1. Relationship between different planes:

(111) planes intercept (100) planes at 54.75°

(110) planes intercept (100) planes at 45°

2. <u>Chapter 10</u> → Bulk Micromachining and Si Anisotropic Etching

"Bulk Micromachining" → a portion of the substrate "bulk" is removed to realize the MEMS structure

→ many materials can be used: Si, glass, SiC, GeAs, etc.

→ we will focus on Si here

a. other than photolithography, the main fabrication process used in Bulk Micromachining is "etching" → the removal of bulk material

→ 2 major etch processes → <u>Wet Etching</u> and <u>Dry Etching</u>

<u>Wet Etching</u> → uses liquid chemicals to convert solid Si bulk to Si compound particles or liquid

<u>Dry Etching</u> → uses a gas or a plasma to convert solid Si bulk to gaseous Si compounds

Wet Etching <u>may</u> depend on crystal orientation: (100), (110) or (111)

Dry Etching <u>may</u> depend on direction in the wafer

→ Review terms for anisotropic etch, isotropic etch and undercut

→ Important Issues to Consider in Selecting a Bulk Etching Process:

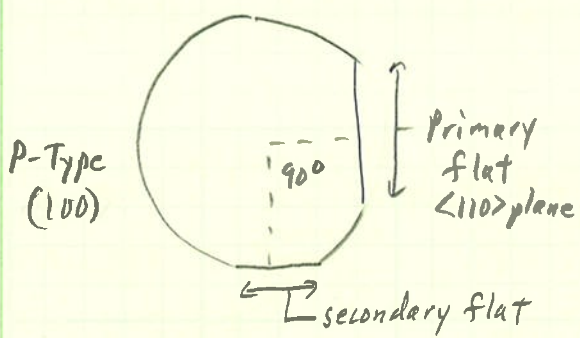
1) Etch Rate
2) Etch Rate Selectivity
3) Processing Temperature
4) Etch Uniformity across a Wafer
5) Sensitivity to Overtime Etch
6) Safety and Cost of Etchants
7) Surface Finish and Defects

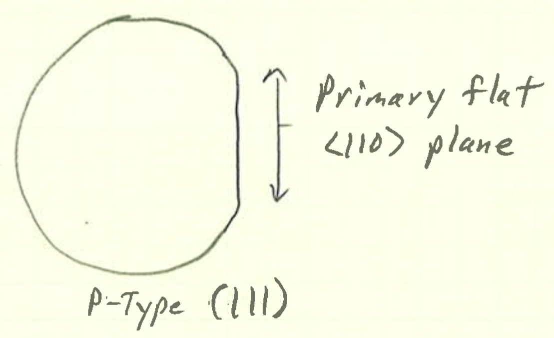
3. <u>Anisotropic Wet Etching</u> → very important 20+ years ago

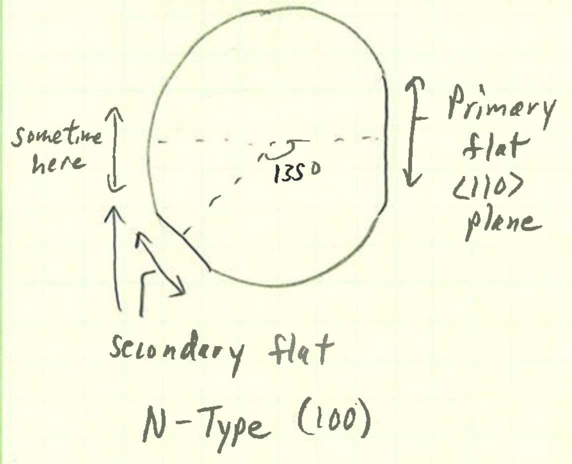
→ today it is "somewhat" replaced by dry etching techniques

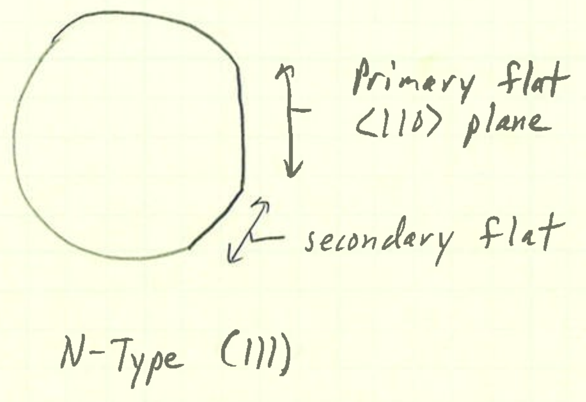
① → Liquid chemicals that etch Si, but the etch rate is crystal plane dependent

* Identifying a Si Wafer → many wafers have ID "flats"









