Fabrication of Microneedles

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What are Microneedles?

- Sharp pointed objects made using microelectronics fabrication techniques
- Usually fabricated in arrays
- Solid or hollow
- In-plane or out-of-plane
- Uses include microcombustion, fluid extraction, and drug delivery

Transdermal Drug Delivery

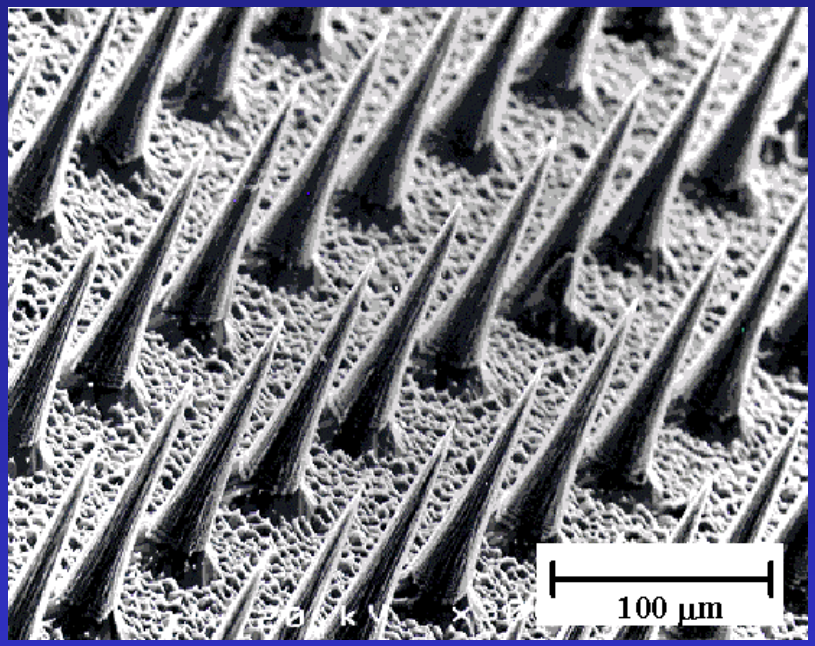
- Needles penetrate the outer layer of skin but are short enough not to stimulate nerves in the deeper tissues
  - painless, minimally invasive
- Enhance transport of molecules across skin
- One-time use or continuous administration of medication
- Could be used like a patch
- Attractive alternative to pills or injections

Design Considerations

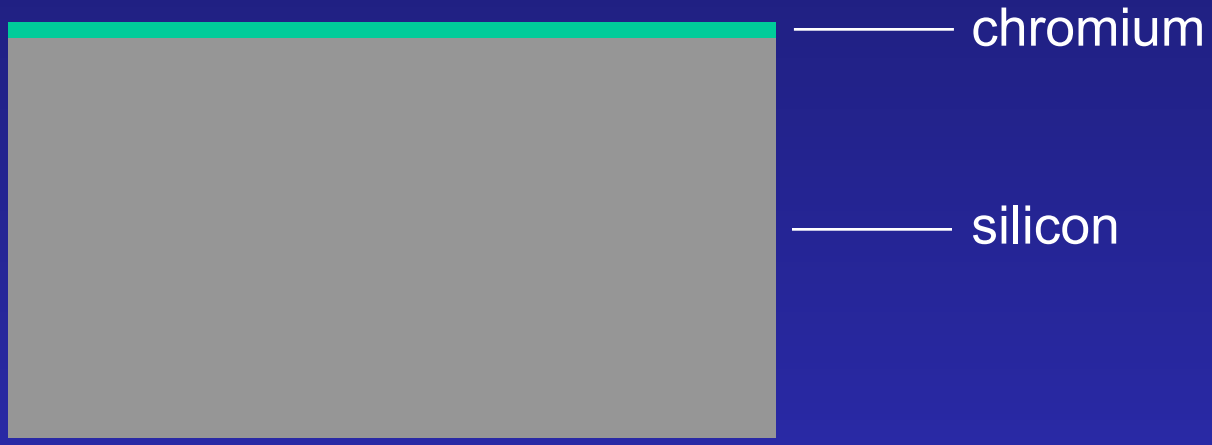
- Smooth, sharp, small diameter
- Length (from 100 to over 1000 μm)
- Needle density
- Lateral force tolerance
- Buckling force, penetration force
- Fluid pressure (hollow needles only)
- Biocompatibility (materials)
- Cheap (high throughput)

Solid Needles

- Fabricated using modified Black Silicon Method
- For increased skin permeability



