ME 517: Micro- and Nanoscale Processes

Lecture 5: Microfabrication - Techniques II

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Piezoresistivity

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$$\frac{\Delta\rho}{\rho} = \pi_{ll}\sigma_{ll} + \pi_{\perp}\sigma_{\perp}$$

ρ Resistance

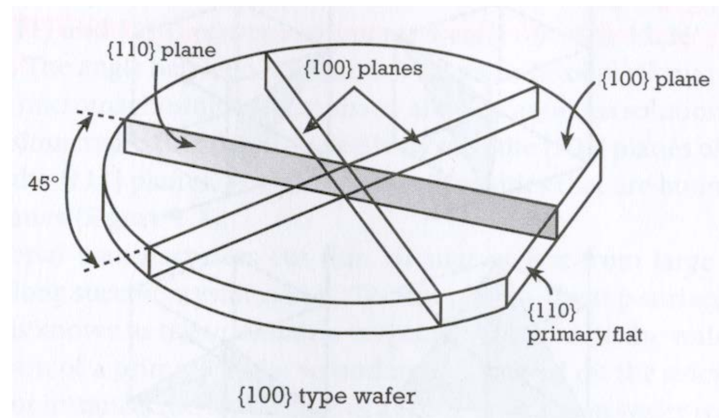
σ_{ll} Stress parallel to direction of the resistor

$\sigma_{\perp}$ Stress perpendicular to resistor

Single Crystal {100} Wafer

	$\pi_{//}$ (10^{-13} m^2/N)	$\pi_{\perp}$ (10^{-13} m^2/N)	
p-type	0	0	in <100> direction
	72	−65	in <110> direction
n-type	−102	53	in <100> direction
	−32	0	in <110> direction

* The values decrease precipitously at higher doping concentrations

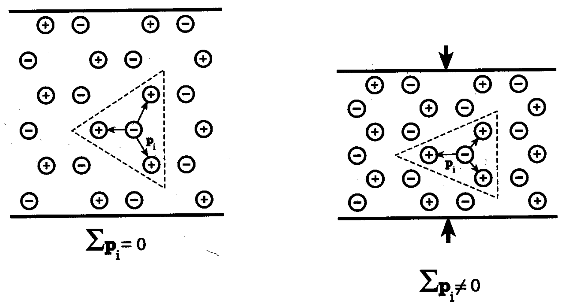


N. Maluf, Artech House, 2000.

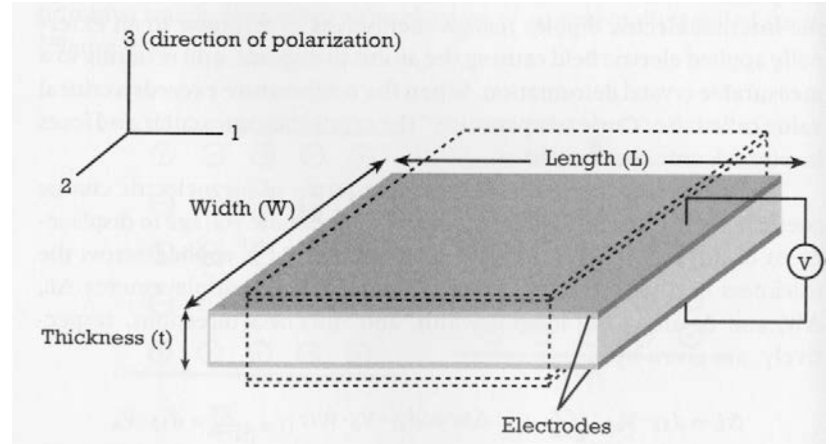
Polysilicon

Piezoresistance coefficients are smaller for polysilicon, but are not direction dependent and do not depend on temperature as strongly.

