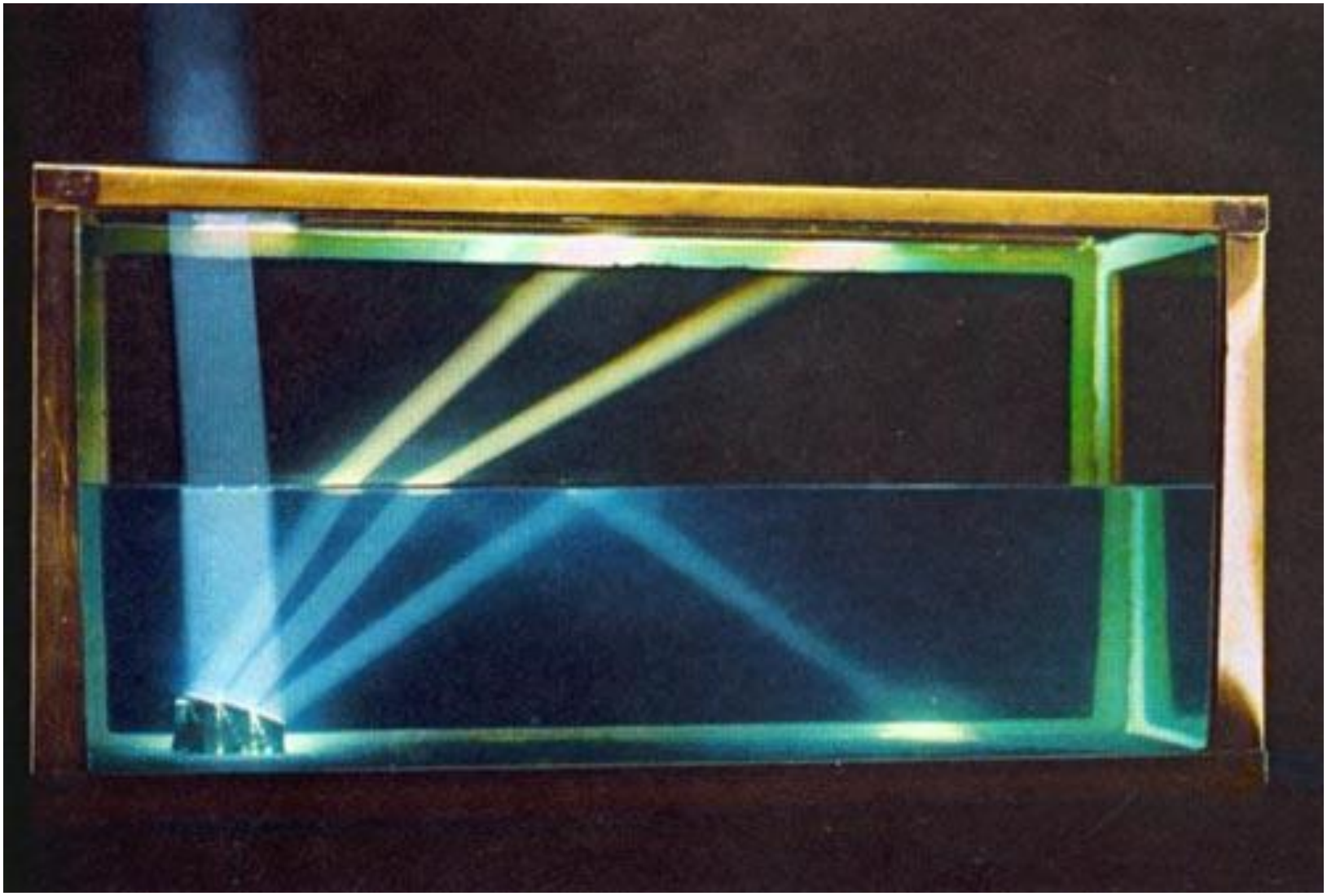
Optics for light propagation and detection

