflection (%)

Wavelength (nm)

500 nm

Top and cross section view



Etch time= 35 minutes

Etch time= 45 minutes

900 nm

1000 nm

(b)

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

結論

- 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 decreases surface reflections below 4% in broad wavelength range compare to their micro pyramids (9%).
- NBE applied to texture honey comb pattern.
- Using NBE, we achieve very low reflectance, 5% to 1% in the spectral range from 400nm to 1040 nm.

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Thank you very much for kind attention