Piezoelectricity



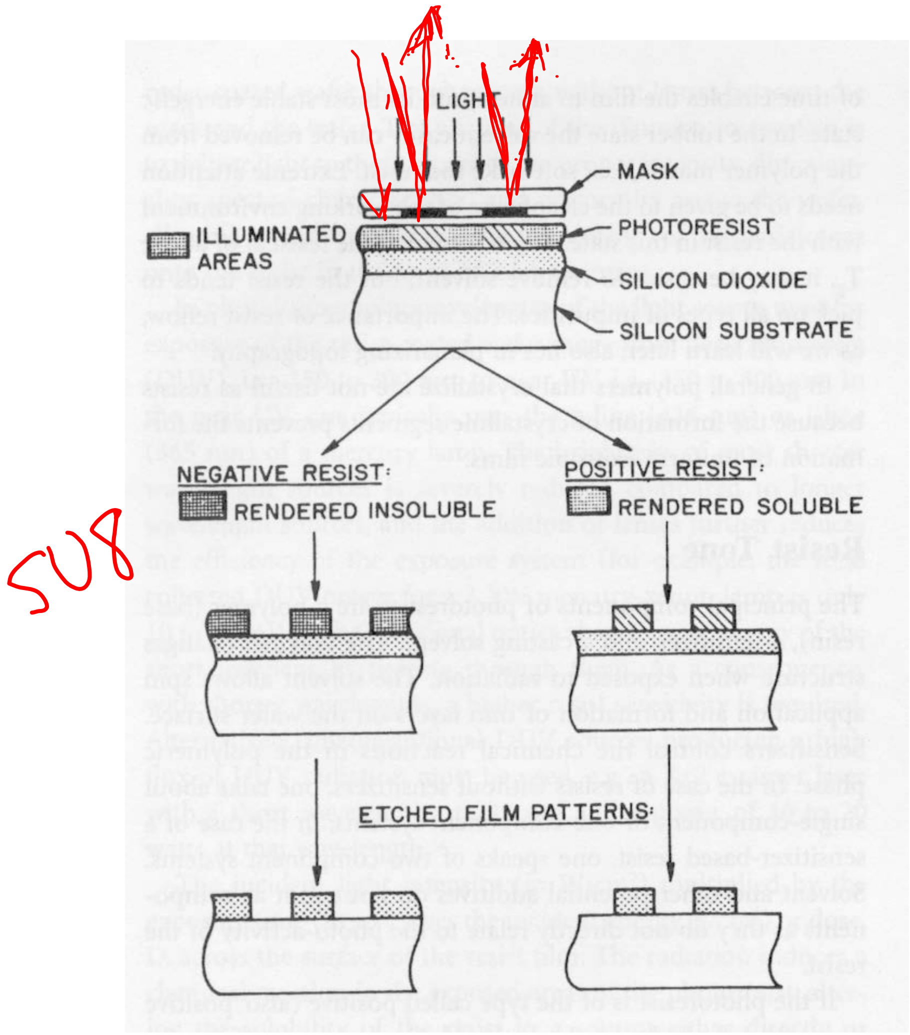
N. Maluf, Artech House, 2000.



Displacement Transducer	Force Sensor
$\Delta L = d_{31} V_a L / t$	$V_m = d_{31} \frac{F}{\varepsilon L}$
$\Delta W = d_{31} V_a W / t$	$V_m = d_{31} \frac{F}{\varepsilon W}$
$\Delta t = d_{33} V_a$	$Vm = d_{33} \frac{Ft}{\varepsilon LW}$

Material	**Piezoelectric Constant (d_{3n}) (10^{-12} C/N)**	**Relative Permittivity (ε)**	**Density (g/cm^3)**	**Young's Modulus (GPa)**	**Acoustic Impedance (10^6 kg/ $m^2 \cdot s$)**
Quartz	$d_{33} = 2.31$	4.5	2.65	107	15
Polyvinyledene -fluoride (PVDF)	$d_{31} = 23$ $d_{33} = -33$	12	1.78	3	2.7
$LiNbO_3$	$D_{31} = -4$, $d_{33} = 23$	28	4.6	245	34
BaTiO3	$d_{31} = 78$, $d_{33} = 190$	1,700	5.7		30
PZT	$D_{31} = -171$, $d_{33} = 370$	1,700	7.7	53	30
ZnO	$d_{31} = 5.2$, $d_{33} = 246$	1,400	5.7	123	33