경북대학교 물리학과
여준엽

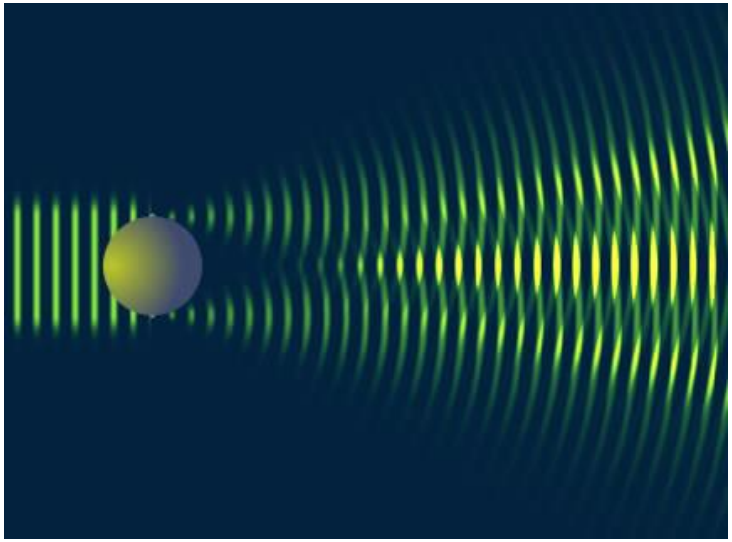
Light propagation and detection

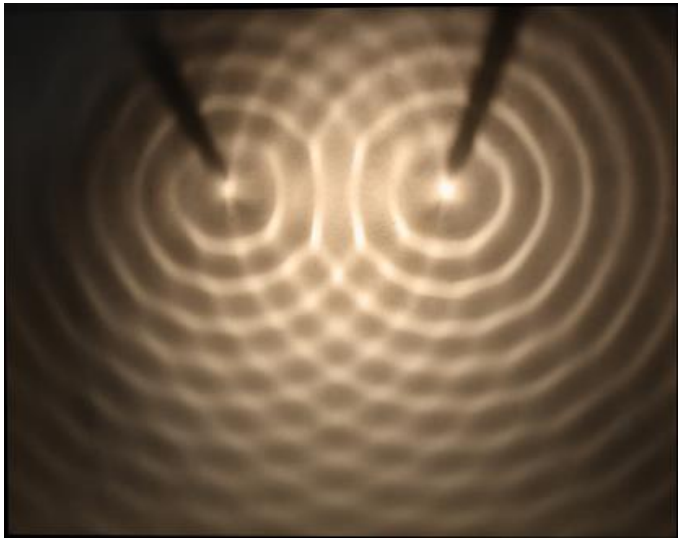
Refraction and reflection



Dispersion

Diffraction and inteference

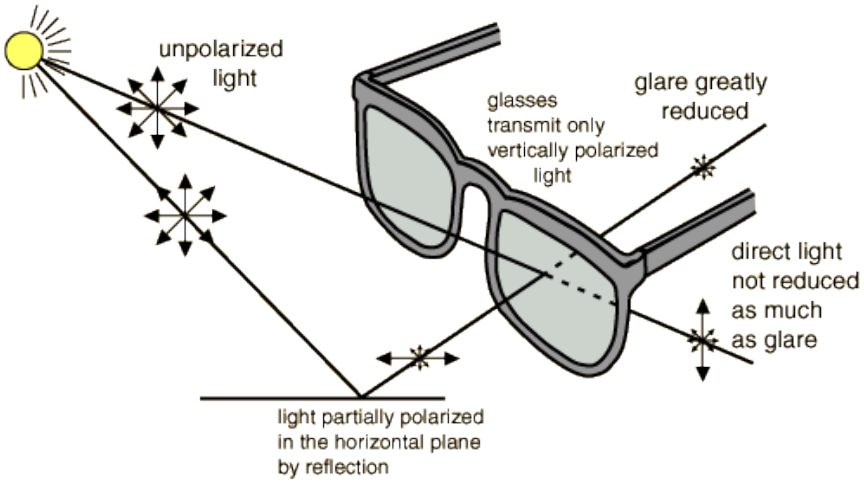


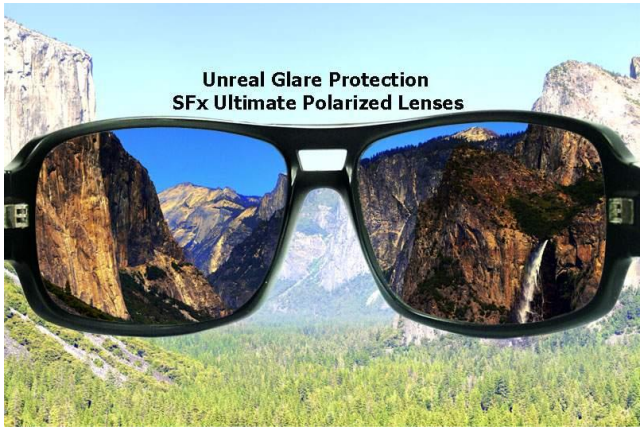


Scattering

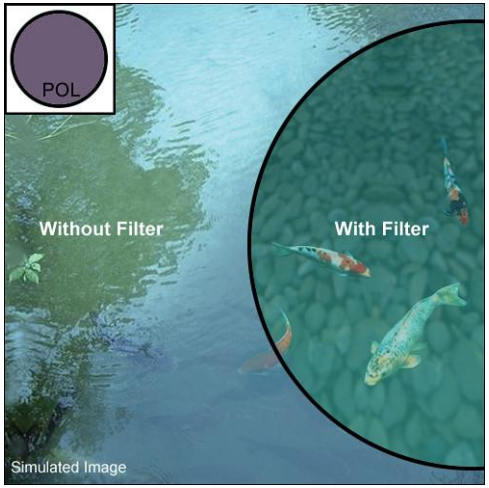
Polarization

선글라스 (Sunglass)



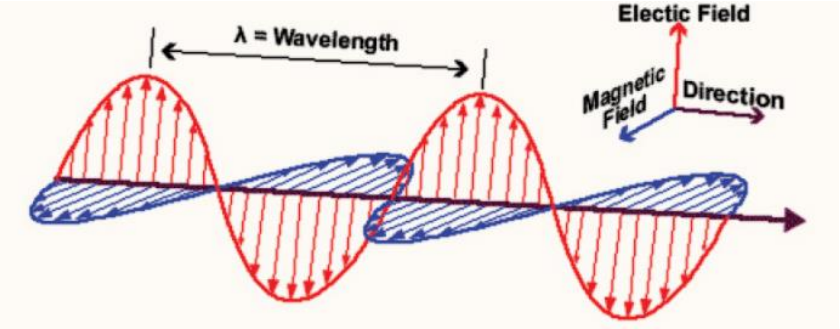


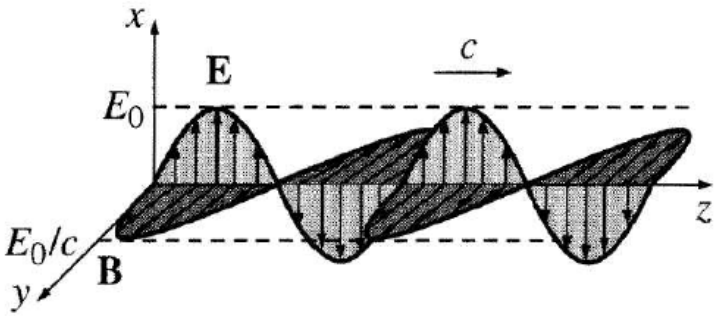
카메라 편광 필터 (DSLR polarizer filter)



