Macroporous Silicon as an IR Filter

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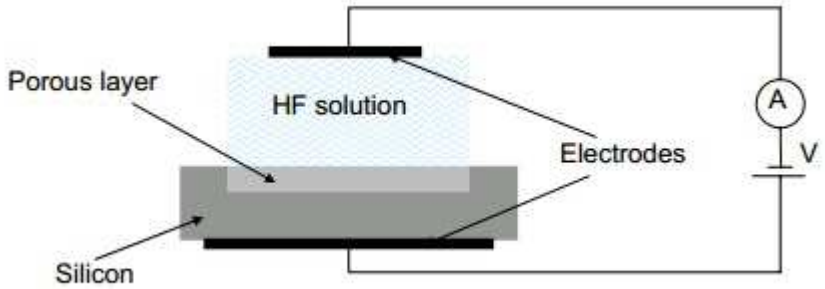
Pore Formation

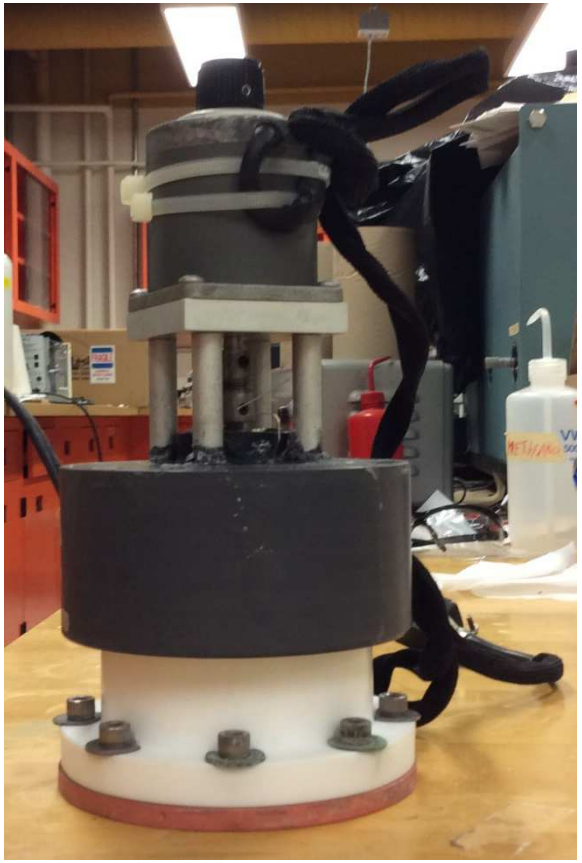
- Pores formed by electrochemical etching
- Uses anodization cell made up of electrodes and an electrolyte
- Electrolytes are made up of HF and a solvent
- Wafer is immersed in electrolyte, then current is run across it



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

Parameter Increased	Porosity
HF Concentration	Decreases
Current Density	Increases
Etching Time	Increases
p-type Doping	Decreases
n-type Doping	Increases

Chart adopted from [4]

