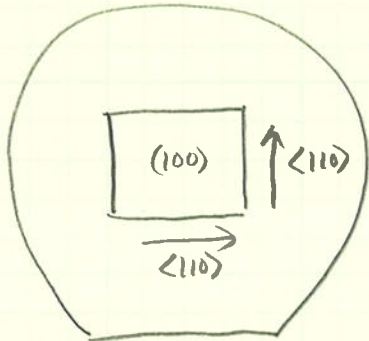


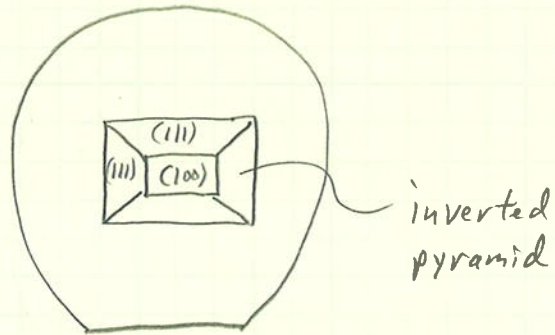
## Anisotropic Wet Etching - Continued

### 1. Review :

before Etching



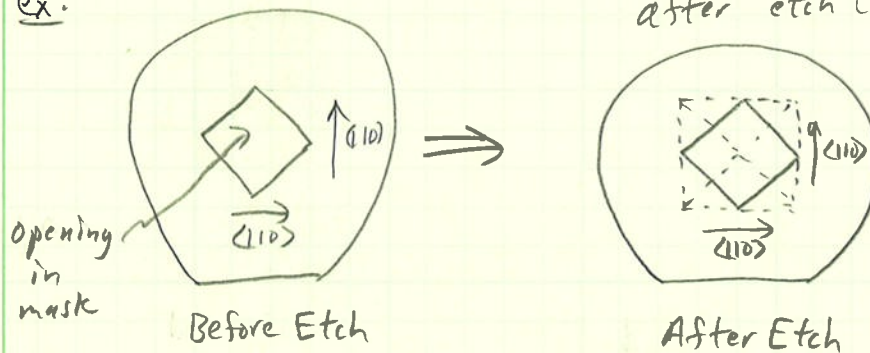
after a timed etch



hole is open in mask layer

a. What if mask opening is not aligned to the  $\langle 110 \rangle$  planes?

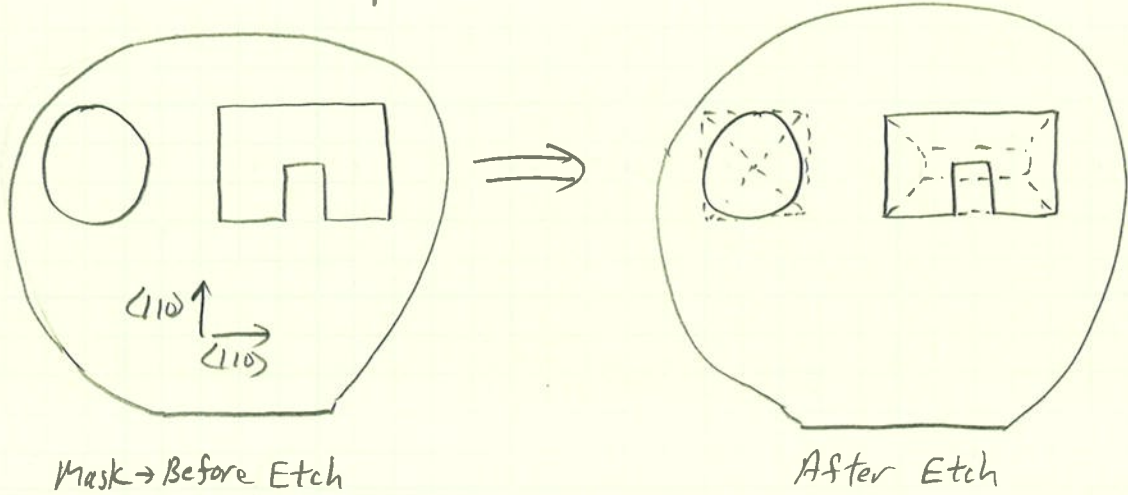
ex:



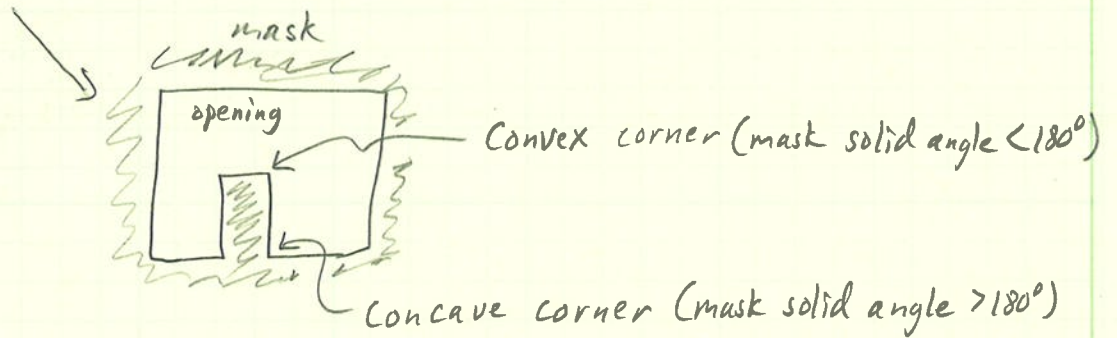
The region being etched expands until all sides are along  $\langle 110 \rangle$  directions.