Intensity

Intensity (빛의 세기)





1. 빛 = 전자기파

$$\mathbf{S} = \frac{1}{\mu_0}(\mathbf{E} \times \mathbf{B})$$

2. Poynting Vector (에너지 흐름 밀도)
단위시간에 단위 면적을 지나가는 전자기파에 실린 에너지

$$I \equiv \langle S \rangle = \frac{1}{2} c \epsilon_0 E_0^2$$

3. Irradiance (빛의 세기)
전자기파가 단위 면적에 실어오는 평균 일률 (시간 평균값)

출처: 기초전자기학 (Introduction to electrodynamics, David J. Griffiths)

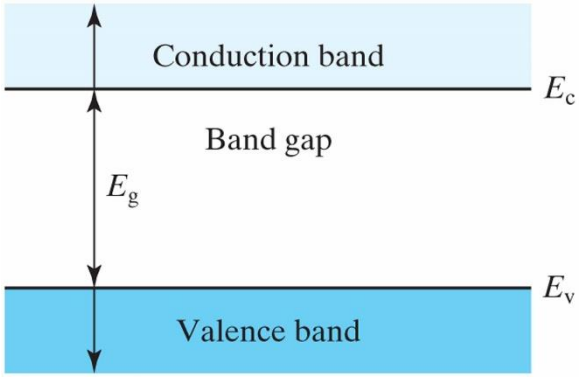
Detection

How to measure light intensity?

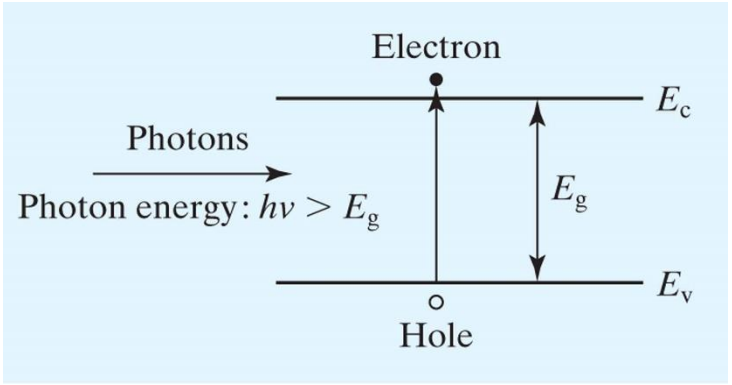
Detection

How to measure light intensity?

소자 (매질) 내부의 밴드갭 (Bandgap)



반도체의 에너지 밴드 다이어그램



빛 검출기, 광전도체 (Photoconductor)

반도체들의 밴드 갭 에너지

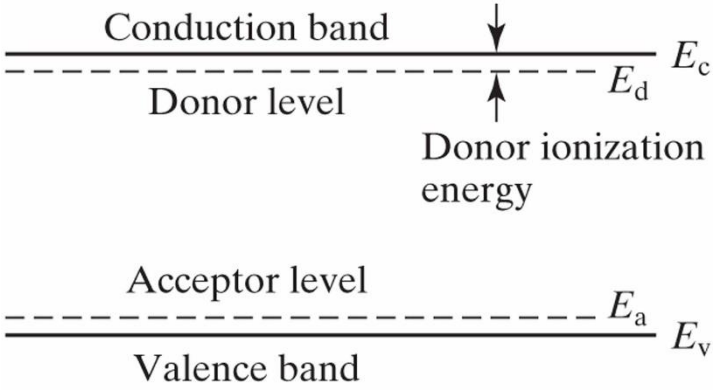
TABLE 1–1 • Band-gap energies of selected semiconductors.

Semiconductor	InSb	Ge	Si	GaAs	GaP	ZnSe	Diamond
E_g (eV)	0.18	0.67	1.12	1.42	2.25	2.7	6.0

Detection

How to measure light intensity?

도핑 (doping) 과 도너/억셉터



도너와 억셉터의 에너지 준위

구리나 금과 같은 불순물을 첨가하면 생성.
이들은 매우 다른 방법으로 실리콘 특성에 영향을 줌

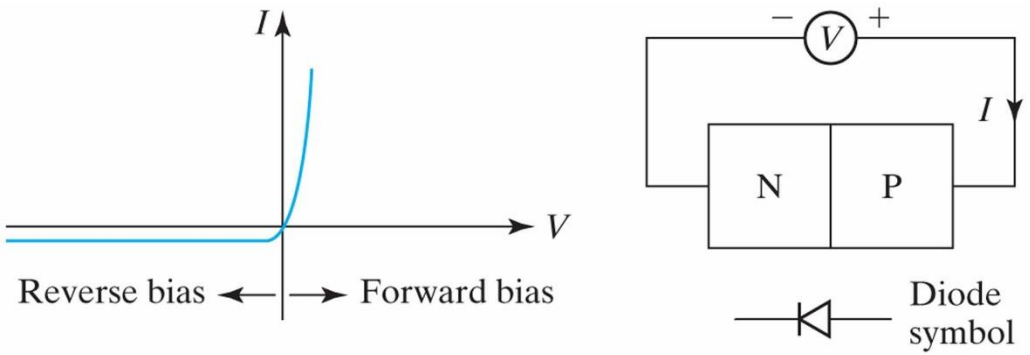
TABLE 1–2 • Ionization energy of selected donors and acceptors in silicon.

