Lecture 13

Microfabrication
– Pattern Transfer (VI)

- Wet Etching
  - Anisotropic Wet Etching of (110) Silicon Wafer
    - (110) Silicon Wafer
    - Alignment Target
    - Fabrication using Different Masks
    - Etch Rate
    - Etch-Rate-Ratio
    - Surface Profiles
    - Results
    - Ultrasonic Agitation in Wet Etching
    - Surface Roughness due to Micromasking

(110) Silicon Wafer

- (110) Silicon wafer를 사용하면 벽면이 90° 인 통로를 만들 수 있다.

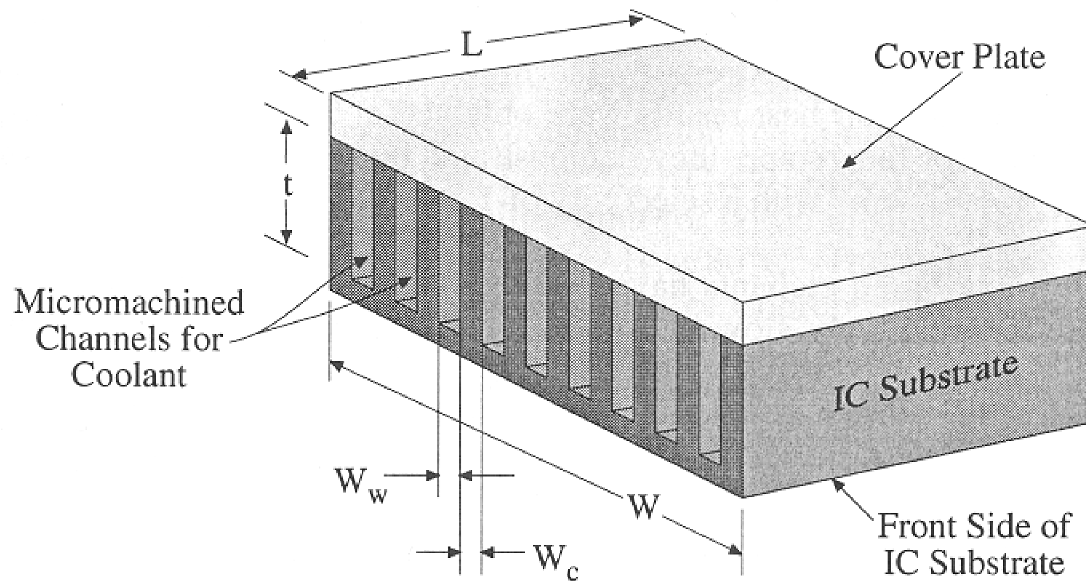
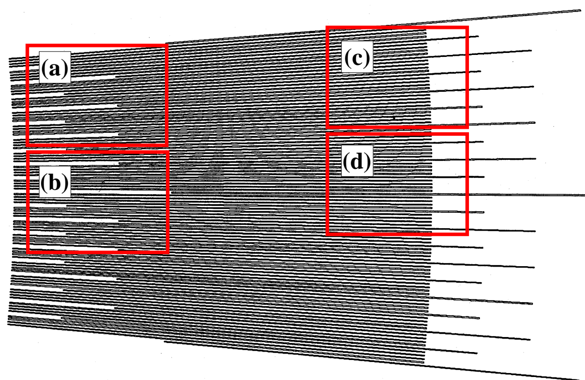


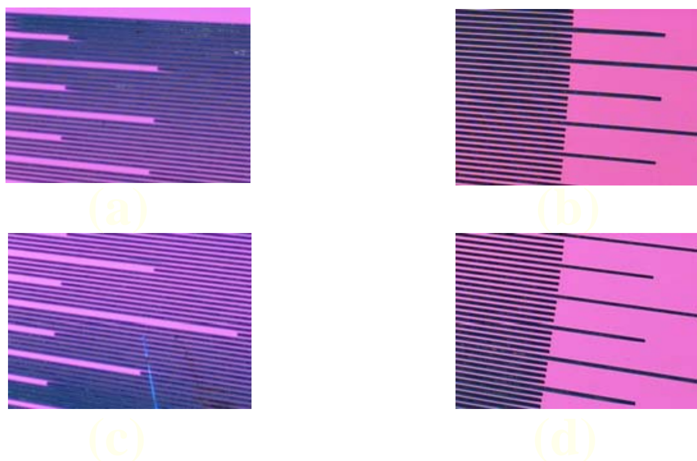
Diagram of a micromachined silicon heat sink incorporated into an integrated circuit (IC). For a 1 cm^2 silicon IC chip, using water as the coolant, the optimum dimensions are approximately $W_w = W_c$ = 57 μm and z = 365 μm. The channels are anisotropically etched into the (110) wafer with a KOH-based etchant. The cover plate is 7740 (Pyrex™) glass anodically bonded to the silicon (see below) forming a fluid-tight seal. Thermal resistances less than 0.1°C/W were measured, demonstrating extremely high heat transfer capability. Adapted from Tuckerman and Pease (1981).

