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The Effect of Alcohols on the Anisotropic Etching of Silicon

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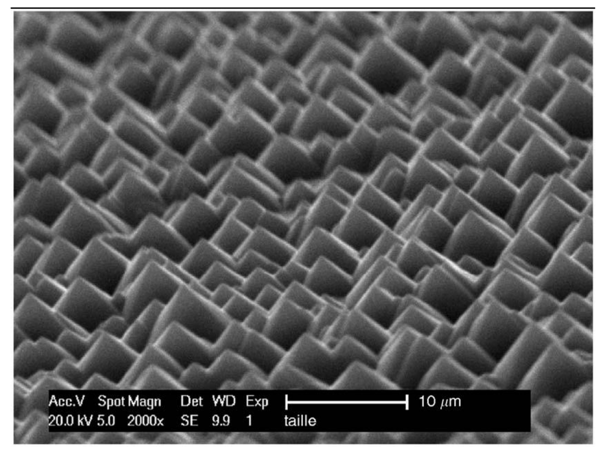
Introduction

How can solar cells be more efficient?

If the surface of the solar cell is textured, light reflected from one part of the surface may be absorbed at another.



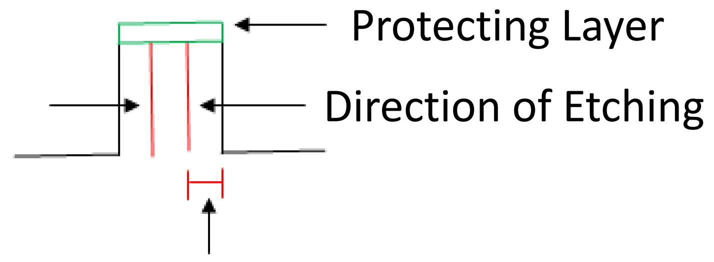
To the left is an SEM image of a solar cell surface covered with small pyramids. (Papet 2006)

Can a textured surface be created using chemical reactions?

Anisotropic etching causes small pyramids to form during etching.