	Donors			Acceptors		
Dopant	Sb	P	As	B	Al	In
Ionization energy, $E_c - E_d$ or $E_a - E_v$ (meV)	39	44	54	45	57	160

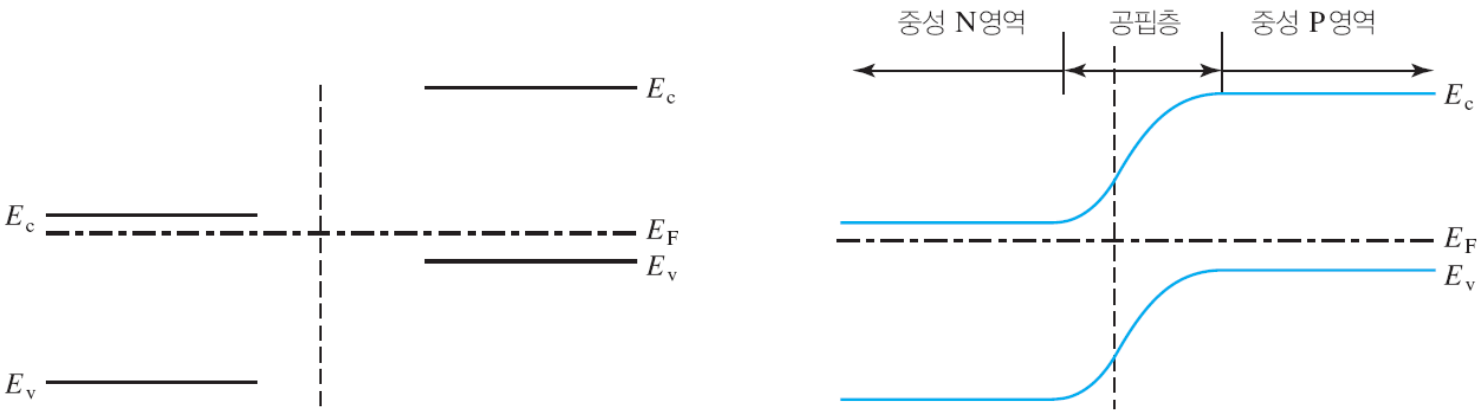
실리콘의 경우 선택된 도너와 억셉터들의 이온화 에너지

Detector (PN junction, Diode)

PN junction



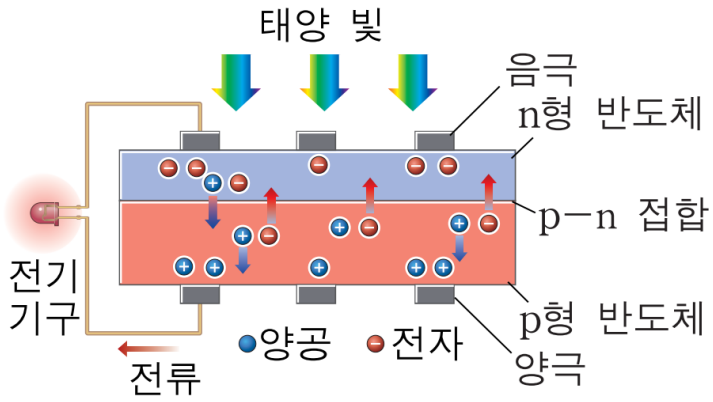
PN 접합의 정류성 IV 특성

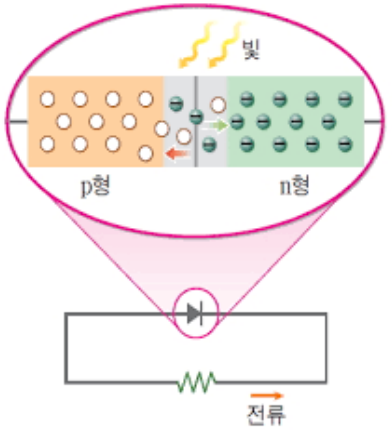


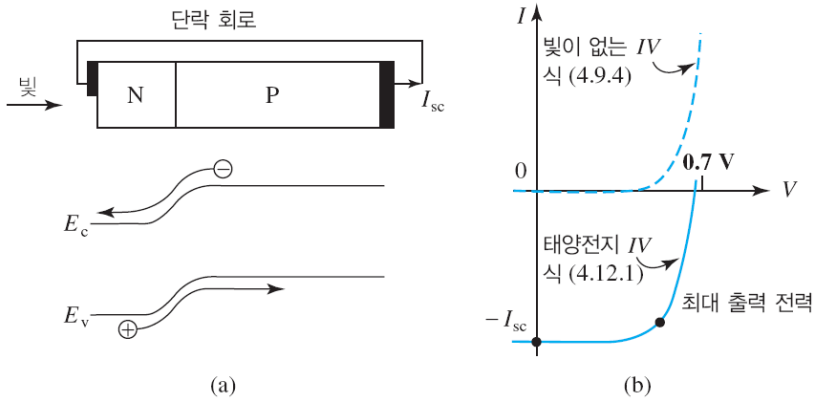
PN 접합의 밴드 다이어 그램

Detector (PN junction, Diode)

Photo diode, Photovoltaic







$$I = I_0(e^{qV/kT} - 1) - I_{sc}$$

총 다이오드 전류 = 전압에의해 생성된 전류 + 빛에 의해 생성된 전류

PN 접합에서 역방향 전류 발생

Lithography

Photo-Lithography

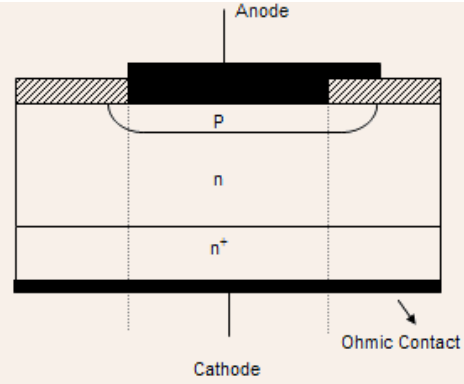
How to make the PN junction?