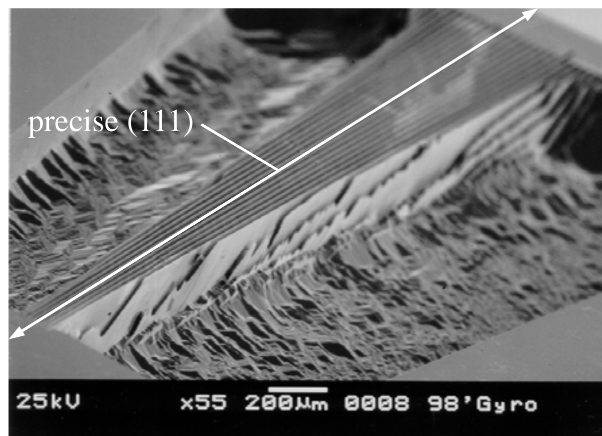
Alignment Target



Alignment target is etched before fabrication of desired structure

- Alignment target
  - Need for minimizing the undercut
  - Indicator for precise (111) orientation
  - Effect on aspect ratio
- 250㎛ etching
  - 45%, 60℃ in KOH





Each narrow hole (10㎛×5㎜) is apart by 0.1 degree

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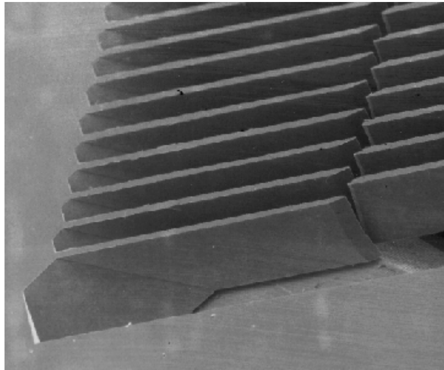
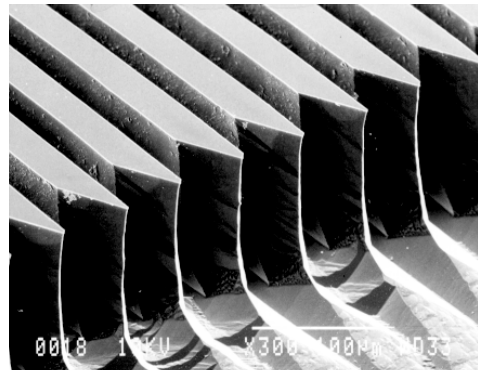
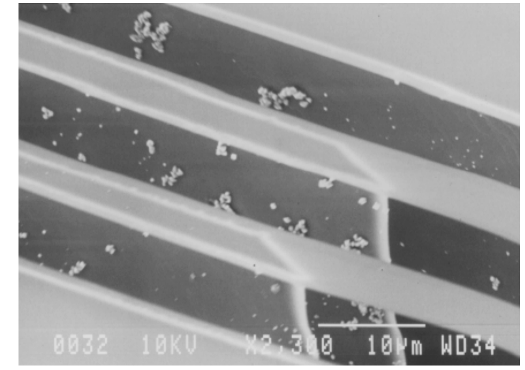
Fabricated Structures Using Different Masks

	Film mask	Emulsion mask	E-beam mask
			
Layout	100㎛ width 50㎛ gap	40㎛ width 20㎛ gap	10㎛ width 10㎛ gap
Fabrication	75㎛ width 75㎛ gap	35㎛ width 25㎛ gap	8㎛ width 12㎛ gap
Selectivity	45	55	90