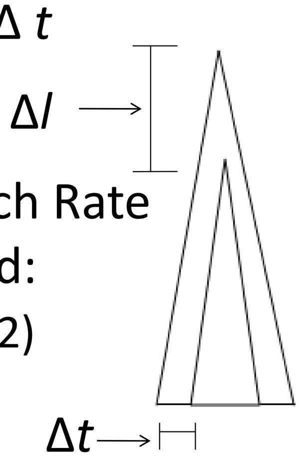
Methods

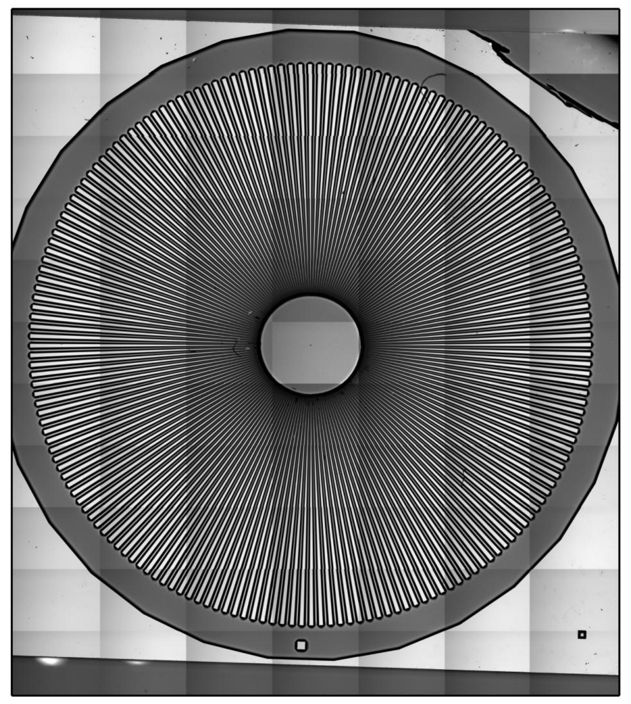
Back View of Silicon Wedge



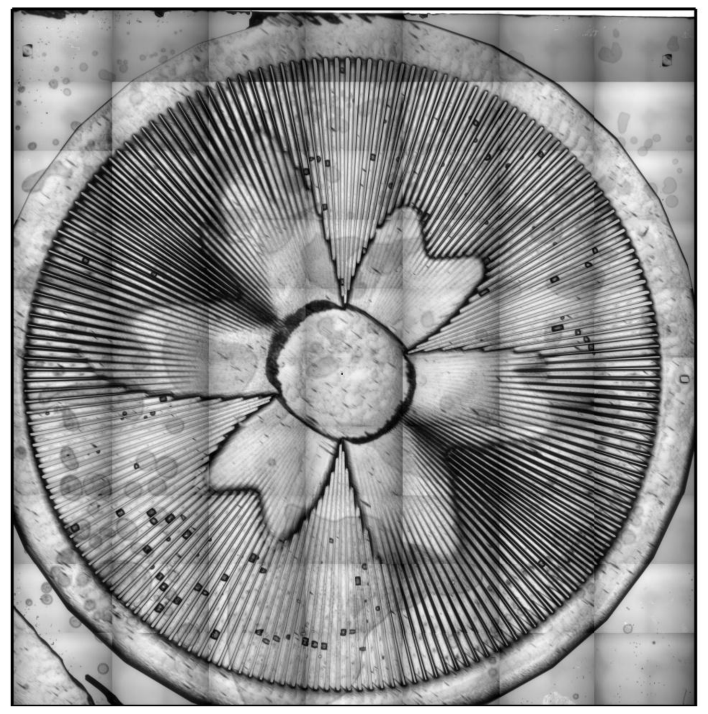
How the Etch Rate is Calculated:

$l = t*\cos(\theta/2)$

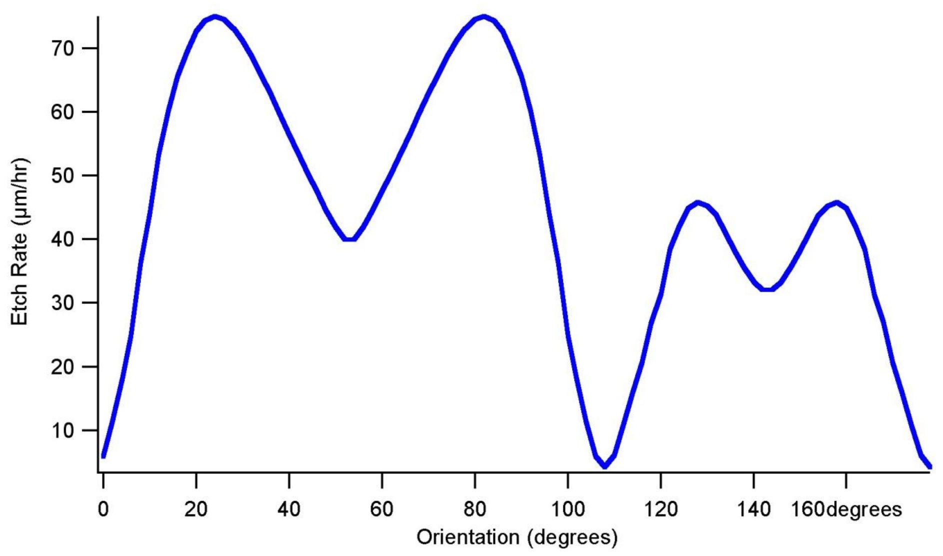




Before etching, the pattern consists of a circular array of 180 silicon wedges.



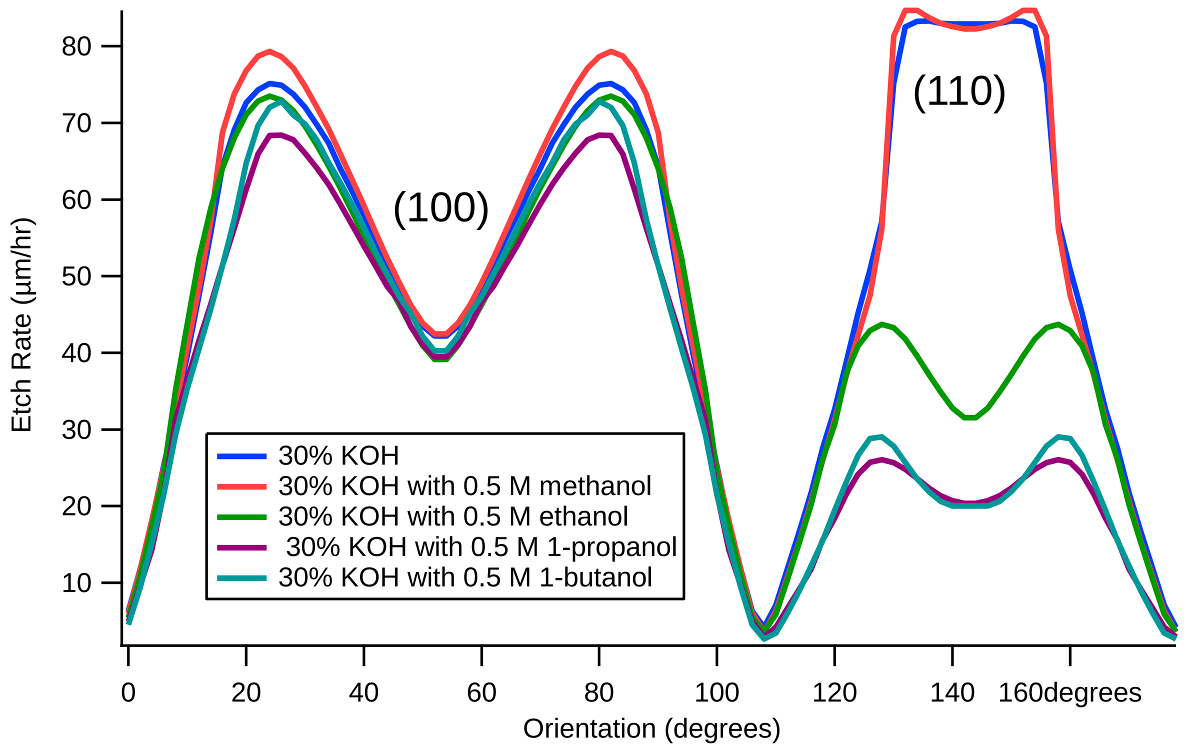
Etching for 30 minutes causes the wedges to retract, giving rise to a "flower pattern."



