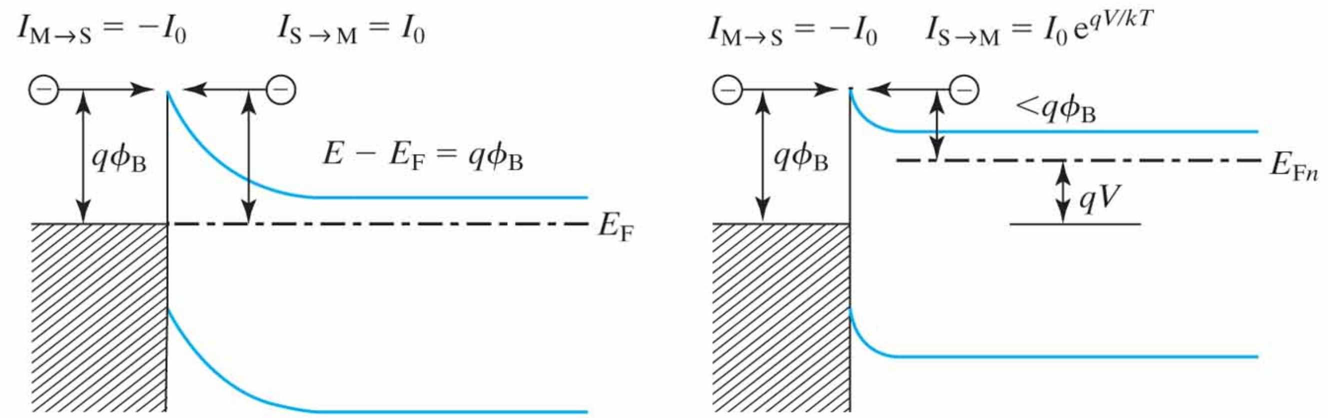
Fråga 81

- En pn-övergång backspänns -0.6 V. $I_o=10^{-12}$ A. Beräkna strömmen I som går genom pn-övergången.

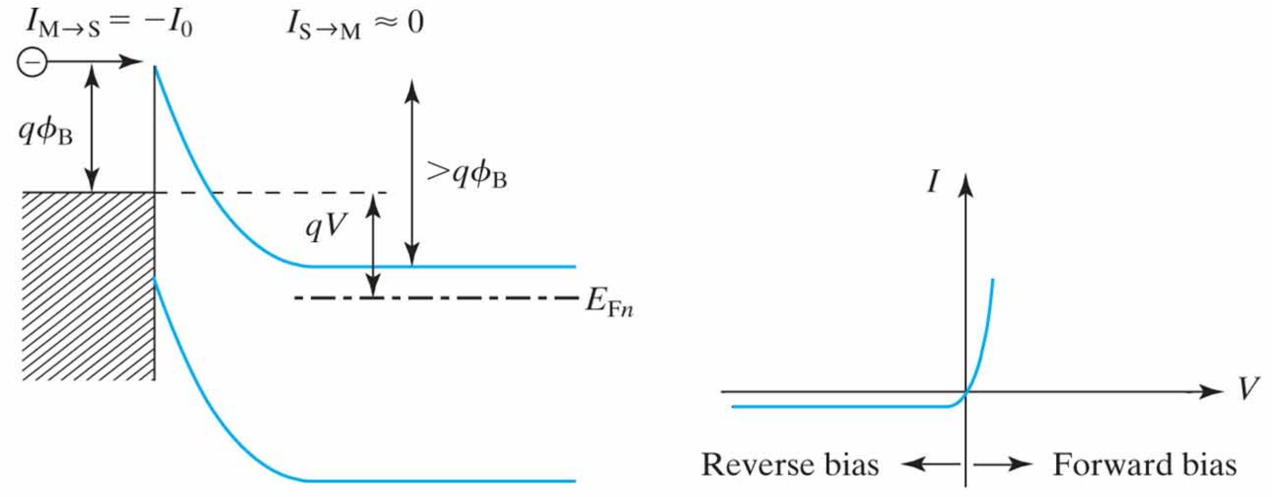
A) $I=1$ A
B) $I=10^{-12}$ A
C) $I=11$ mA
D) $I=8 \cdot 10^{-23}$ A

Figure 4.39 Explanation of the rectifying *IV* characteristics of Schottky diodes. The arrows in the subscripts indicate the direction of electron flows.