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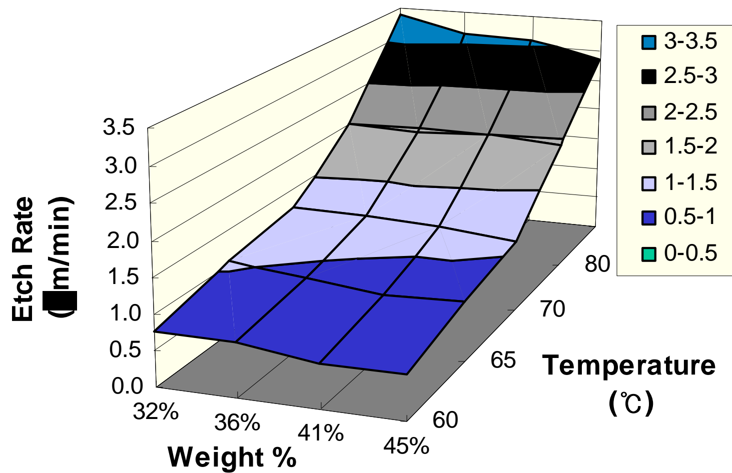
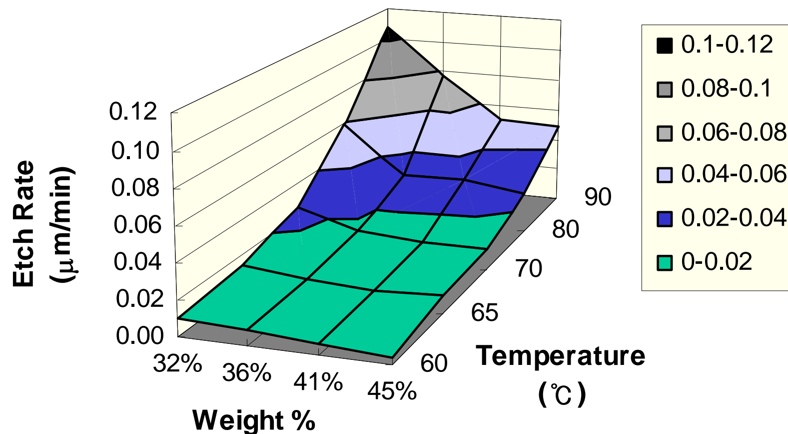
Etch Rate of (110) and (111) Planes



- Etch rate of (110) plane

$$= \frac{Height\ of\ structure}{Etching\ Time}$$

  - Increasing with temperature increasing
  - Decreasing with concentration increasing
  - Strong dependence on temperature



- Etch rate of (111) plane

$$= \frac{Underetch\ of\ structure}{Etching\ Time}$$

  - Strong dependence on concentration at high temperature

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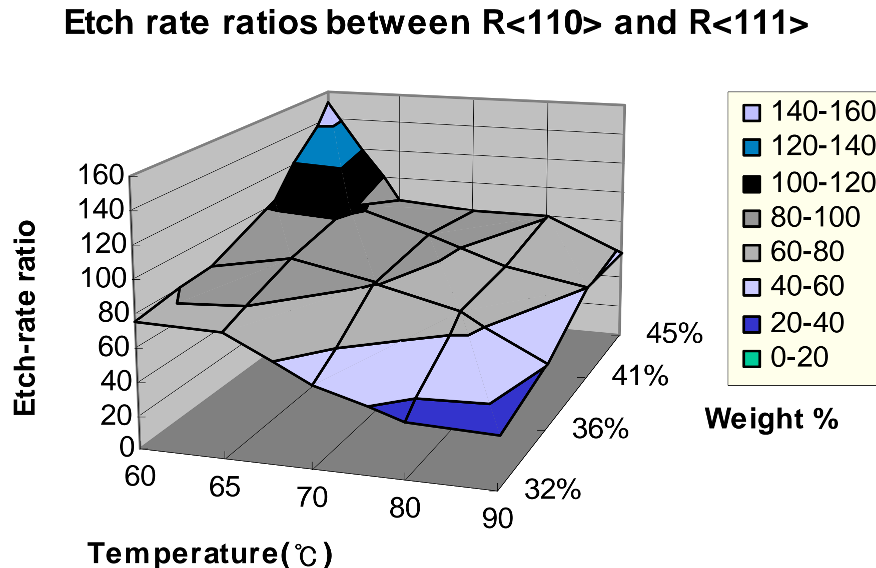
Etch-Rate-Ratio between (110) and (111) Planes



- Etch-Rate-Ratio

$$= \frac{Etch\ Rate\ of\ (110)\ Plane}{Etch\ Rate\ of\ (111)\ Plane}$$

- The highest etch-rate-ratio in lower temperature and higher concentration.
- The maximum etch-rate-ratio 150 in 45 wt.%, 60℃ KOH aqueous solution.