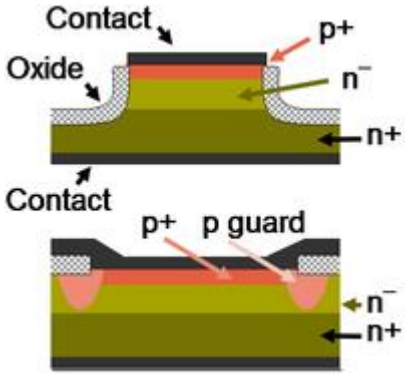
How to realize the PN junction experimentally?

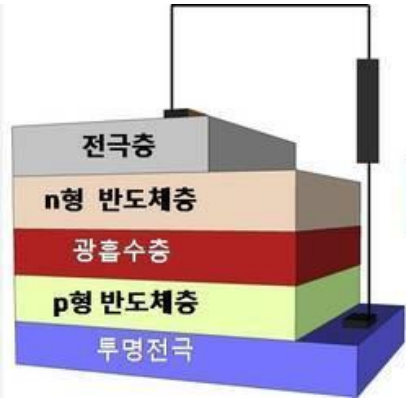
Photo-Lithography

How to make the PN junction?

How to realize the PN junction experimentally?







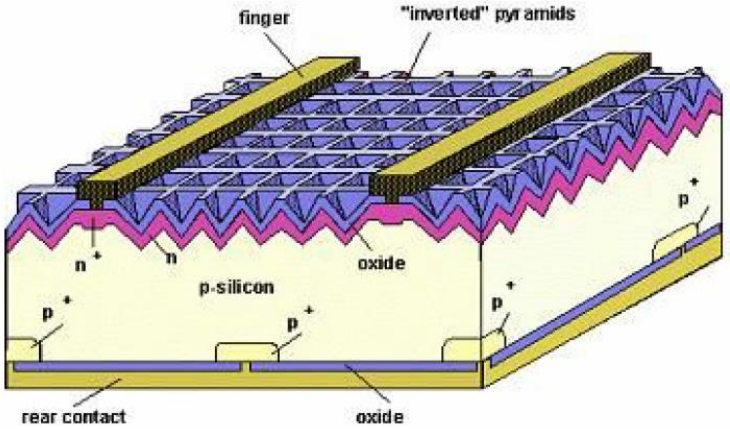
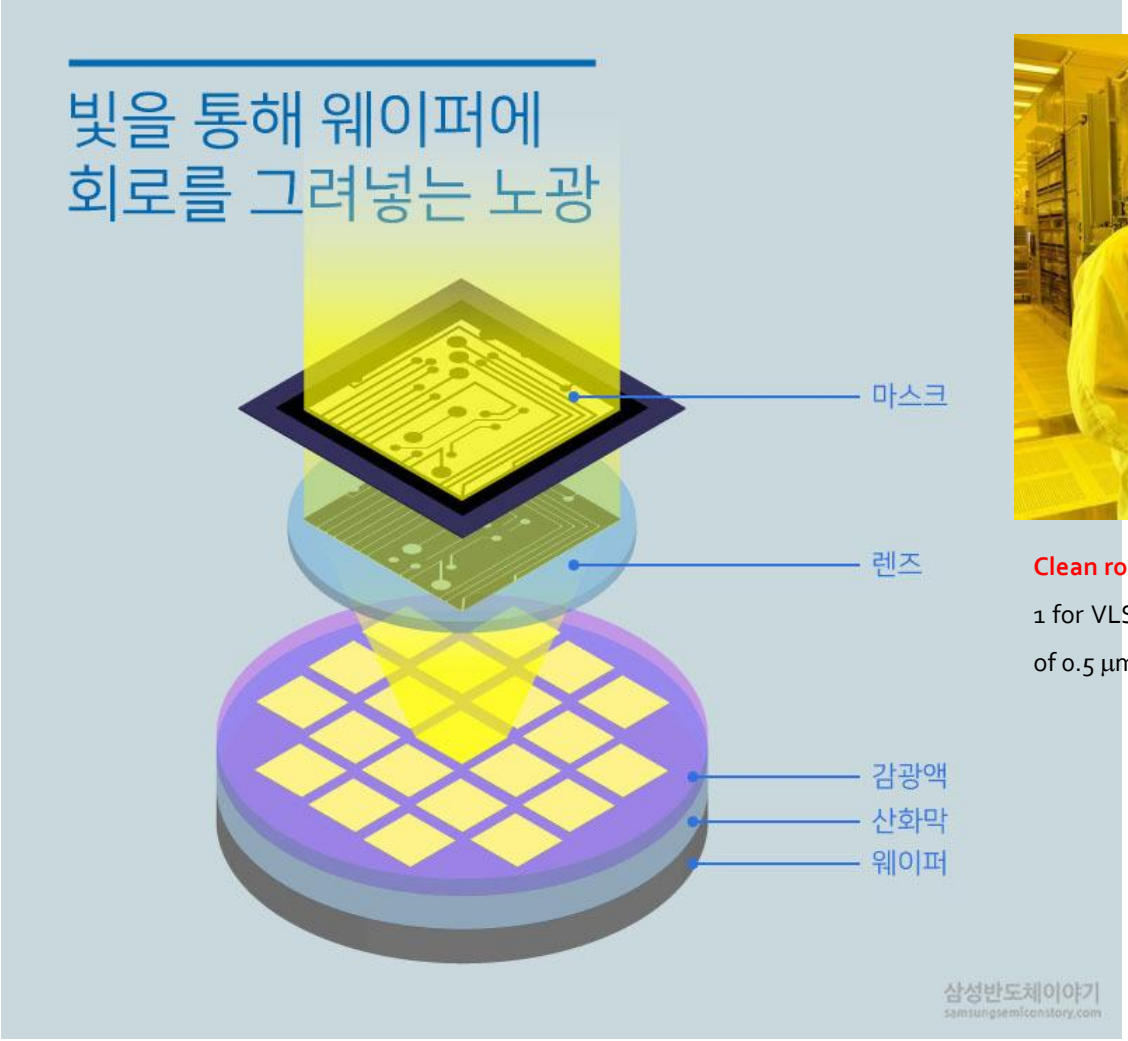
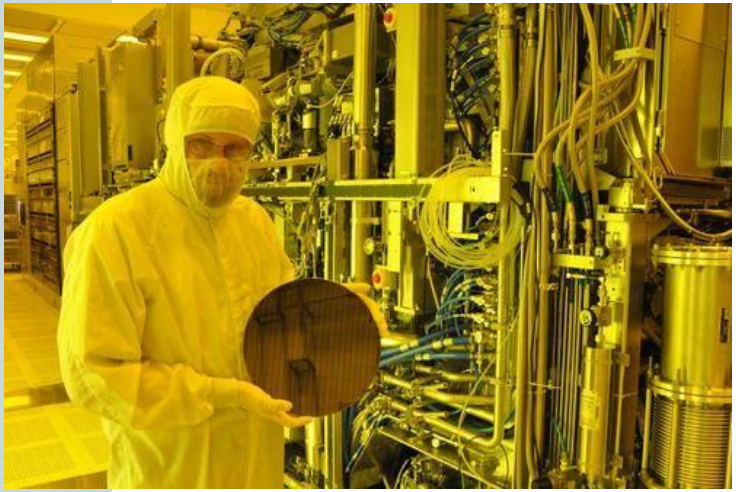


