Anisotropic Wet Etching - Continued

Review:

Before Etching

\[
\begin{align*}
\text{(100)} & \uparrow \langle 110 \rangle \\
\text{<110>} & \rightarrow
\end{align*}
\]

After a timed etch

\[
\begin{align*}
\text{(111)} & \uparrow \langle 110 \rangle \\
\text{<110>} & \rightarrow \\
\text{inverted pyramid}
\end{align*}
\]

The region being etched expands until all sides are along \( <110> \) directions.

What if mask opening is not aligned to the \( <110> \) planes?

Ex:

Opening in mask

Before Etch

\[
\begin{align*}
\text{(110)} & \uparrow \langle 110 \rangle \\
\text{<110>} & \rightarrow
\end{align*}
\]

After Etch (long etch)

\[
\begin{align*}
\text{(110)} & \uparrow \langle 110 \rangle \\
\text{<110>} & \rightarrow
\end{align*}
\]

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

$\{110\}$

$\langle 110 \rangle$

$\langle 110 \rangle$

$\Rightarrow$

Mask → Before Etch

After Etch

Circle mask opening forms a square inverted pyramid along $\{110\}$ directions

Extended beams in mask etch away to $(110)$ planes

Convex corner (mask solid angle < 180°)

Concave corner (mask solid angle > 180°)

b. Creating mesas

Before Etch

$(001)$

$\Rightarrow$

Short Etch (mask removed)

Mesa with rounded corners

Longer time

Real long time

Mesa eventually etches completely away
c. Mesas with corner compensation

![Images showing before and after etch with corner compensation.]

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

d. Designs that are bound by slow-etching Ellips planes are called **Self-Limiting Stable Profile (SLSP)**.

**UUTP**

*Unstable Transitional Profiles* → change rapidly with time → ex: circle

*Stable Transitional Profiles* → change slower with time

→ *(STP)*

**Ex:** SLSP →

![Image showing an example of SLSP and its change over etch.]

→ tolerant to overtime etch

**STP** →

![Image showing an example of STP and its change over etch.]

→ much less tolerant to overtime etch
2. (110) Si wafer → \textbf{Note}: not in text book

before Etch \hspace{1cm} after timed etch

\begin{center}
\begin{tikzpicture}
\draw (-1,0) -- (1,0) -- (1,1) -- (-1,1) -- cycle;
\draw (0.5,0) -- (0.5,1);
\draw (1.5,0) -- (1.5,1);
\node at (-0.5,0.5) {mask};
\end{tikzpicture}
\end{center}

\textit{Note}: ends of the "channel" do not have straight side walls

top view

\begin{center}
\begin{tikzpicture}
\draw (-3,0) -- (-3,2) -- (3,2) -- (3,0) -- cycle;
\draw (-2,1) -- (-2,2);
\draw (2,1) -- (2,2);
\node at (-3,1) {bottom};
\node at (3,1) {sloped sidewall};
\end{tikzpicture}
\end{center}

3) Wet Anisotropic Etchants for Si

\textbf{(1) Ethylene Diamine Pyrocatechol (EDP)}

- selectivity \(\rightarrow (111): (100) \approx 1:35\)
- \((100)\) etch rate: 0.5 to 1.5 \(\mu m/min\)
- does not readily etch \(SiO_2, Si_3N_4, Au, Cr, Ag, Cu, Ta\)
- EDP is toxic, often heated to 90-100°C during etching

\textbf{(2) Potassium Hydroxide (KOH)}

- selectivity \(\rightarrow (111): (100) \approx 1:400\)
- does not readily etch \(Si_3N_4\)
- etch rate of \(SiO_2 \approx 14 \AA/min\), also etches some metals
- "non-toxic"
3. Tetra Methyl Ammonium Hydroxide (TMAH)

- Selectivity \((111):(100) = \sim 1:10\) to \(\sim 1:35\)
- Typically results in a poorer surface finish than with EDP or KOH
- Does not readily etch SiOx, Si3N4, Cr, Au
- "With additives" 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

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