(a) $V = 0$. $I_{S\to M} = |I_{M\to S}| = I_0$

(b) Forward bias. Metal is positive wrt Si. $I_{S\to M} \gg |I_{M\to S}| = I_0$



(c) Reverse bias. Metal is negative wrt Si. $I_{S\to M} << |I_{M\to S}| = I_0$

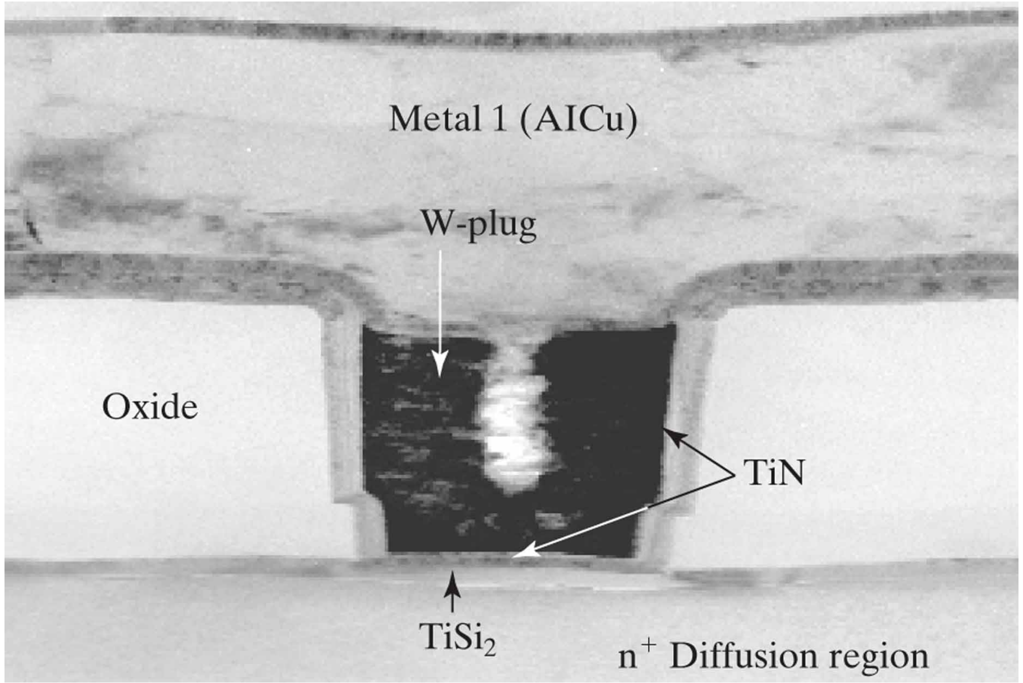
(d) Schottky diode *IV*.

TABLE 4–4 Measured Schottky barrier heights for electrons on N-type silicon (ϕ_{Bp}) and for holes on P-type silicon (ϕ_{Bp}). (From [7].)

Metal	**Mg**	**Ti**	**Cr**	**W**	**Mo**	**Pd**	**Au**	**Pt**
ϕ_{Bn} (V)	0.4	0.5	0.61	0.67	0.68	0.77	0.8	0.9
ϕ_{Bp} (V)		0.61	0.50		0.42		0.3	
Work Function ψ_M (V)	3.7	4.3	4.5	4.6	4.6	5.1	5.1	5.7

TABLE 4–5 Measured Schottky barrier heights of metal silicide on Si.