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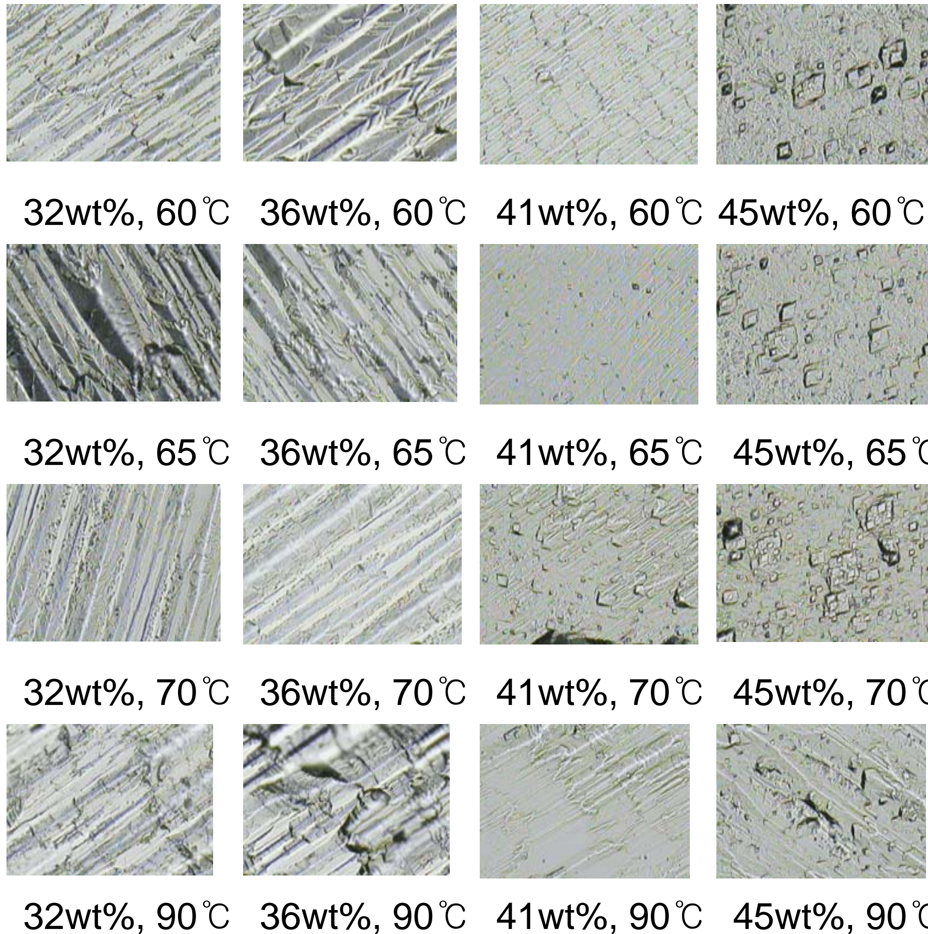
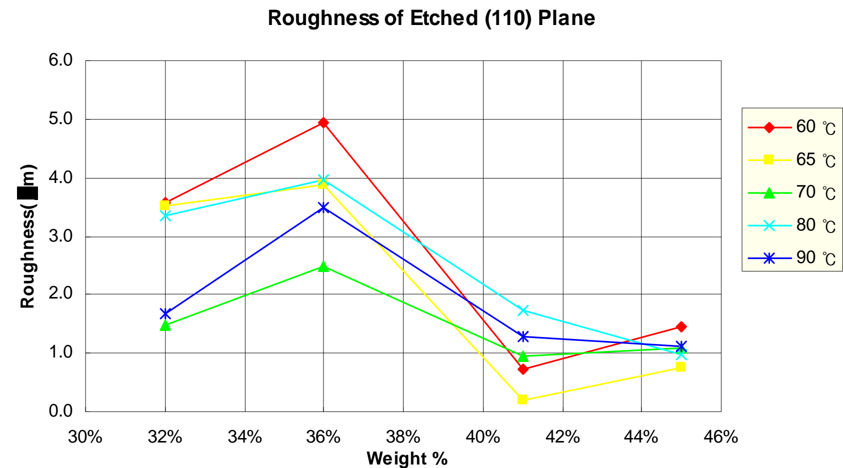
Surface Profiles of Etched (110) Planes





