Porous Silicon for Biosensing Applications

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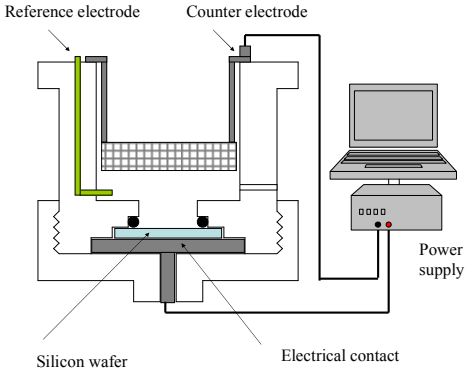
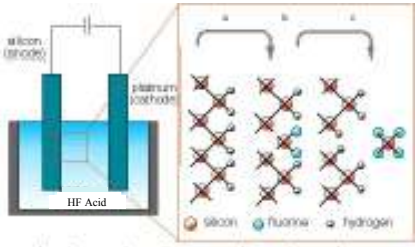
Porous silicon formation



One way to obtain porous silicon is through electrochemical dissolution in HF based solutions. This dissolution is obtained by monitoring either the anodic current or potential. The simplest cell which can be used to anodise Si is shown on the left. The Si wafer serves as the anode while the cathode is made of platinum. The cell body is made of a highly acid resistant polymer such as Teflon, PP or PVC. A metal contact is made to the back side of the wafer and sealed so that only the front side of the sample is exposed to the anodising electrolyte. In our case, due the high conductivity of p+-doped Si wafer no metal deposition is necessary.



basic reaction of porous silicon formation

$Si + 2F^- + h^+ \rightarrow SiF_{2(s)} + e^-$

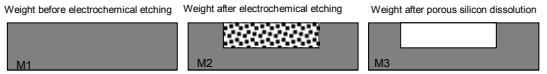
$SiF_{2(s)} + 2H^+ + 2F^- \rightarrow SiF_4 + H_2$ (gas)

$SiF_4 + 2F^- \rightarrow H_2SiF_6$

Total reaction $Si_{(s)} + 6F^- + 2H^+ + 2h^+ \rightarrow SiF_6^{2-} + H_2$ (gas)

What is the porosity?

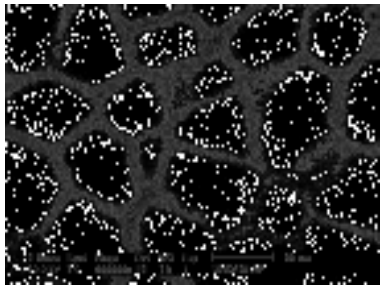
Is defined the porosity, measured gravimetrically, as the ratio between the pore weight removed during the etching and the weight of the entire layer



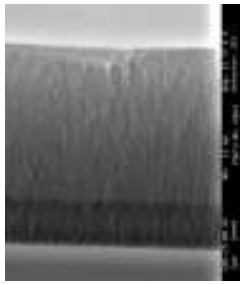
$$P = \frac{M1 - M2}{M1 - M3}$$

Advantages of porous materials compared to bulk material

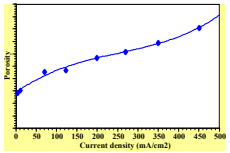
♦ Scanning electron micrograph (SEM) of nanoporous surface



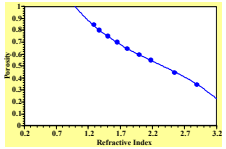
♦ Cross-sectional SEM of porous Silicon bilayers



♦ porosity depends on current density:



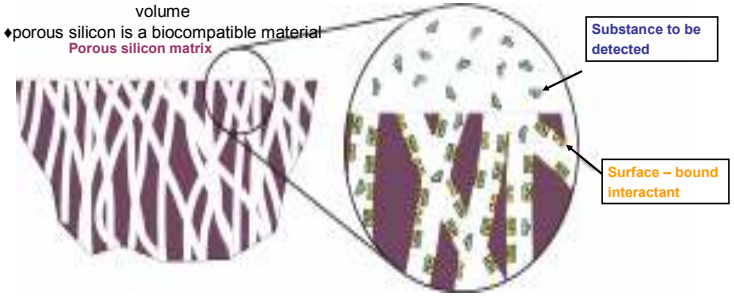
♦ refractive index depends on porosity:



♦The high internal surface area of porous silicon (200–1000 m^2/cm^3) permits a high concentration of biomolecules in a small volume

♦porous silicon is a biocompatible material

♦ The high reactivity of the surface facilitates Proteins and DNA binding inside the pore



Strategies for immobilizing proteins inside porous silicon matrix

Two different photoactivation techniques to functionalize porous silicon

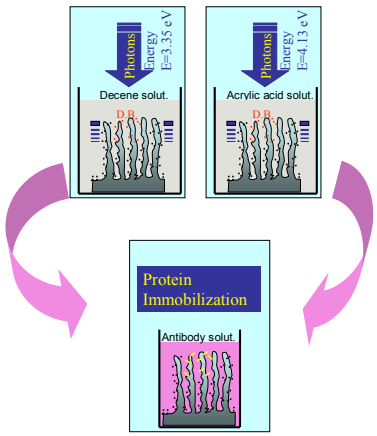
METHOD 1:

PREPARATION:

- Prepare porous silicon
- Immerse in Decene solution in quartz cuvette, under N_2 flux (15 min.)
- UV illumination (λ = 370 nm, 1 hr.)
- Ethanol wash and rinse under N_2 flux

BIOCONJUGATION:

1. Alkylated Si surface activated by 4-benzoylbenzoic acid succinimidyl ester (BBA) in deaerated anhydrous carbon tetrachloride
2. UV illumination (λ = 365 nm, 15 min.)
3. Rinse with carbon tetrachloride
4. Immerse in antibody solution: Alexa 488 dye-labeled rabbit anti-MS2 antibody



METHOD 2:

PREPARATION:

- Prepare porous silicon
- Immerse in Acylic acid solution in quartz cuvette, under N_2 flux (15 min.)
- UV illumination (λ = 300 nm, 1 hr.)
- Ethanol wash and rinse under N_2 flux

BIOCONJUGATION:

1. Acid-derivatized Si surface immerse in antibody solution: Alexa 488 dye-labeled rabbit anti-MS2 antibody
2. Add 1-ethyl-3-[3-dimethylaminopropyl]carbodiimide hydrochloride solution in DI water
3. Reaction carried out in dark (2 hr.)

Fluorescence characterization

Dye fluorescence intensity measurements, performed on PS samples of varying thickness, verified the effective protein penetration inside nano-porous silicon structure.