Photolithography



Steps in Photolithography

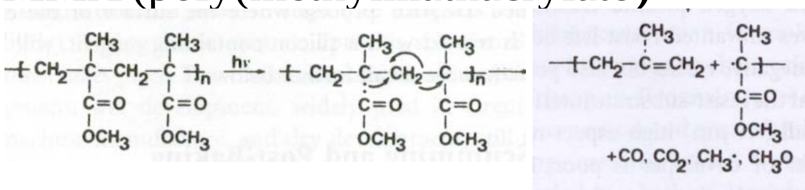
1. Design mask
2. Fabricate Mask
3. Grow an oxide
4. Spin coat a polymer resist on the wafer and bake.
5. Expose with Deep UV (150-300 nm) or UV (350-500 nm) light
6. Develop, descum, and bake.
7. Etch with HF or HF+ NF_4F
8. Strip etch with H_2SO_4 or oxygen plasma.

Brodie, I and J.J. Muray, The Physics of Microfabrication, Plenum, 1982.

Photoresists

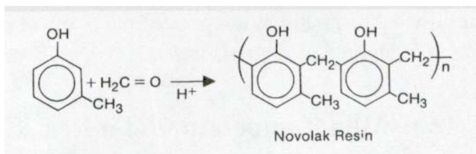
Positive Photoresists (irradiated polymer is rendered soluble)

PMMA (poly(methylmathacrylate)

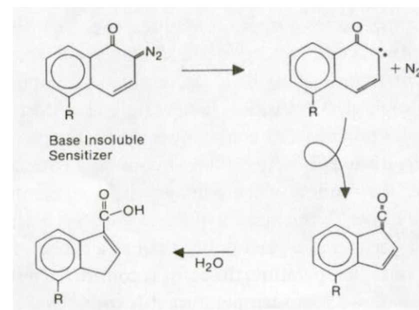


DQN (diazoquinone ester) and phenolic novolak resin (N)

N



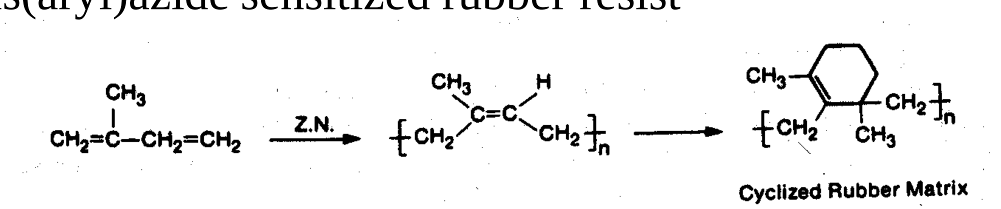
DQN



Negative Photoresist (irradiated polymer is rendered insoluble)

Bis(aryl)azide sensitized rubber resist

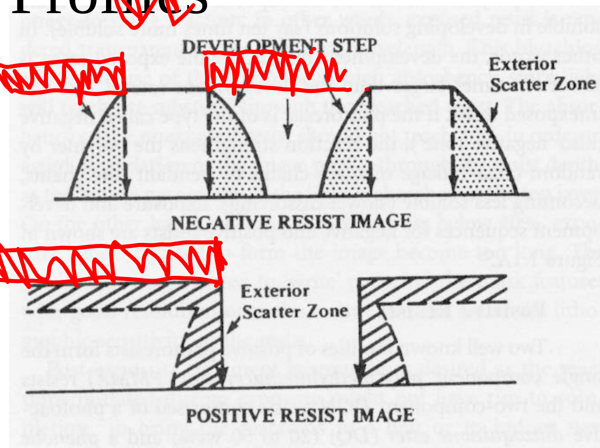
SU8



M.Madou, Fundamental of Microfabrication, CRC, 1997.

