Macroporous Silicon as an IR Filter

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June 13, 2016
Pore Formation

- Pores formed by electrochemical etching
- Uses anodization cell made up of electrodes and an electrolyte
- Electrolytes are made up of HF and a solvent
- Wafer is immersed in electrolyte, then current is run across it

Electrochemical Reaction: \( Si + 6HF \rightarrow H_2SiF_6 + H_2 + 2H^+ + 2e^- \)

Image adopted from [4].
Electrochemical Cell
Pore Formation Trends

- It has been observed that when the etching conditions are changed, there are certain trends that occur in the formation of pores.

<table>
<thead>
<tr>
<th>Parameter Increased</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF Concentration</td>
<td>Decreases</td>
</tr>
<tr>
<td>Current Density</td>
<td>Increases</td>
</tr>
<tr>
<td>Etching Time</td>
<td>Increases</td>
</tr>
<tr>
<td>p-type Doping</td>
<td>Decreases</td>
</tr>
<tr>
<td>n-type Doping</td>
<td>Increases</td>
</tr>
</tbody>
</table>

Chart adopted from [4]
Advantages of Porous Silicon Filters

- Macroporous silicon acts as a long-wave pass filter in the IR.
- Current filters for such a range are multilayer filters or scattering-type filters.
- Multilayer filters do not stand up well to low temperatures.
- Scattering-type filters are very fragile; the scattering layer can be easily blown off or washed away from the filter.
- Macroporous silicon filters are not nearly as fragile and as such are an improvement over current filters.
Macroporous Filters

- Macroporous silicon filters seem to operate very similarly to scattering filters; longer wavelengths are passed through the sample while shorter wavelengths are scattered away.

Image adopted from [3].
Method

• Electrochemical etching performed systematically under different etching conditions
• Room temperature optical measurements performed using Bomem MB102 and Bruker IFS 66v/S
• Scanning Electron Microscopy performed using Amray Model 1600 SEM to determine geometric properties
• Pore density determined using ImageJ software
• Ideally will be able to determine a trend between geometric properties/etching conditions and cutoff wavelength
Sample Imaging

SEM Image – $\rho = 10 \ \Omega \cdot \text{cm}$ ,
$<1 \ 0 \ 0>$ Orientation

SEM Image – $\rho = 10 \ \Omega \cdot \text{cm}$ ,
$<1 \ 1 \ 1>$ Orientation

Pore Density = 0.098 pores/$\mu$m$^2$

Pore Density = 0.13 pores/$\mu$m$^2$
Sample Imaging

SEM Image – High Resistivity, <1 0 0> Orientation

SEM Image – ρ > 200 Ω·cm, <1 1 1> Orientation

Pore Density = 0.0017 pores/μm²

Pore Density = 0.021 pores/μm²
Transmission as a Function of Pore Density

[Graph showing transmission as a function of wavelength for different pore densities and orientations.]
As current is increased, the cutoff wavelength decreases.

Transmission Plot for Porous Si Samples - 3 hours, 10% HF
As etching time is increased, the cutoff wavelength decreases.

Transmission Plot for Porous Si Samples - 25 mA, 10% HF
As HF concentration is increased, the cutoff wavelength seems to experience no change.

Transmission Plot for Porous Si Samples - 25 mA, 3 hours

- unetched
- 15%
- 10%
## Summary Table

<table>
<thead>
<tr>
<th>Parameter Increased</th>
<th>Cutoff Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etching Current</td>
<td>Decreases</td>
</tr>
<tr>
<td>Etching Time</td>
<td>Decreases</td>
</tr>
<tr>
<td>Etching HF Concentration*</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Pore Density</td>
<td>Decreases</td>
</tr>
</tbody>
</table>

*More measurements need to be performed to determine whether the [HF] actually has no effect on cutoff wavelength.*
References


Acknowledgements

- Dr. Maureen Reedyk
- Colin Vendromin
- Nichole Dwyer
- Nick Majtenyi