Advantages of Porous Silicon Filters

- Macroporous silicon acts 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

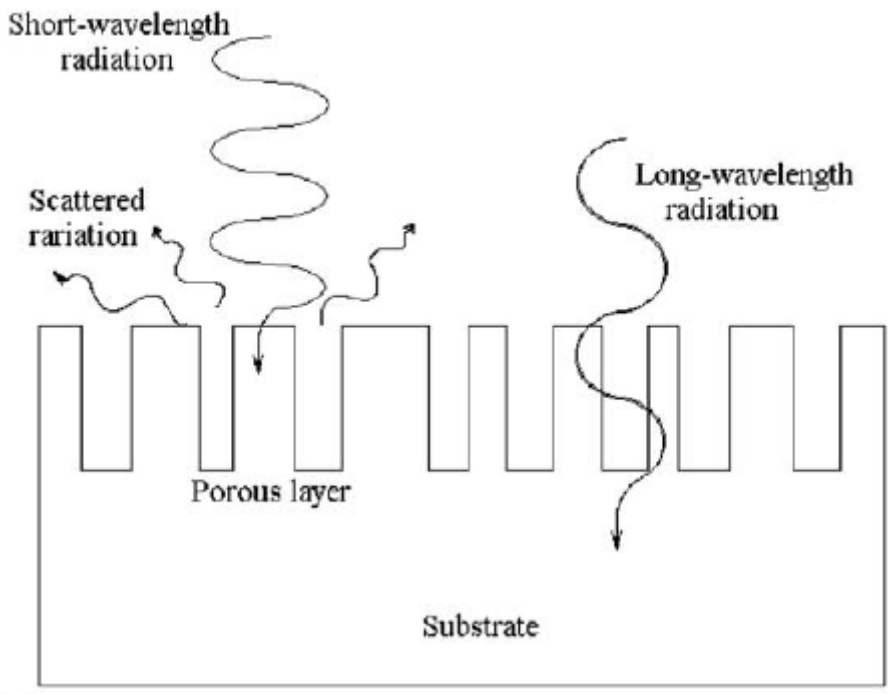


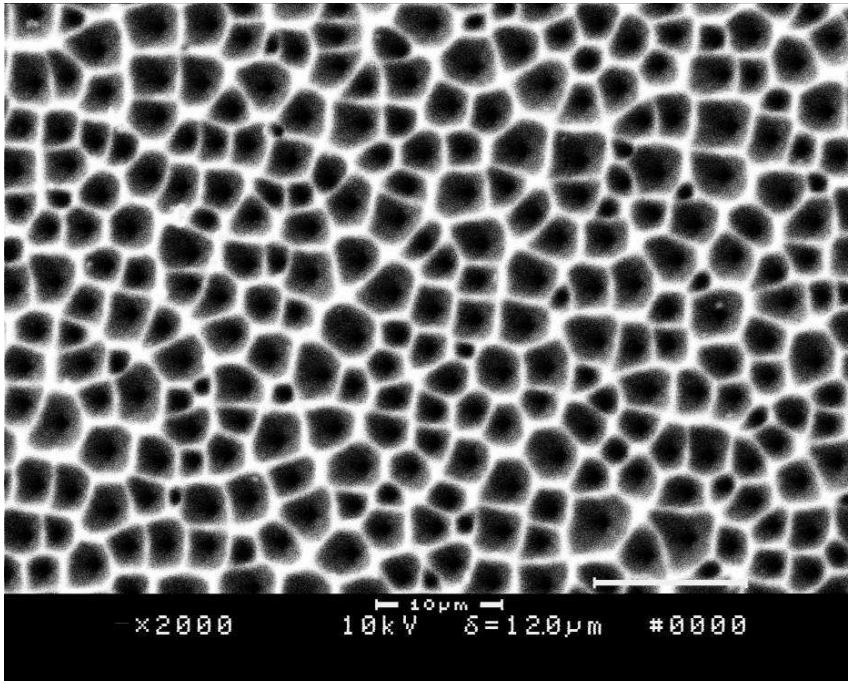
Image adopted from [3].