Photo-Lithography





Clean room class : have evolved from the Class 10,000 to Class 1 for VLSI (ULSI) processing. - No. of particle exceeding a size of 0.5 μm per ft^3

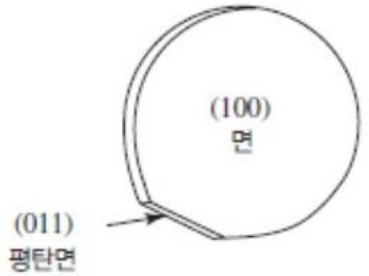
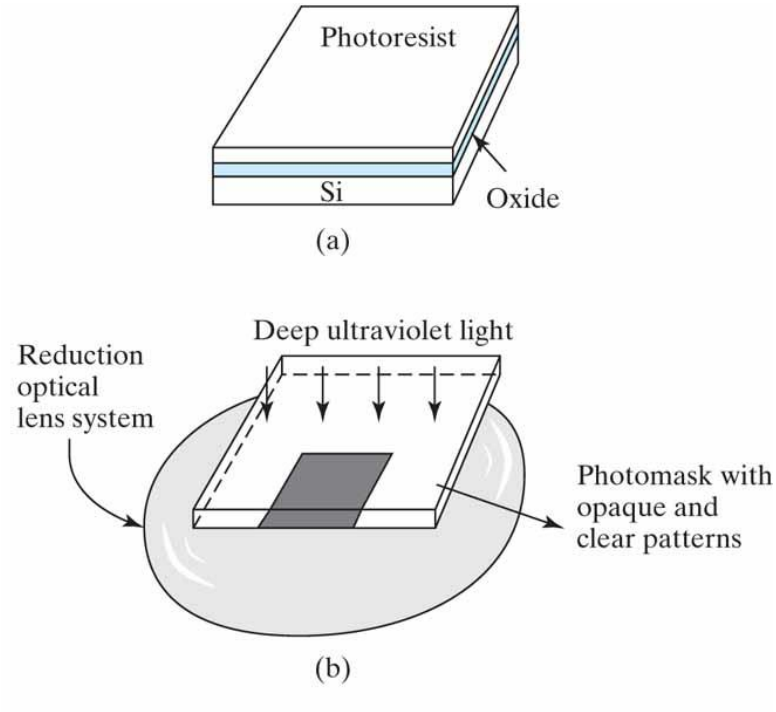
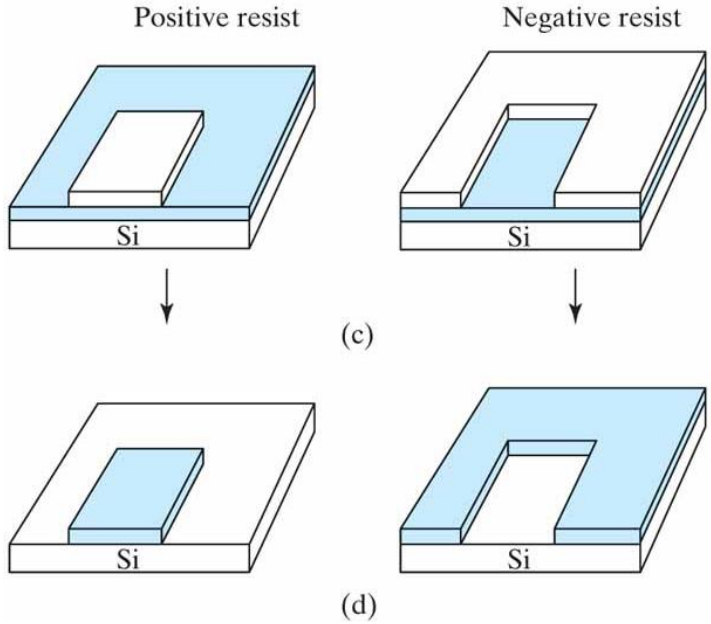


Photo-Lithography

Step of photolithography process





Major steps in the lithography process:
(a) application of resist;
(b) resist exposure through a mask and an optical reduction system;
(c) after development of exposed photoresist;
(d) after oxide etching and resist removal.