Solid Needle Fabrication

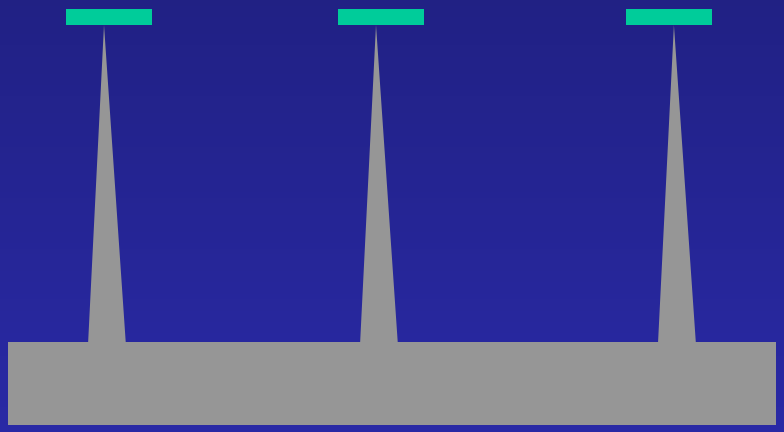


Sputter-deposit a 1000 Å thick layer of chromium masking material

Solid Needle Fabrication

Pattern the mask with circular patterns, 50 to 80 μm in diameter

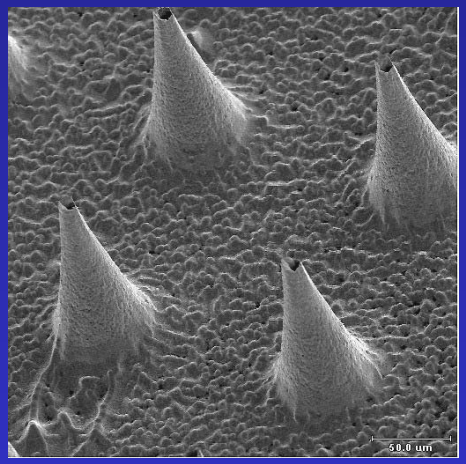
Solid Needle Fabrication



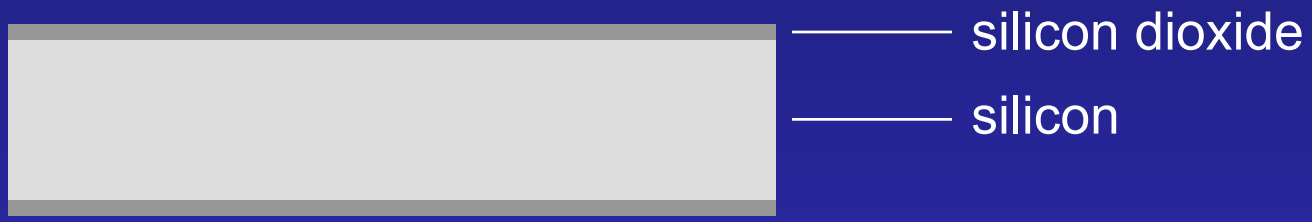
Etch the wafer in a reactive ion etcher using SF_6/O_2 gas chemistry

Hollow Needles

- Increased rates of transport and better control over drug delivery profile
- Flow resistance is inversely proportional to needle density
  - too high density could reduce efficiency of needle penetration



Two Mask Method

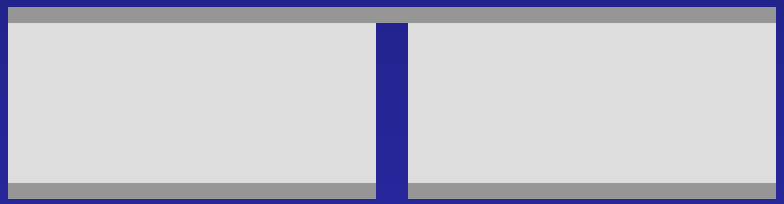


Deposit silicon dioxide (LPCVD)

Two Mask Method

Pattern 40 μm diameter holes in oxide layer (photolithography followed by CF_4-CHF_3-He plasma etch)

Two Mask Method

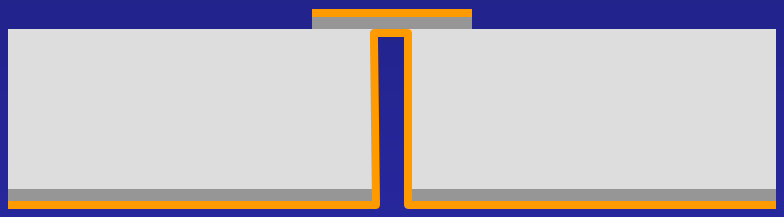


Define the channels (deep reactive ion etching)