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

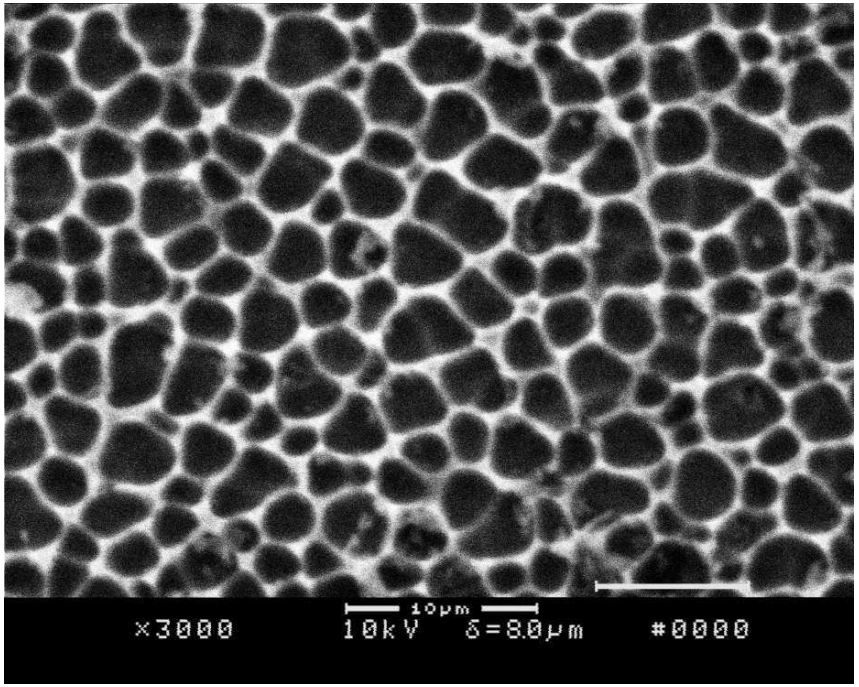
Sample Imaging

SEM Image – ρ = 10 Ω·cm ,
<1 0 0> Orientation



Pore Density = 0.098 pores/μm^2

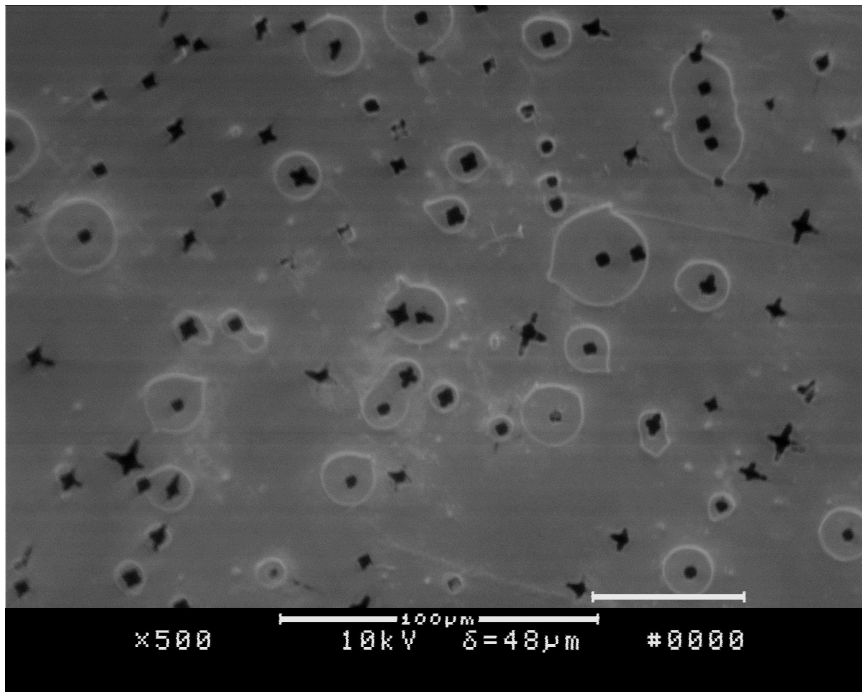
SEM Image – ρ = 10 Ω·cm ,
<1 1 1> Orientation