Notice that the mask is significantly undercut in areas  
 → this can be used to create cantilevered or "released" structures

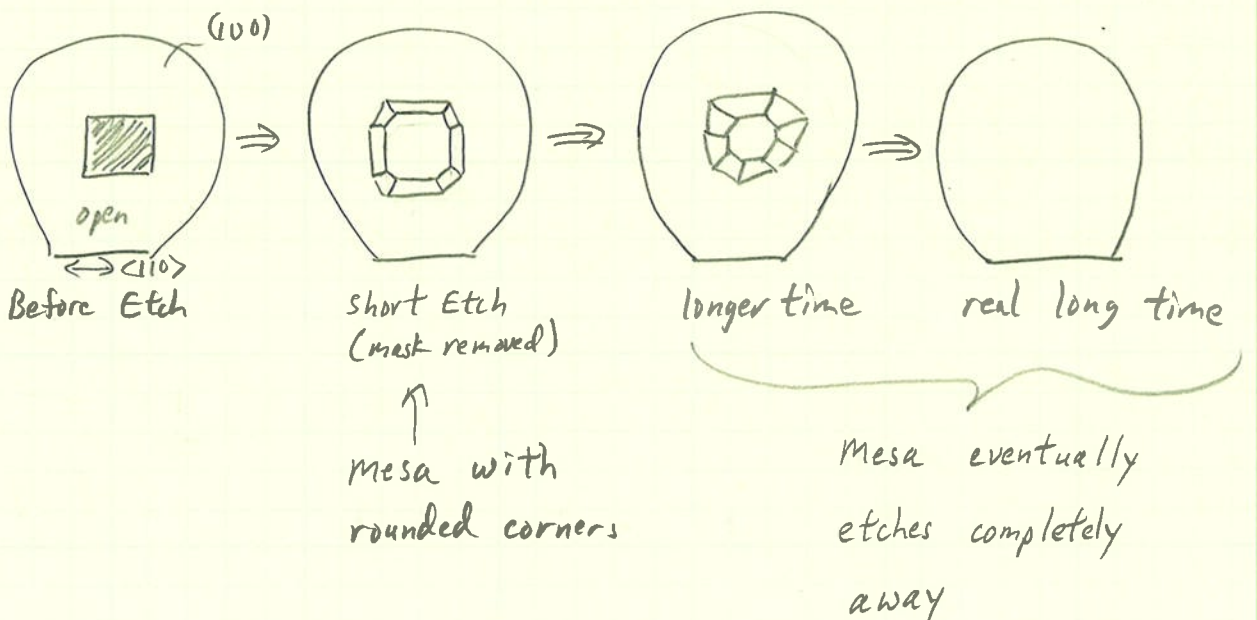
Consider this example



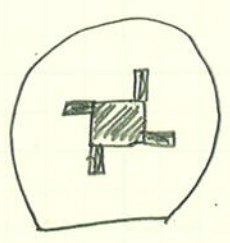
- Circle mask opening forms a square inverted pyramid along  $\langle 110 \rangle$  directions
- Etended beams in mask etch away to  $(110)$  planes



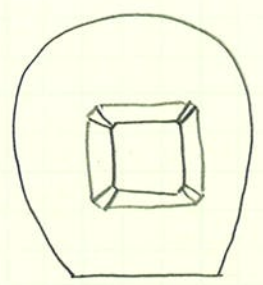
b. creating mesas



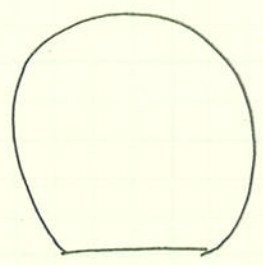
### c. Mesas with corner compensation



Before Etch



After Etch  
(mask removed)



much longer etch  
Mesa still etches away

The protruding beams on the mask help to create mesas with better corners

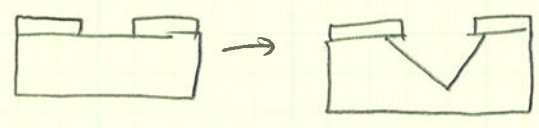
d. Designs that are bound by slow-etching  $\{111\}$  planes are called Self-Limiting Stable Profile (SLSP)

Unstable Transitional Profiles  $\rightarrow$  change rapidly with time  $\rightarrow$  ex: circle