The pattern is unwrapped to reveal a plot of etch rate vs. orientation.

Results

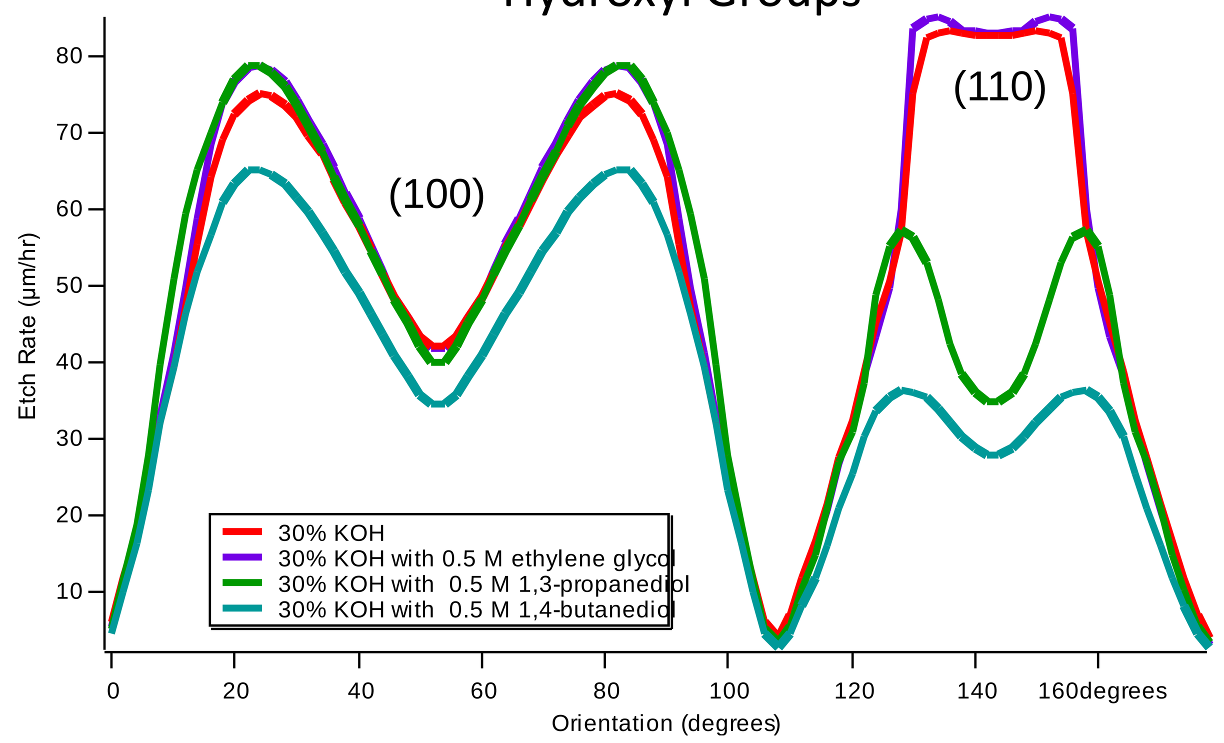
Monofunctional Ligands: Increasing the Length of the Carbon Chain



Alcohol	Structure	(110) Etch Rate	pKa
Methanol		82.3	15.5
Ethanol		31.6	15.9
1-propanol		20.4	16.1
1-butanol		20.0	16.1

- Longer carbon chains decrease (110) etch rate
- Methanol and ethanol have similar pKas but ethanol changes the (110) etch rate and methanol does not.
- A 3-carbon chain decreases the (110) etch rate the most.