Pore Density = 0.13 pores/μm^2

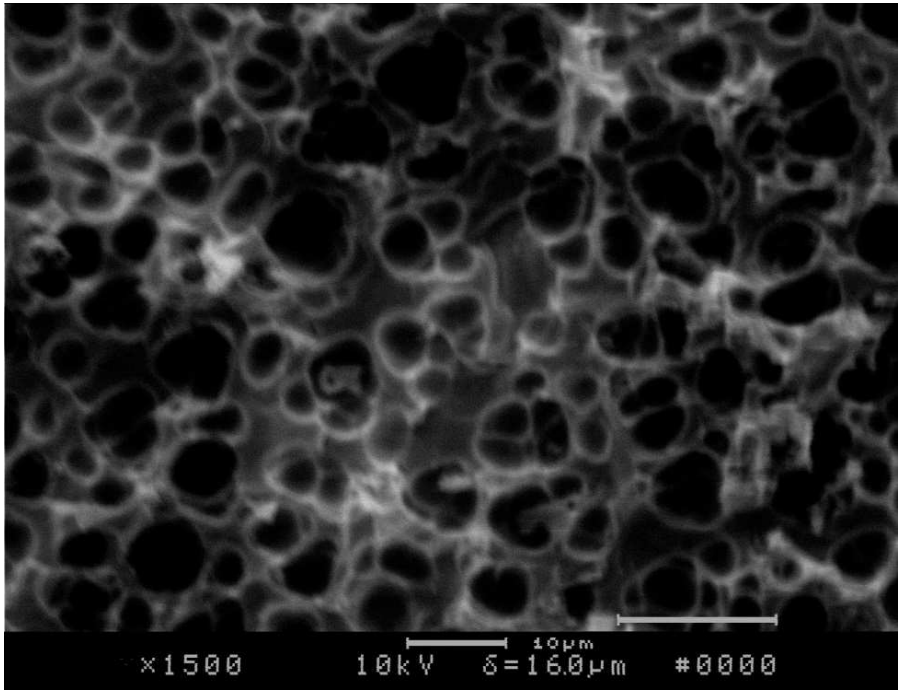
Sample Imaging

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