Two Mask Method

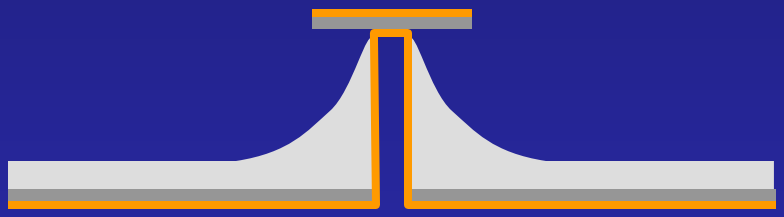
Deposit 0.4 μm silicon nitride to protect the channels (LPCVD)

Two Mask Method



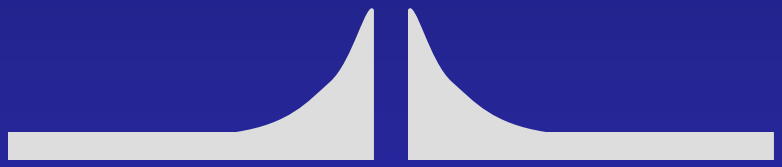
Pattern disks on the front side

Two Mask Method



Isotropic etch (SF_6 plasma, then wet chemical etch to smooth the surface)

Two Mask Method



Remove the layers of silicon dioxide and silicon nitride (HF for 12 hours)

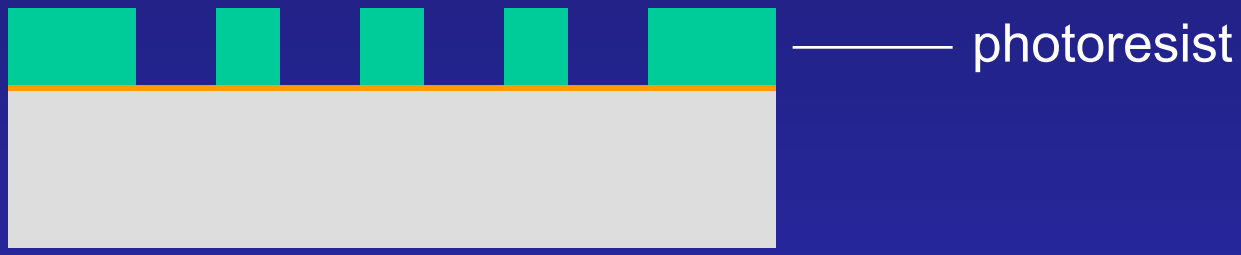
In-Plane Needles

- Fine control over needle shape
- More complicated fabrication

Fabrication Steps (In-Plane)

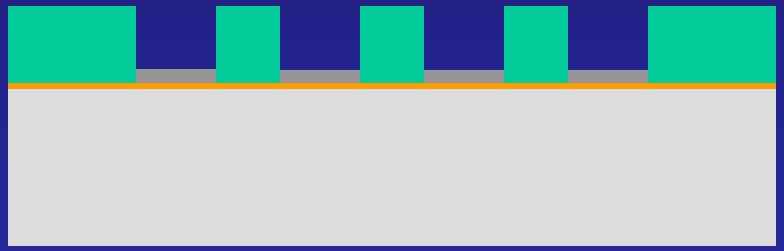
Deposit a metal system of adhesion layers

Fabrication Steps (In-Plane)



