An original one-step solution method to fabricate silicon nanopyramid texture and its application to crystalline silicon heterojunction solar cells

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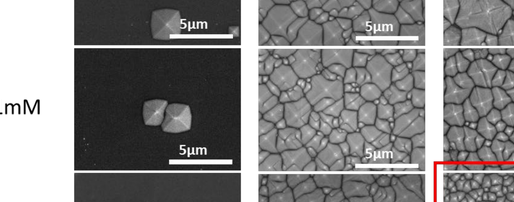
Purpose

The needs to reduce texture size



Si nano-pyramids

➢Si pyramid < 1μm
✓Small texture size and low etching margin
✓Suitable for developed c-Si PV devices.

- Thinner Si solar cells.
- Finer screen printing.[1]
- Perovskite/silicon tandem solar cell.

DEMERITS[2-5]

- Uncontrollable masking effect.
- Complicated process
- High cost

One step wet etching pross to fabricate Si nanopyramids

Purpose Small texture size + low fabrication cost

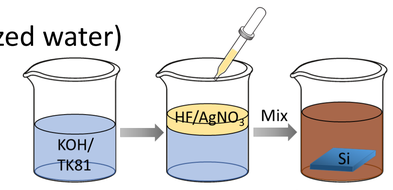
Experimental

$AgNO_3$-assisted alkaline etching

1. Substrates preparation
   n-type c-Si <100> 5cm x 5cm
   Acetone by supersonic cleaning
2. Alkaline etching (condition A,B,C)
   - **KOH solution(48%)**
   - **Surfactant**
     (Pure EtchTK81 Hayashi Pure Chemicals Ltd.)
   - **$AgNO_3$ solution**
     ($AgNO_3$: HF: deionized water)
3. Ag removal
   - **HNO_3 solution**

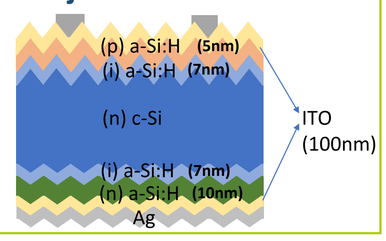
   Etching time: 15min
   Temperature: 70°C

	A	B	C
	KOH only	Reference (conventional micro-TEX [8])	$AgNO_3$-assisted etching
Etchant	KOH	KOH	KOH
Surfactant	×	TK81	TK81
Masking	×	TT72	$AgNO_3$ solution



Alkaline etching (C)

c-Si heterojunction solar cell[6,7]

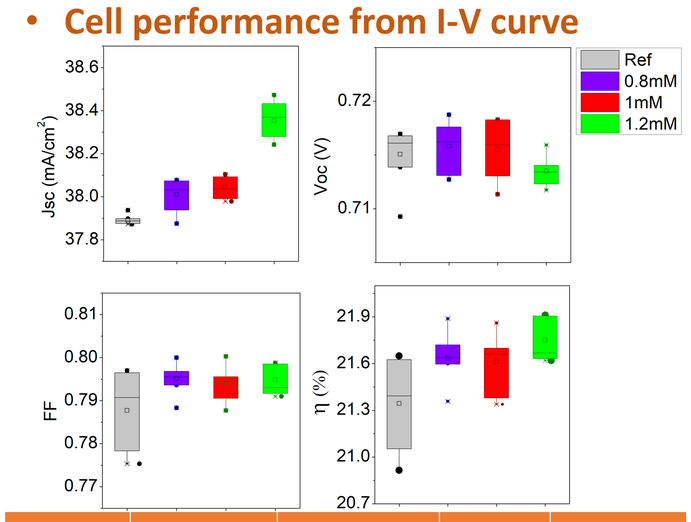


Results

• Si nanopyramids

A: Few pyramids.
➢etching masks are removed quickly due to high etching speed.
B: Uniform pyramids with almost unchanged size.
➢The masking effect is not enough for nanopyramid formation.
C: Si nano-pyramid formation.
➢Controllable size by the amount of $AgNO_3$ additive.

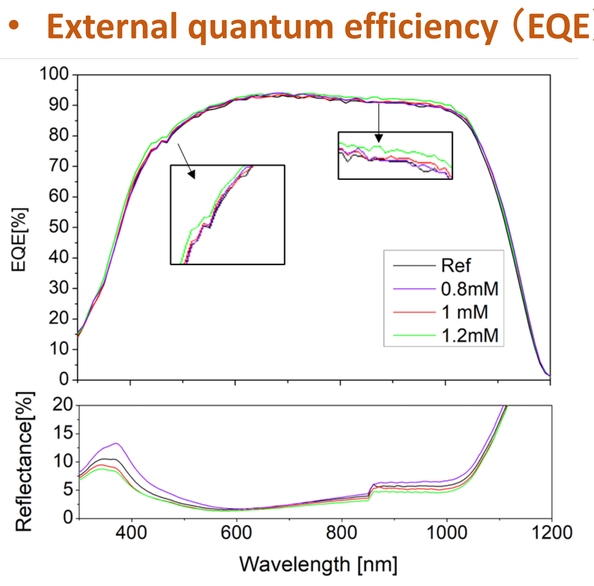
• Cell performance from I-V curve



	Jsc (mA/cm²)	Voc(V)	FF	η(%)
Ref	37.89	0.715	0.788	21.34
Nano Pyramid	38.35	0.714	0.795	21.75