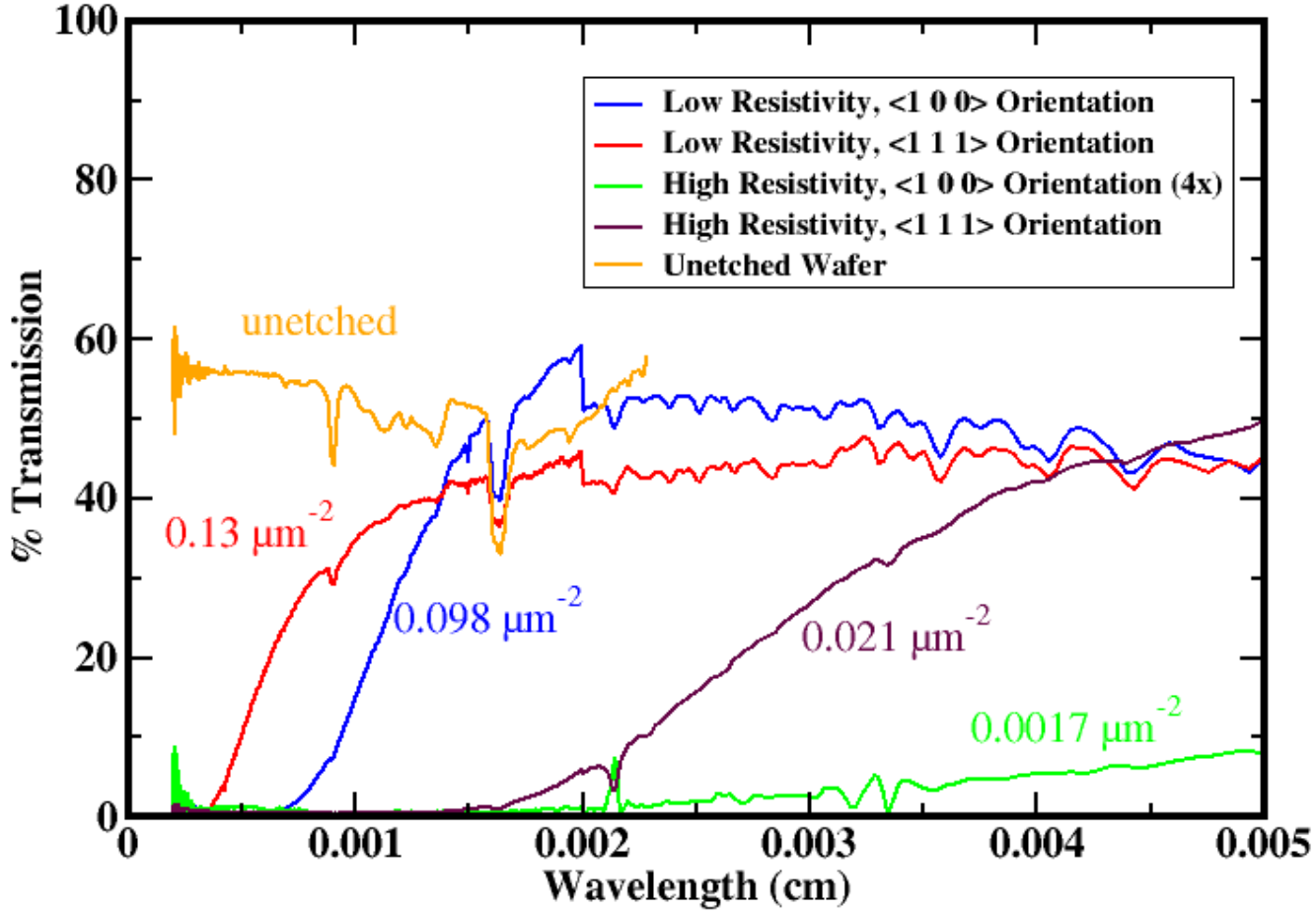
Pore Density = 0.0017 pores/µm^2

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