Stable Transitional Profiles  $\rightarrow$  change slower with time

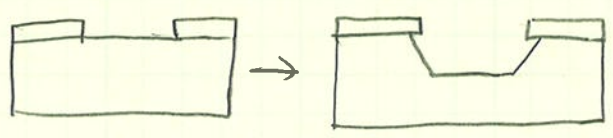
$\hookrightarrow$  (STP)

ex: SLSP  $\rightarrow$



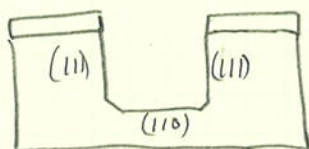
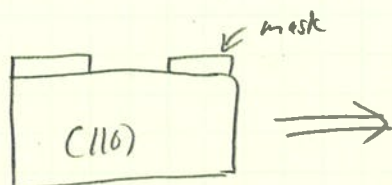
$\rightarrow$  tolerant to overtime etch

STP  $\rightarrow$



$\rightarrow$  much less tolerant to overtime etch

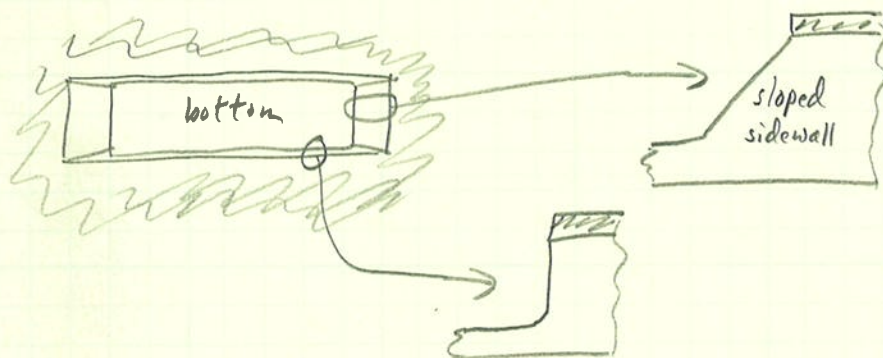
2. (110) Si wafer → Note: not in text book  
 before Etch                      after timed etch



↑  
 notice the straight side walls

Note: ends of the "channel" do not have straight side walls

top view



3) Wet Anisotropic Etchants for Si

① Ethylene Diamine Pyrocatechol (EDP)

selectivity → (111):(100) → ~1:35 ((100) etch rate: 0.5 to 1.5 μm/min)

does not readily etch SiO<sub>2</sub>, Si<sub>3</sub>N<sub>4</sub>, Au, Cr, Ag, Cu, Ta

EDP is toxic, often heated to 90-100°C during etching

② Potassium Hydroxide (KOH)

selectivity → (111):(100) → ~1:400

does not readily etch Si<sub>3</sub>N<sub>4</sub>

etch rate of SiO<sub>2</sub> ~ 14 Å/min, also etches some metals

"non-toxic"

### ③ Tetra Methyl Ammonium Hydroxide (TMAH)

selectivity  $\rightarrow$  (111):(100)  $\rightarrow$   $\sim$ 1:10 to  $\sim$ 1:35

$\rightarrow$  typically results in a poorer surface finish than with EDP or KOH

Does not readily etch  $\text{SiO}_2$ ,  $\text{Si}_3\text{N}_4$ , Cr, Au

"with additives"  $\rightarrow$  can be used with Al

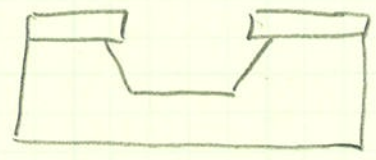
"non toxic"

a) heavily doped Si (B or P) greatly reduces etch rate of Si when etched with EDP or KOH

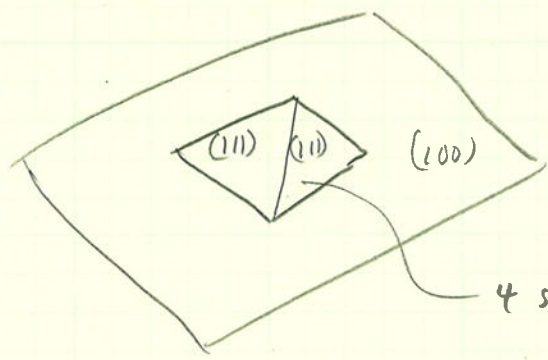
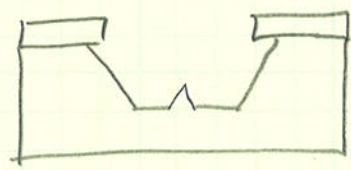
b) etching behavior can be influenced by adding a bias voltage or exposure to light

c) Hillocks - unwanted pyramid defects that sometimes appear on (100) planes

Ideal



actual



4 sided pyramid  $\rightarrow$  (111) planes are sides  
 $\rightarrow$  pyramid "grows" as (100) layer is etched