Photo-Lithography

Step of photolithography process

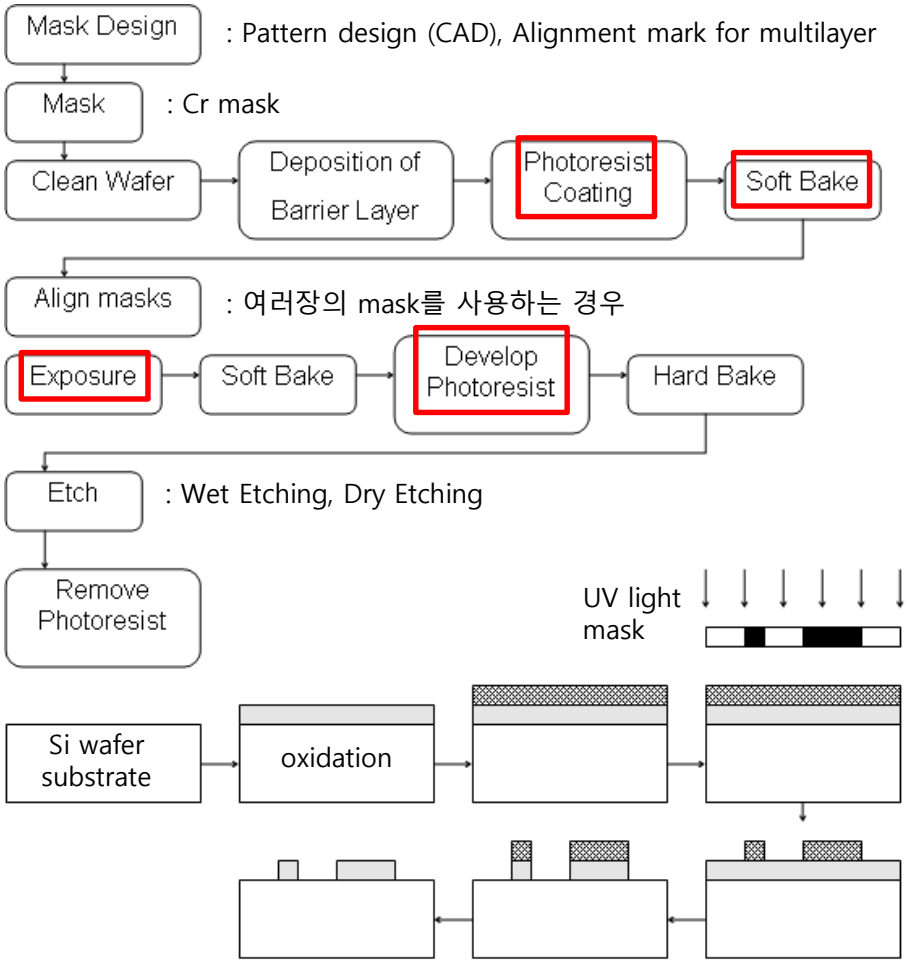
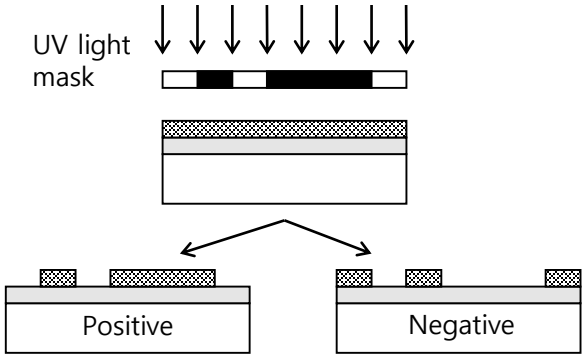


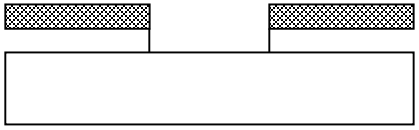
Photo-Lithography

Etching (Wet, Dry)



Exposure and Development :
The wavelength of the light source ranges from deep UV,
i.e. 150 - 300 nm, to near UV, i.e. 350 - 500 nm.
In the near UV, **G-line**, 436 nm, and **I-line**, 365 nm, are typically used.