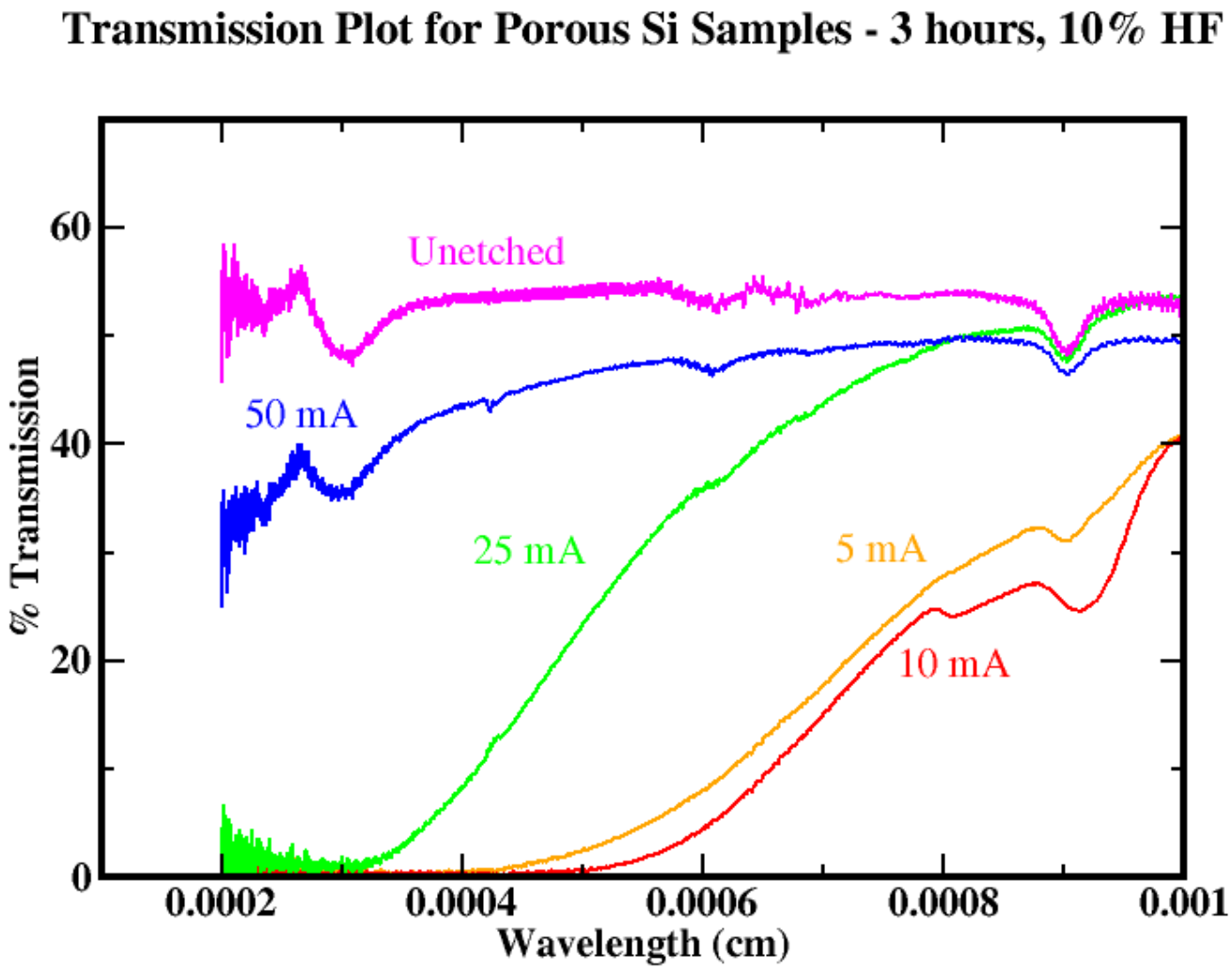


Pore Density = 0.021 pores/µm^2

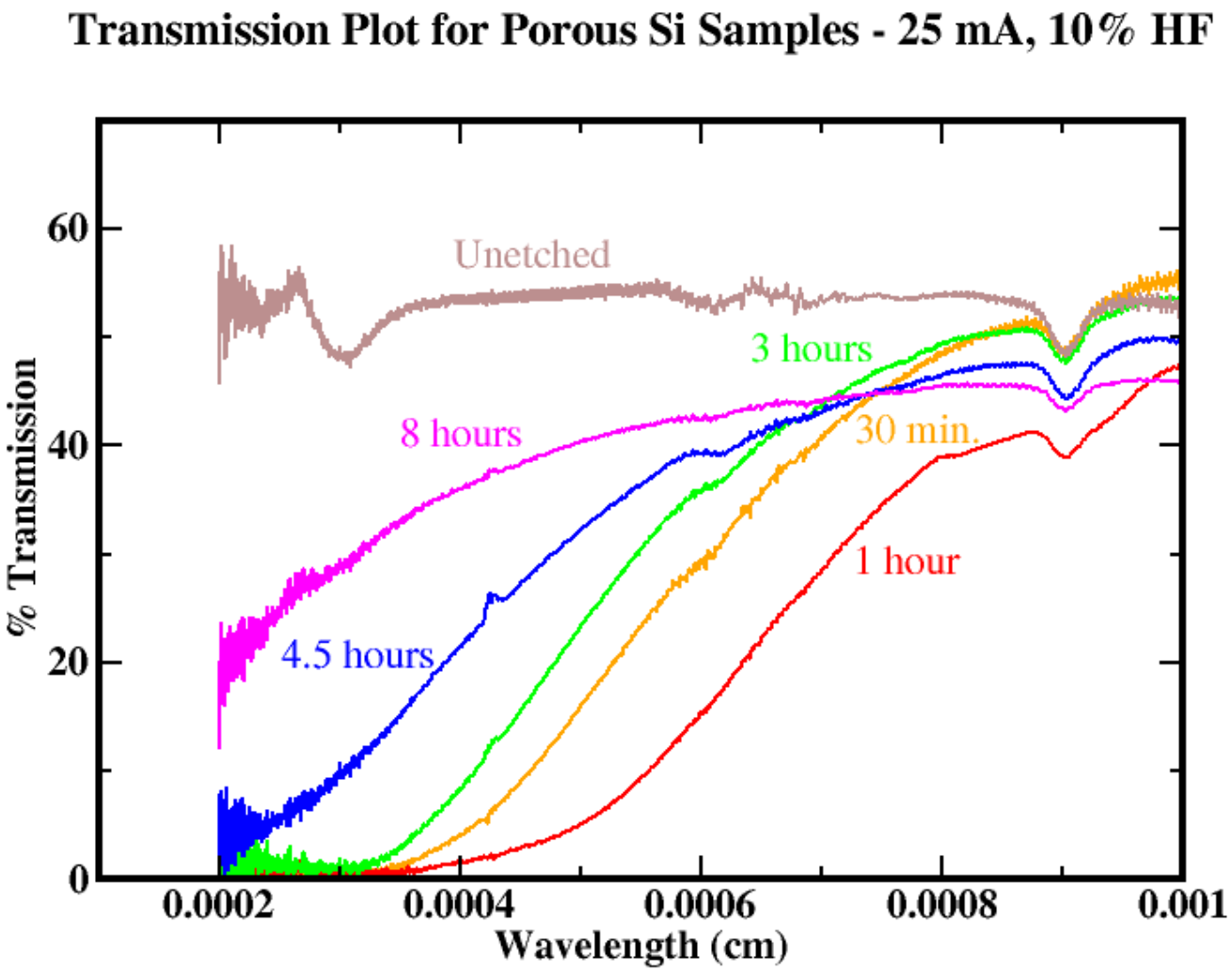
Transmission as a Function of Pore Density