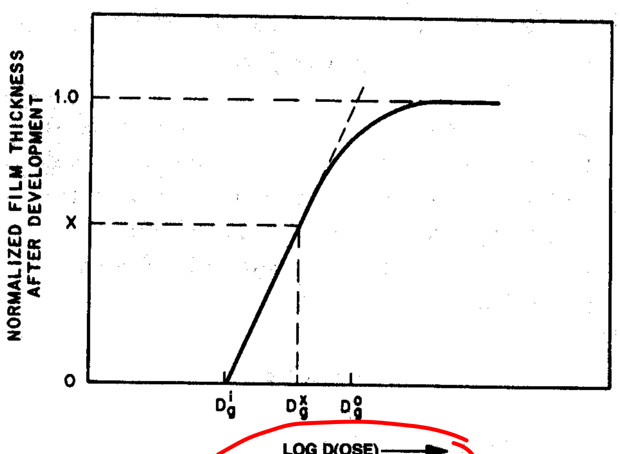
Photoresist Sensitivity

Typical Profiles



Brodie, I and J.J. Muray, The Physics of Microfabrication, Plenum, 1982.

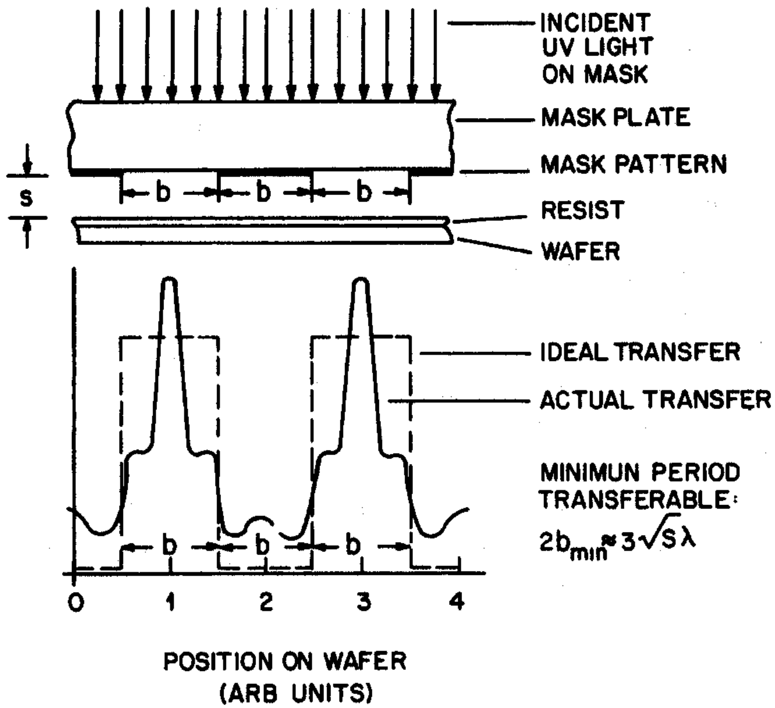
Typical Response Curve of a Negative Resist



Definition of contrast

$$\gamma_p \equiv \frac{1}{\log D_g^o - \log D_g^i}$$

Lithography Resolution



C.G. Wilson, in Introduction to Microlithography, Thompson, L.F., Willson, C.G., and Bowden, M.J., ACS, 1994.

$$2b_{\min} = 3\sqrt{\lambda\left(s + \frac{Z}{2}\right)}$$

Contact Printing

$s = 0$
λ =400 nm
Z = 1000 nm (photoresist thickness)
$b_{\min}$ ~ 750 nm

Proximity Printing

$$2b_{\min} = 3\sqrt{\lambda s}$$

$b_{\min}$ ~ 2,000 nm