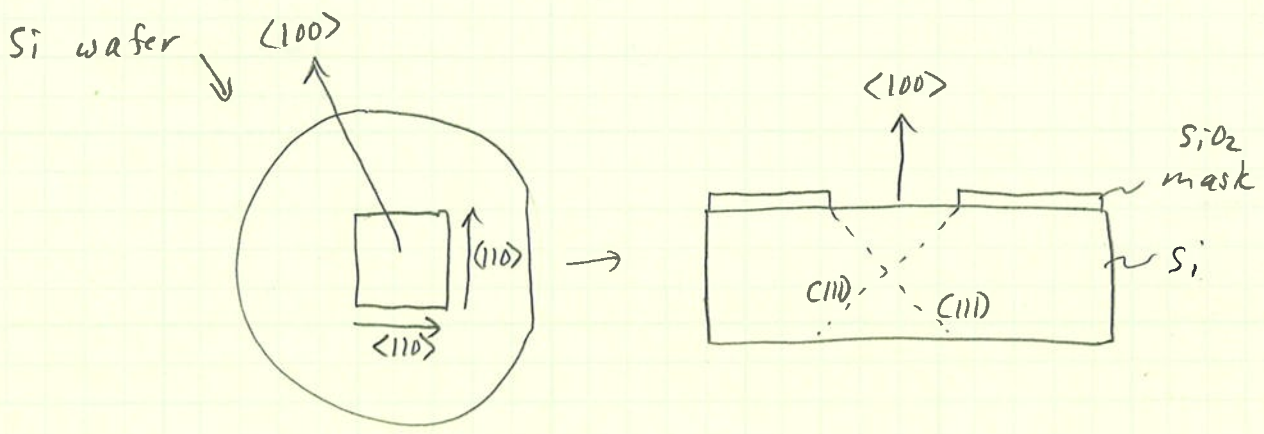
The primary flat can be used for aligning the photolithography mask to the wafer so that features are aligned along the <110> planes

Consider a (100) Si wafer

→ (110) planes intercept (100) planes at 45° (includes 90°)

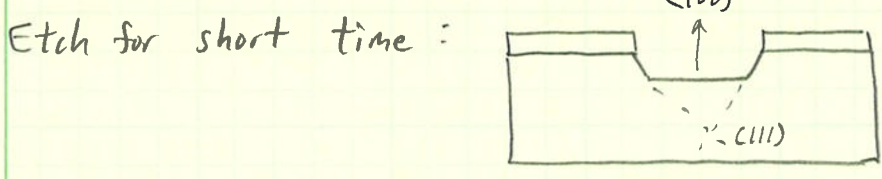
→ Consider an open square on the mask

→ Suppose mask is used to pattern a SiO_2 layer on the Si wafer

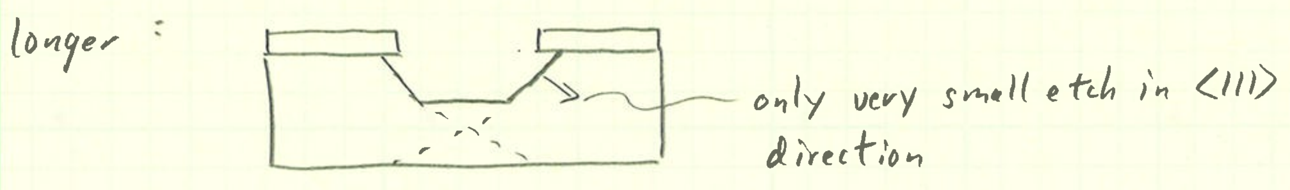


anisotropic wet etchants : <u>generally</u> Etch Rate$|_{\langle 100 \rangle}$ >> Etch Rate$|_{\langle 111 \rangle}$

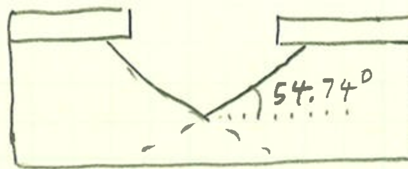
Etch for short time :



longer :



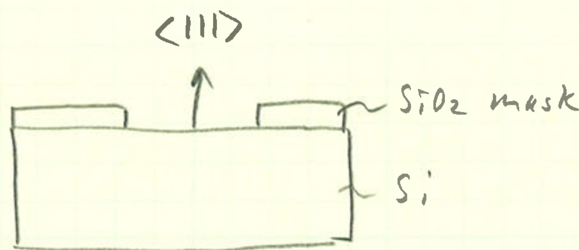
even longer →



etching in ⟨100⟩ direction has stopped !

the etched hole is actually a 4-sided pyramid

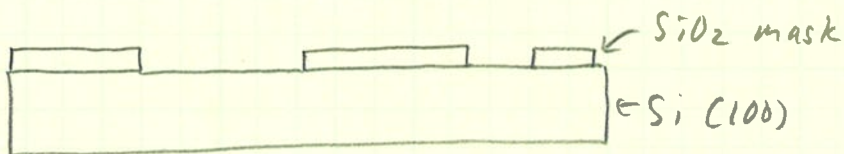
* what happens if we try the same thing with a (111) wafer ?



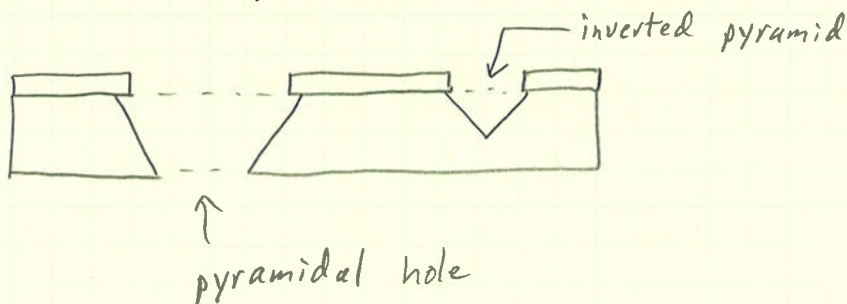
answer → almost nothing , only very slow etch in the ⟨111⟩ direction

* Could Etch all the way through the wafer :

Ex



⇓ etching



perspective view

<100>

A

<110>

<110>

<100>

<110>

<110>

<100>

A′

top view

<110>

mask

<110>

A

A′

<100>

w

A–A′
cross-sectional
view

54.75°

d

FIGURE 10.6
Cross-sectional profile of an etched cavity.