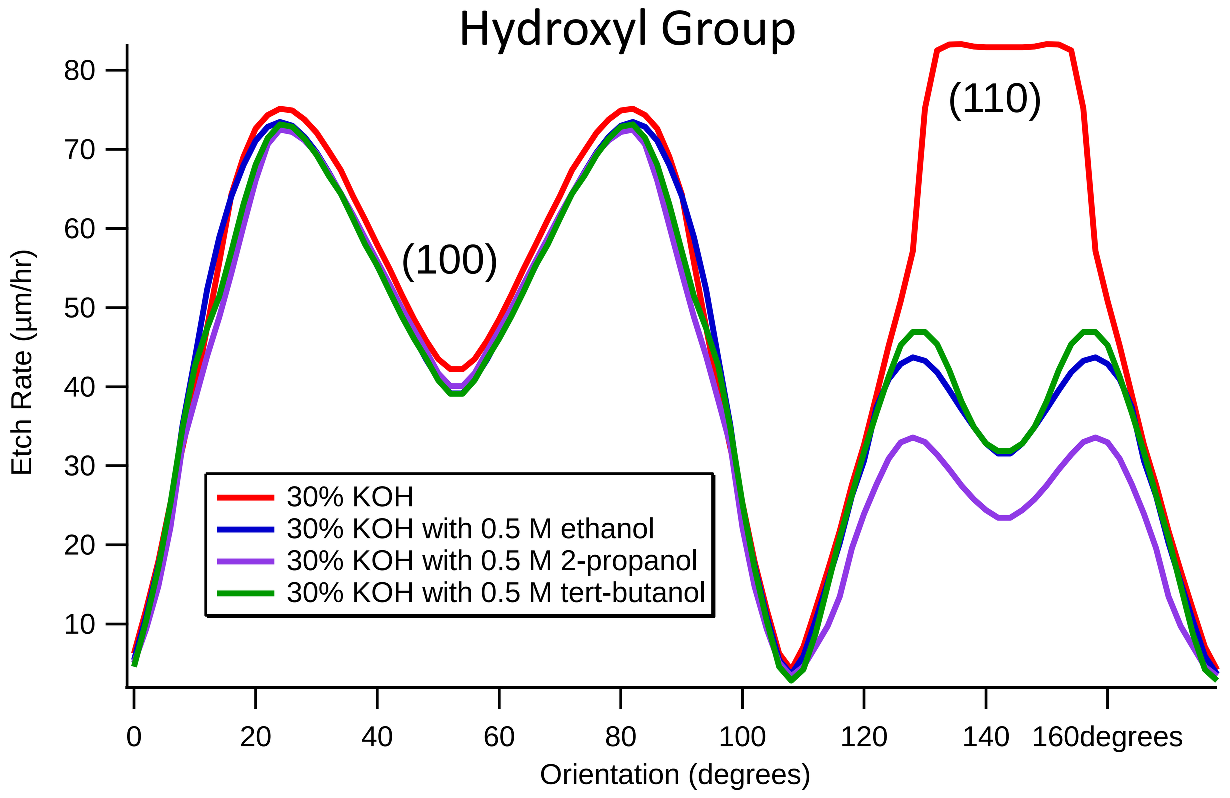
Bifunctional Ligands: Increasing the Number of Carbons Between Hydroxyl Groups

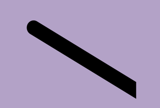


Alcohol	Structure	(110) Etch Rate	pKa
1,2-ethanediol		83.1	14.77
1,3-propanediol		35.0	15.1
1,4-butanediol		28.0	15.1

- Bifunctional ligands follow the same pattern as monofunctional ligands.
- However, the etch rate does not decrease as much as with monofunctional ligands.

Steric Hindrance: Increasing the Number of Carbons at the Hydroxyl Group



Alcohol	Structure	(110) Etch Rate	pKa
ethanol		31.6	15.9
2-propanol		23.5	17.1
tert-butanol		31.9	18

- 2-propanol has a larger pKa, but decreases the (110) etch rate more than ethanol.
- The(110) etch rate does not follow a clear trend when steric hindrance is increased.

Why should pKa Matter?

- Alkoxide is thought to be the reactive species of the ligand.
- Lower pKa = Higher concentration of alkoxide
- Higher concentration of alkoxide = Slower removal of silicon
- pKa of a typical alcohol is between 14-18
- pH of etchant solution is 14.83

Summary

Changing the ligand has little effect on the (100) surface. Several ligands decreased the (110) surface etch rate. These ligands slow down the removal of atoms from the (110) surface. Ligands with a larger number of carbon atoms tend to have a larger effect. Monofunctional alcohols are more effective than bifunctional alcohols with the same number of carbon atoms. pKa does not effect the (110) etch rate decrease.

Further questions

- What effect does changing the concentration of the ligand have on the (110) surface etch rate?
- What ligands change the (100) etch rate?

Acknowledgements

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