Wet etching
isotropic process, solution process

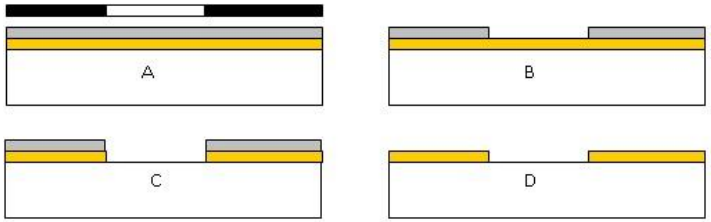


Dry etching
Highly an-isotropic etching , VLSI fabrication, Plasma etching

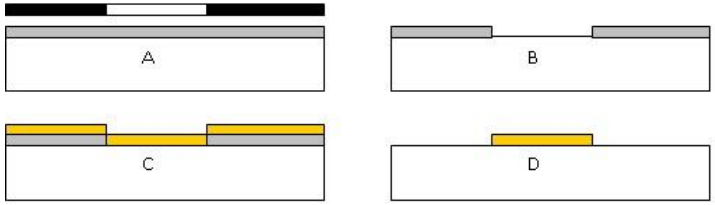
Photo-Lithography

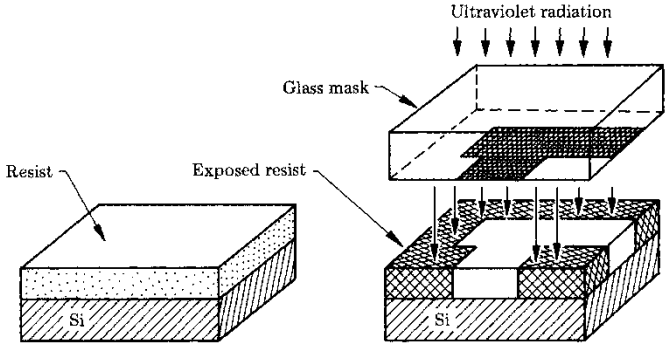
Metal patterning

Conventional lithography



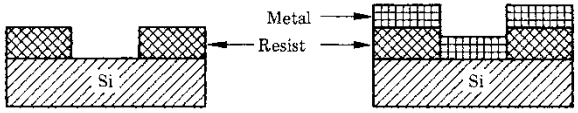
Lift-off process





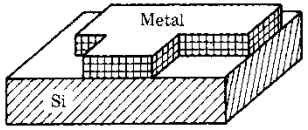
(a) Coat with photoresist

(b) Expose photoresist (negative, bonds cross-link)



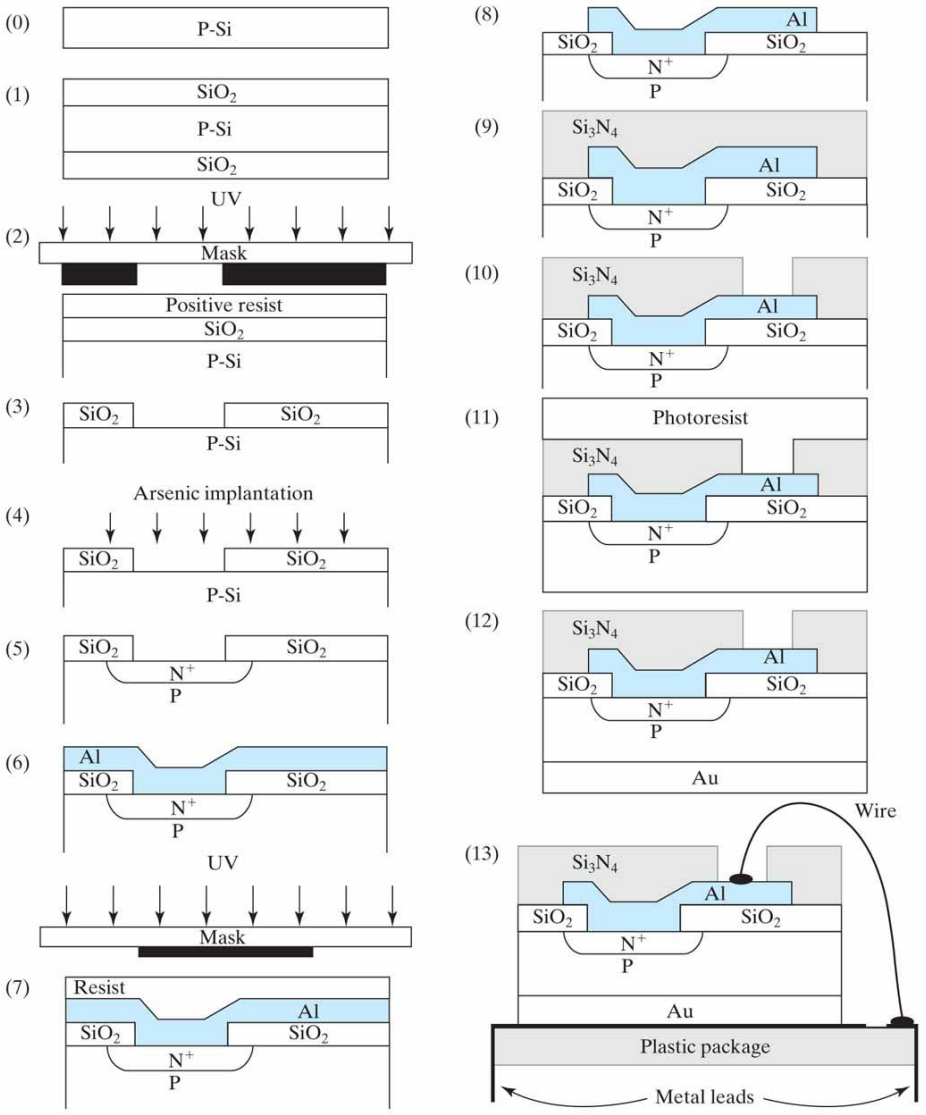
(c) Remove *unexposed* resist

(d) Deposit metal film



(e) Remove resist and metal on resist—metal pattern remains on Si

Photo-Lithography



Graphical summary of
the major processing steps
in the formation of a PN junction diode.
(0) Start;
(1) oxidation;
(2) lithography;
(3) oxide etching;
(4) As implantation;
(5) annealing and diffusion;
(6) sputtering Al;
(7) lithography;
(8) metal etching;
(9) CVD nitride deposition;
(10) lithography and bonding window etching;
(11) removal of oxide from back side of wafer;
(12) deposition of Au on back side; and
(13) dicing and packaging.

감사합니다