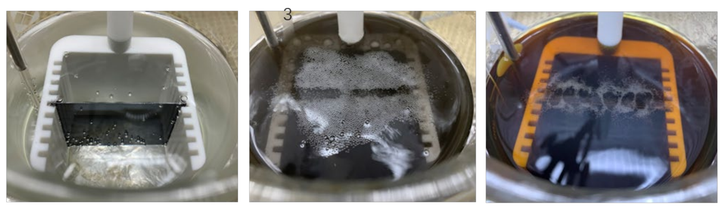
☐Advantage in J_{sc} .
✓Improved light absorption.
☐Acceptable change in V_{OC} and FF.
☐**Improved conversion efficiency** than reference.

• External quantum efficiency（EQE）



➢Si nanopyramids fabricated by $AgNO_3$-assisted alkaline etching method exceeding the EQE of that of industry-standard Si solar cells.
➢Great potential for the application in thin Si solar devices.

Discussion



- Medium etching rate, large bubbles
- High etching rate, small bubbles
- Medium etching rate, tiny bubbles

Step 1- Ag plating

Oxidability: $Ag^+ > H^+$

$Si + 6F^- \rightarrow SiF_6^{2-} + 4e^-$

$Ag^+ + e^- \rightarrow Ag$

$Si + 6F^- + 4Ag^+ \rightarrow SiF_6^{2-} + 4Ag$

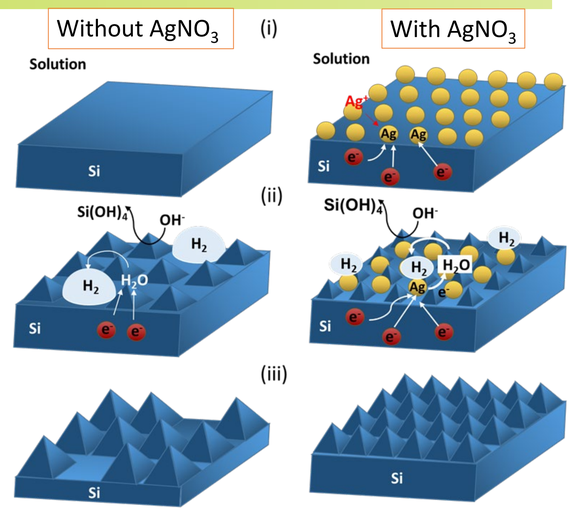
Step 2-Alkaline etching

$Si + 4H_20 \rightarrow Si(OH)_4 + H_2\uparrow$

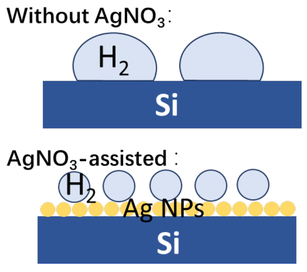
$Si(OH)_4 \rightarrow H_2SiO_3 + H_2O$

$H_2SiO_3 + 2KOH \rightarrow K_2SiO_3 + 2H_2O$

$Si + KOH + H_2O \rightarrow K_2SiO_3 + 2H_2\uparrow$



Without $AgNO_3$:



$AgNO_3$-assisted :

☐**Etchant:** Anisotropic etching with H_2 bubbles generation, resulting in pyramidal textures.
☐**Surfactant:** Removing H_2 bubbles, slowing down the etching reaction.
☐**Ag nanoparticles:** Etching mask, removing H_2 bubbles, accelerating etching reaction.

- Effective masking effect and low etching rate is the key to obtain uniformly distributed and better texture control.
- The equilibrium between $AgNO_3$ and TK81 was achieved at the appropriate ratio, resulting in dense nanoscale pyramid textures.

Conclusion

I. **A simple one-step method** to fabricated Si nanopyramid is developed.
II. Uniform pyramid texture with an average size of **300-500 nm** are formed, with **low reflectance** and **low etching margin**.
III. J_{SC} of c-Si heterojunction solar cells is increased even with submicron textures **without loss of V_{OC} or FF.**[9]

Texture size can be further controlled by adjusting the concentration of $AgNO_3$ and surfactant.

The small etching margin and unique optical performance of textures makes it promising to be applied to **thin Si devices,** and show interesting prospect to be applied as the bottom cell in **perovskite/Si tandem solar cells**.[10]

References

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