- The minimum surface roughness $R_{a,min}$ is taken in 41 wt.% aqueous KOH Solution.
- Unique surface profile
  - Wave shape : Under 41 wt.%
  - Hillock : Over 41 wt.%

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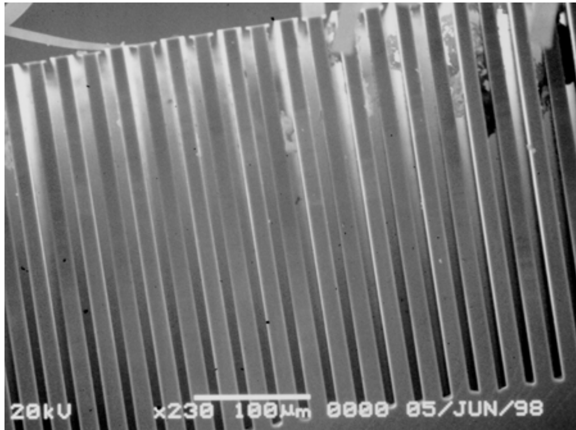
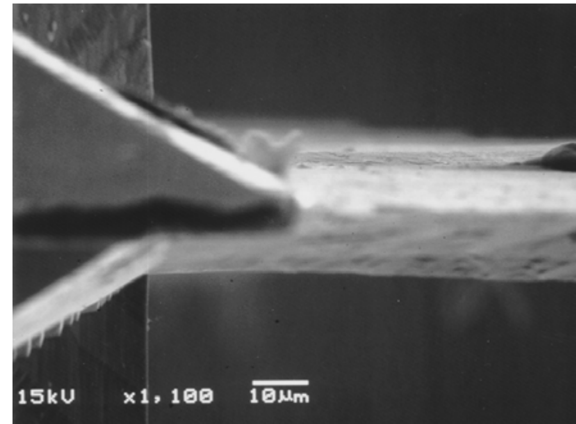
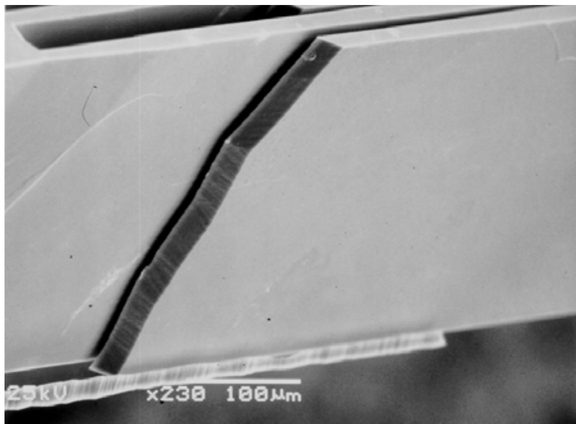
Results on (110) Wet Etching



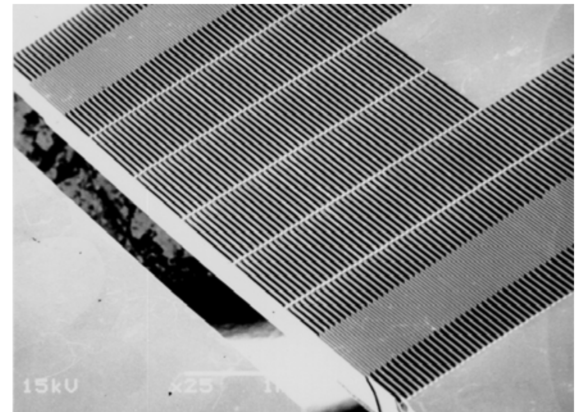
SEM of etched cross section
(One side etching)



Cross section of etch front
(Both side etching)



SEM of comb finger
(Both side etching)



SEM of comb structure
(Both side etching)