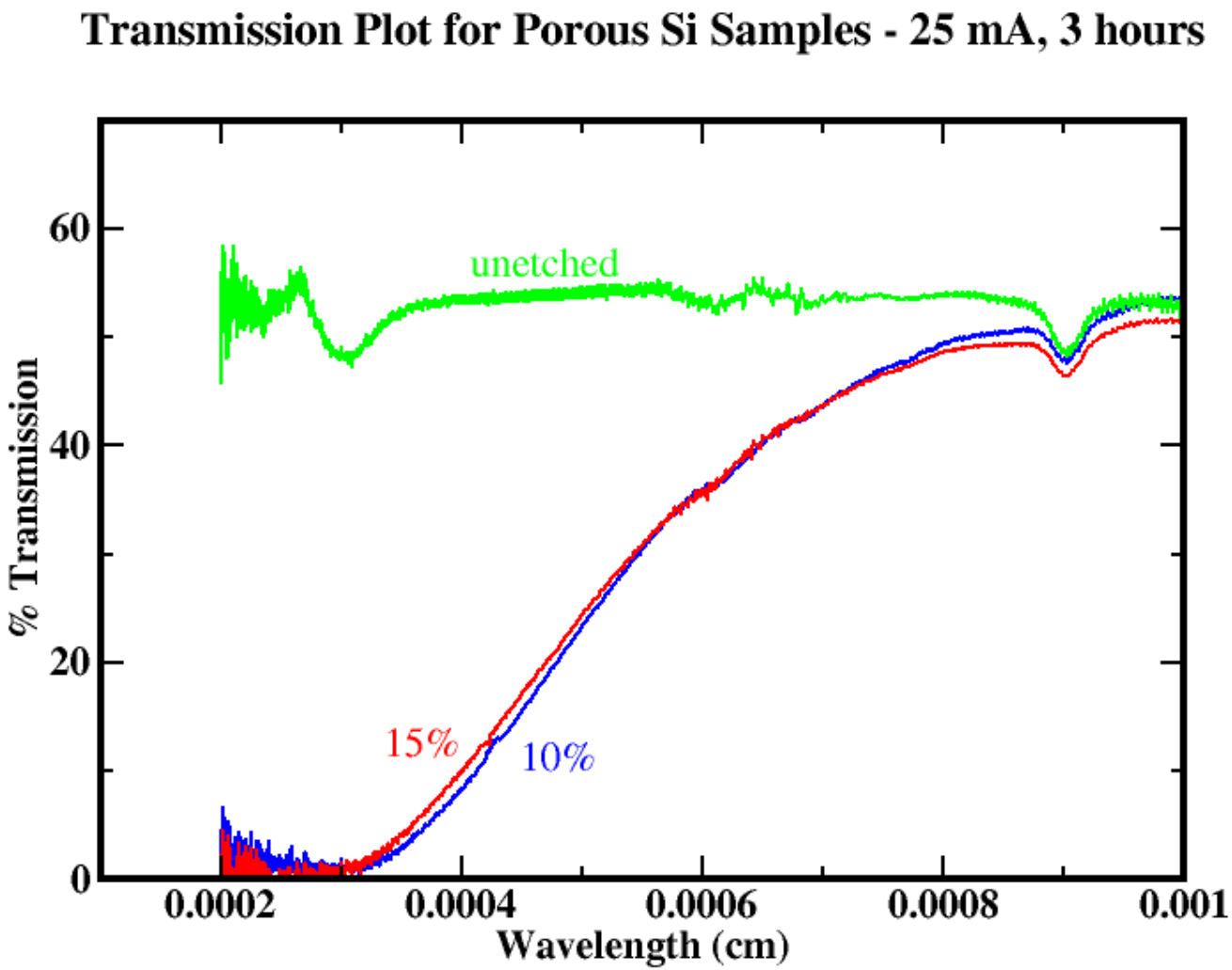
As current is increased, the cutoff wavelength decreases



As etching time is increased, the cutoff wavelength decreases



As HF concentration is increased, the cutoff wavelength seems to experience no change



Summary Table

Parameter Increased	Cutoff Wavelength
Etching Current	Decreases
Etching Time	Decreases
Etching HF Concentration*	Unchanged
Pore Density	Decreases

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

References

1. M. Christophersen, V. Kochergin and P. Swinehart. "Porous Silicon Filters for Mid-to-Far IR Range". *Proceedings of SPIE,* **5524**, 158-168, 2004.
2. H. Föll, M.Christophersen, J.Carstensen and G.Hasse. "Formation and Application of Porous Silicon". *Materials Science and Engineering R,* **39**, 93-141, 2002.
3. V. Kochergin and H. Föll. “Novel Elements Made from Porous Si". *Materials Science and Engineering R*, **52**, 93-140, 2006.
4. E. Xifré Perez. "Design, Fabrication and Characterization of Porous Silicon Multilayer Optical Devices“. *Rovira i Vergili University*, 2007.

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