Etching

D. W. Parent

Etching Goals

- Primary goal is precisely transfer the features on the mask into the underlying material.
  - Hily selective against mask layer material
  - Highly selective again material under layer to be etched.
  - Should be uniform.
  - Etch rate should be as high as possible.
  - Process should be safe.
  - Should not cause damage to the substrate or devices
  - Etch residues should be easily removed.
  - Should be clean.
  - Conductive to full automation.

Topics

- Goals
- Definitions
- Wet Techniques
- Dry Techniques
- Our Process

Definitions

- Bias: Error in the lateral dimension of image transfer.
- Tolerance: Statistical variation of the bias
- Etch Rate: Rate of film removal
  - Vertical and Horizontal
- Anisotropy: How selective to direction the etch is.
  - Anisotropic: Etches is only on direction.
  - Isotropic: Etches in all directions equally.
- Selectivity: Ratio of etch rates to underlying material (Sfs) or ratio of etch rates to mask (Sfm)
- Over Etch: How much extra etching you have to perform to clear all etched areas on a wafer to take into account variences in the thickness and etch rates across the wafer, wafer to wafer or run to run.

Numerical Examples:

$Etch_Rate_Max := .2 \cdot 10^{-4} \frac{cm}{s}$

$Etch_Rate_Min := .1 \cdot 10^{-4} \frac{cm}{s}$

$$Etch_Rate_Uniformity := \frac{Etch_Rate_Max - Etch_Rate_Min}{Etch_Rate_Max + Etch_Rate_Min} \cdot 100$$

$Etch_Rate_Uniformity = 33.333$

$Horizontal_Etch_Rate := .2 \cdot 10^{-4} \frac{cm}{s}$

$Vertical_Etch_Rate := .2 \cdot 10^{-4} \frac{cm}{s}$

$L_R := \frac{Horizontal_Etch_Rate}{Vertical_Etch_Rate}$ $\quad L_R = 1$

$A := 1 - L_R$ $\quad A = 0$

Mean Thinckness $\quad h_f := .4 \cdot 10^{-4} cm$

Varation $\quad \delta := .1$ $\quad$ 10%

Mean Etch Rate $\quad \nu_f := .02 \cdot 10^{-4} \frac{cm}{s}$

Variation $\quad \phi_f := .1$

Maximum line width loss occurs where material is thicknest, etch rate is slowest, and thus the time is longest.

Fraction of ever etch time $\quad \Delta := .2$

$$t_c := \frac{h_f \cdot (1 + \delta) \cdot (1 + \Delta)}{\nu_f \cdot (1 - \phi_f)} \qquad t_c = 29.333\, s$$

The mask has a horizontal and vertical etch rate

$\nu_{ml} := .005 \cdot 10^{-4} \frac{cm}{s}$ $\qquad \nu_{mv} := .005 \cdot 10^{-4} \frac{cm}{s}$

Assume a 60 degree sidwall

$\theta := \frac{60}{180} \cdot \pi$ $\qquad \theta = 1.047$

Total line width loss

$$W := 2 \cdot \nu_{mv} \cdot h_f \cdot (1 + \delta) \cdot \frac{(1 + \Delta)}{\nu_f \cdot (1 - \phi_f)} \cdot \left(\cot(\theta) + \frac{\nu_{ml}}{\nu_{mv}} \right) \qquad W = 4.627 \times 10^{-5} cm$$

Wet Techniques

- HF for silicon dioxide or “Al” Etch for Al
- Selectivities over the mask and substrate are quite high.
- Cheap to buy and run
- Completely isotropic (Etches is all directions at the same time.)

Dry Techniques

- Reactive Ion Etch
  - Low pressure
  - Physical and chemical
  - Directional
  - More selective than sputtering
  - Radiation damage

Dry Techniques

- Plasma
  - higher pressure
  - chemical
  - Isotropic
  - Selective
  - No Radiation Damage

Our Process

- 45mTorr
- -600V
- 45ccm Triflouromethane (CHF_3)
- 8ccm oxygen
- Antisymetrical (RIE)
- Anisotropic
- Selective over Si

Some Reported Parameters

Material	Gas	Etch Rate	Etch Rate Ratio to other materials	To Resist
SiO_2	CHF_3	220	11(Si)	5.5
SiO_2	CHF_3	450	15 (poly-Si)	20
SiO_2	CHF_3	300	20 (Si)	13

H. Toyoda, Journal of Electronic Materials, no. 9, pp 569, (1980)

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