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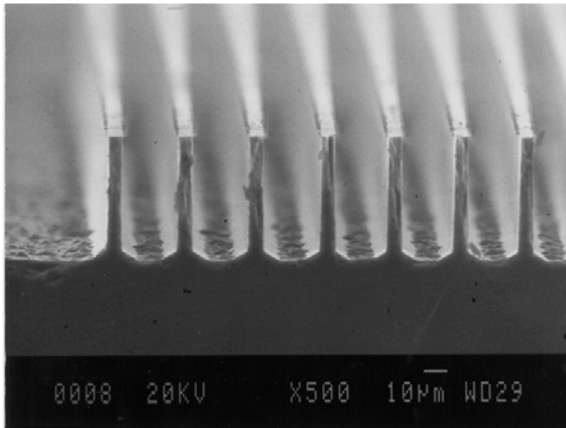
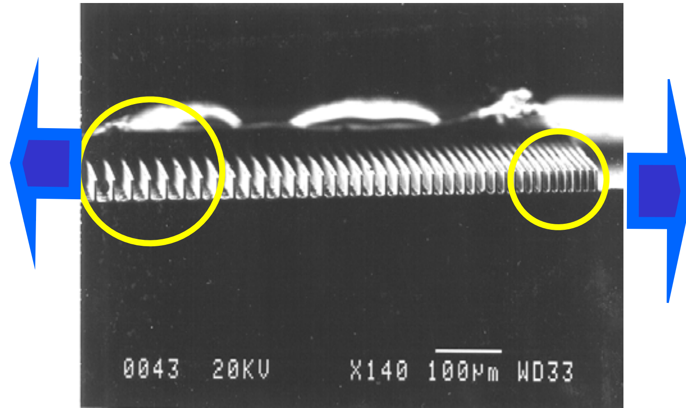
(110) Si Etching at 41 wt.% KOH at 65℃, 60 min.

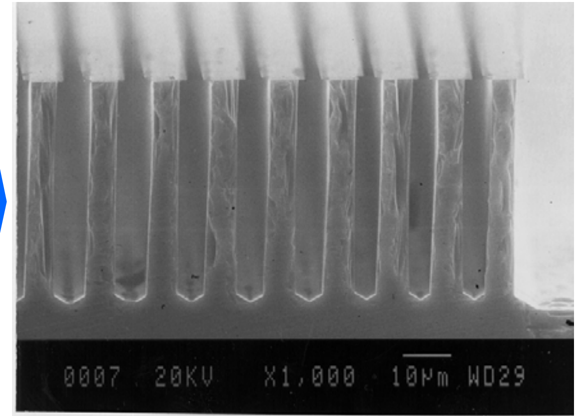
- Gap Variance

- 구조물의 폭 : 10㎛
- 간격 : 2㎛ ~10㎛ (step 1 ㎛), 12㎛ ~20㎛ (step 2 ㎛)