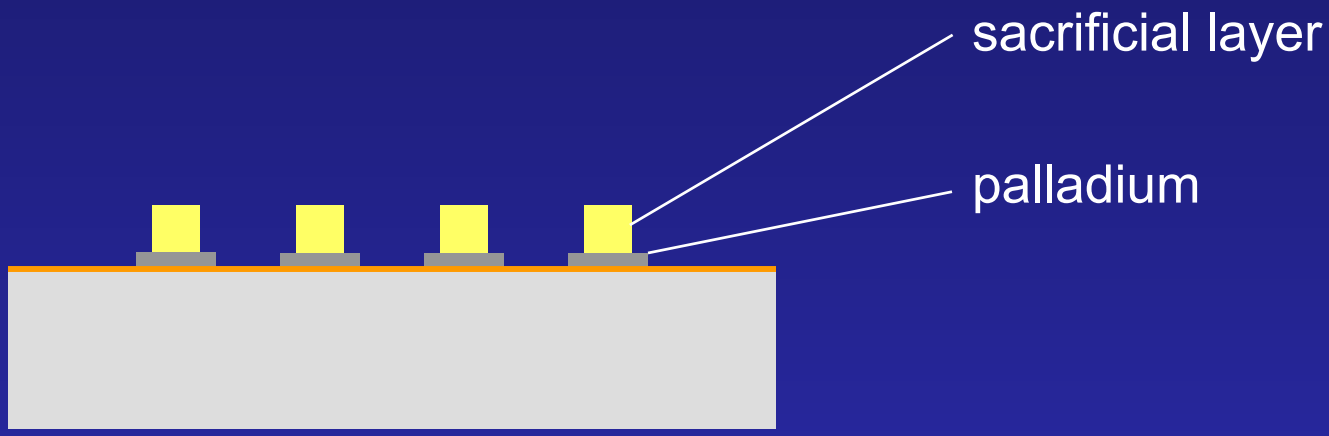
Spin on a layer of photoresist, then pattern to define the micromolds for the bottom wall

Fabrication Steps (In-Plane)



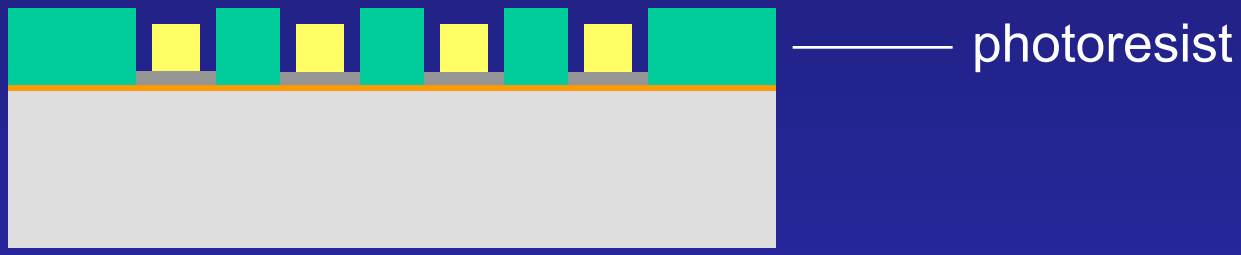
Electroplate the bottom wall with palladium

Fabrication Steps (In-Plane)



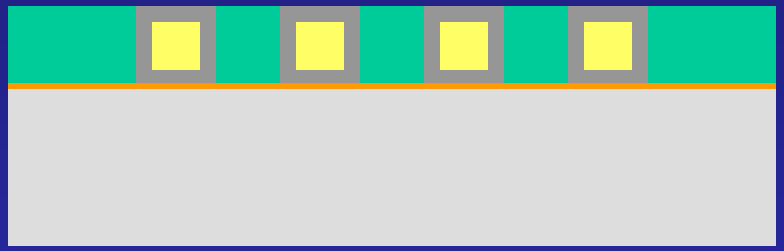
Spin coat photoresist and etch pattern into sacrificial structures

Fabrication Steps (In-Plane)



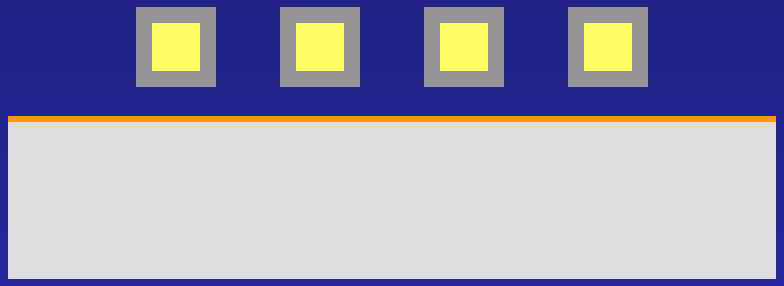
Add another photoresist layer to act as a mold for the side and top walls of the needle

Fabrication Steps (In-Plane)



Electroplate palladium to form the side and top walls

Fabrication Steps (In-Plane)



Etch underlying gold layer to release the array of needles

Fabrication Steps (In-Plane)

Dissolve the sacrificial photoresist that defines the inner lumens (acetone bath for 12 hours)

Discussion

- Solid needles enhance permeability of skin by up to 4 orders of magnitude
- Needle buckling and breakage
- If hollow needles punch the skin, the ‘plug’ could clog the channel
- Flow characteristics
- Other fabrication techniques exist
- Packaging?