Gap : 18㎛ ~20㎛

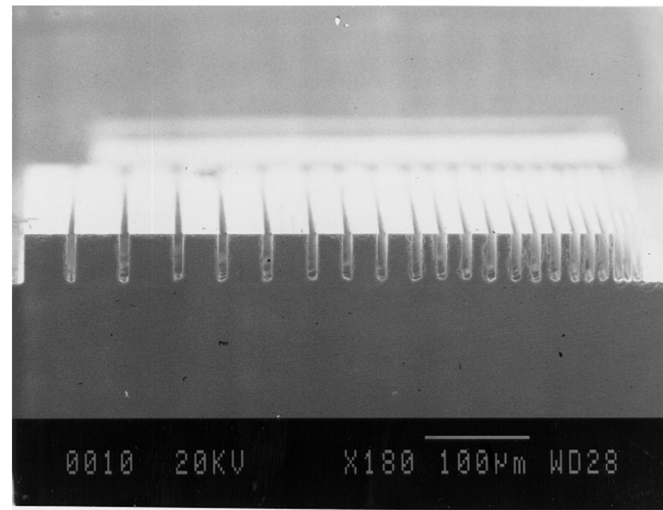




Gap : 2㎛ ~4㎛

- Width Variance

- 구조물의 폭 : 2㎛ ~50㎛
- 간격 : 5㎛



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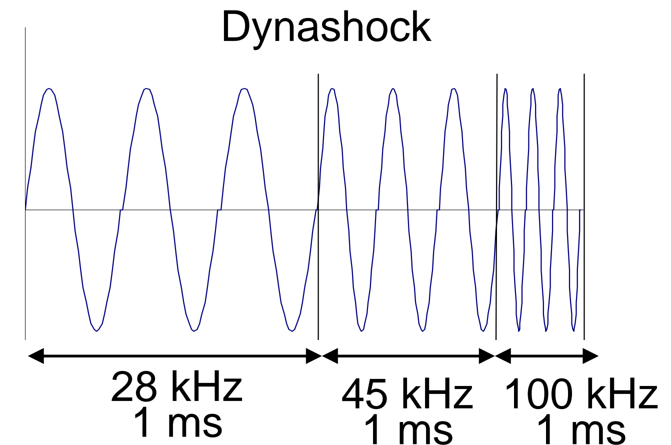
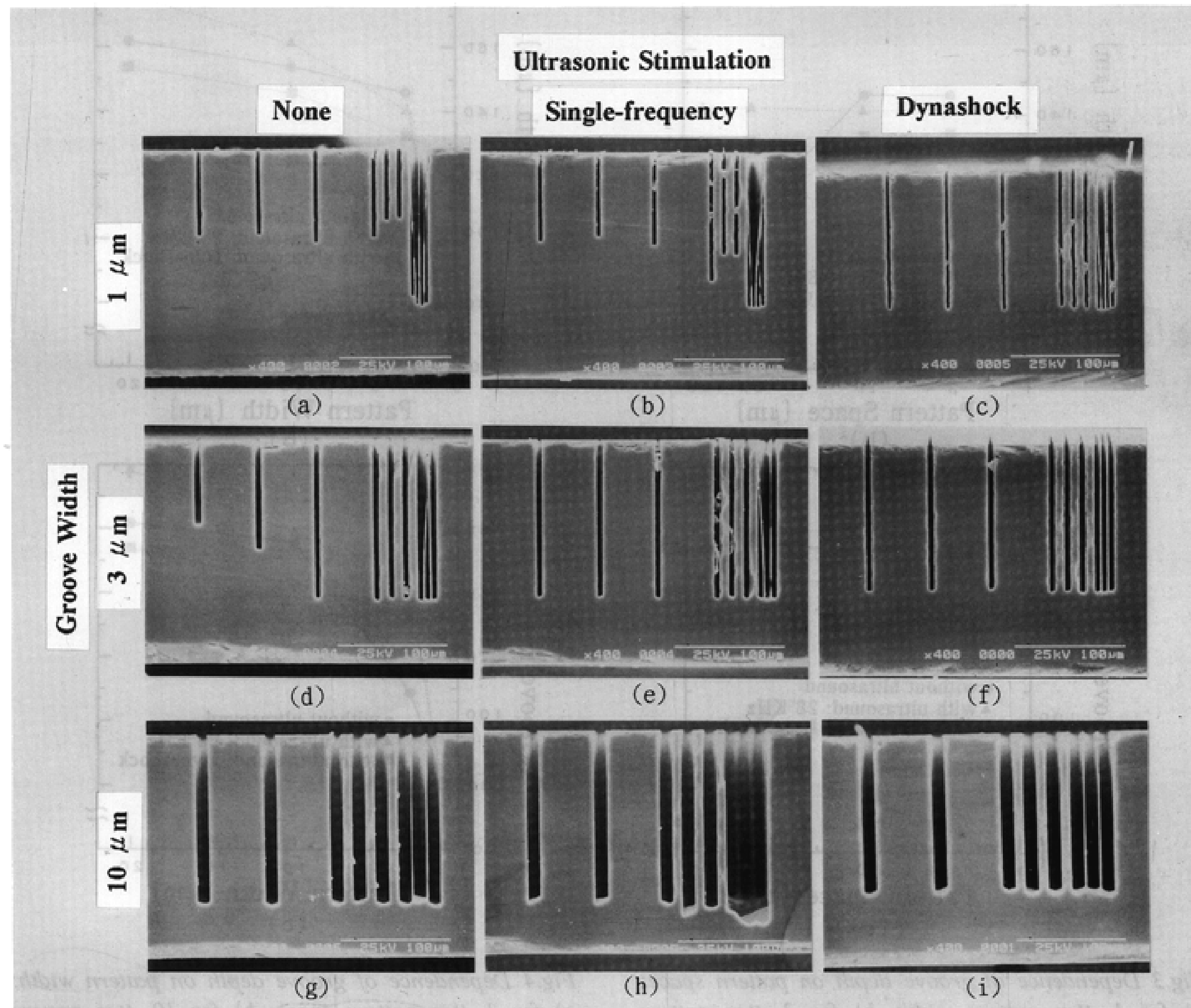
Ultrasonic Agitation in Wet Etching

- 습식 식각에서는 형상에 따라 식각이 달라지며, 기포의 masking에 의해 표면이 거칠게 되는 현상이 보인다.
- Geometry-dependent etching : 결정면의 이방성이 아니고 마스크의 구조물 크기와 이웃에 있는 식각되는 구조물 사이의 상호작용이 영향을 준다.
- Ohwada : (110) 실리콘의 깊고 좁은 홈의 식각율은 홈의 폭과 홈의 피치에 크게 영향을 받는다.
- 비슷한 효과는 plasma/RIE 식각에서 관찰된다. 이는 일반적으로 aperture effect와 국부적인 반응제의 결핍(local reactant depletion)에 기인한다.
- Ohwada : 28 kHz와 28, 45, 100 kHz의 초음파로 교반.

  Dynashock의 경우, 구조물의 크기나 피치 등이 식각율에 영향을 주지 않는다.
- Dynashock이 좋은 결과를 내는 이유는 반응부의 유체를 저어주는 standing wave가 움직이기 때문이다.



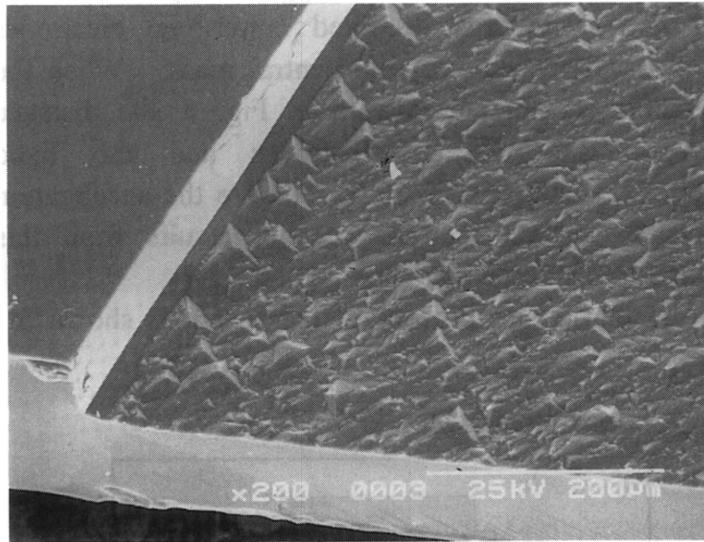
Ultrasonic Stimulation



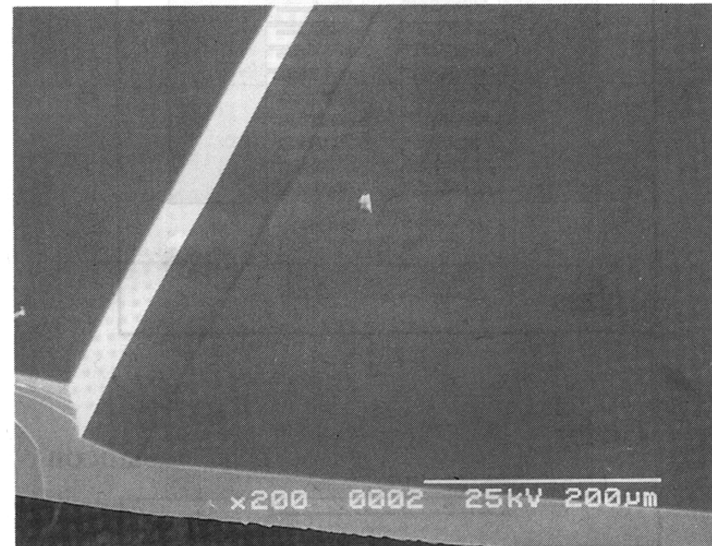
SEM cross-sections of grooves etched at 60 °C in KOH solution for 6 hours, showing the effect of varying groove widths and ultrasonic stimulation

Surface Roughness due to Micromasking

- 실리콘 식각시 수소 가스를 발생시키는 경우, 자주 발생.
- 이런 현상을 줄이는 방법.
  (1) 계면 활성제를 사용.
  (2) 초음파 처리.
  (3) 가스가 생기지 않게 화학적으로 처리.
- Ohwada : Dynashock를 사용, KOH etching시 깨끗한 표면을 얻었다.



(a)



(b)

SEM views of etched surface :a) without ultrasonic, b) with Dynashock ultrasound.