Silicide	**$ErSi_{1.7}$**	**HfSi**	**$MoSi_2$**	**$ZrSi_2$**	**$TiSi_2$**	**$CoSi_2$**	**WSi_2**	**$NiSi_2$**	**Pd_2Si**	**PtSi**
ϕ_{Bn} (V)	0.28	0.45	0.55	0.55	0.61	0.65	0.67	0.67	0.75	0.87
ϕ_{Bp} (V)			0.55	0.55	0.49	0.45	0.43	0.43	0.35	0.23


Metal 1 (AlCu)
W-plug
Oxide
TiN
TiSi$_2$
n$^+$ Diffusion region

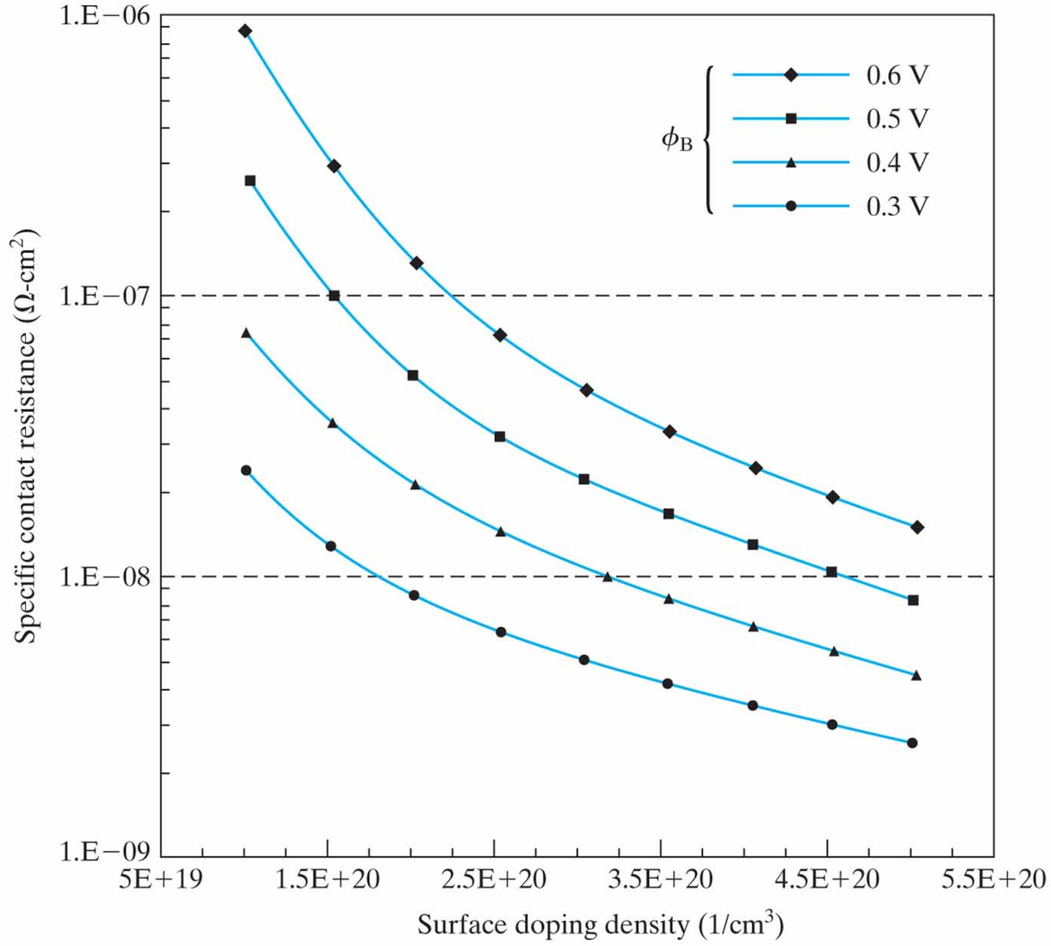
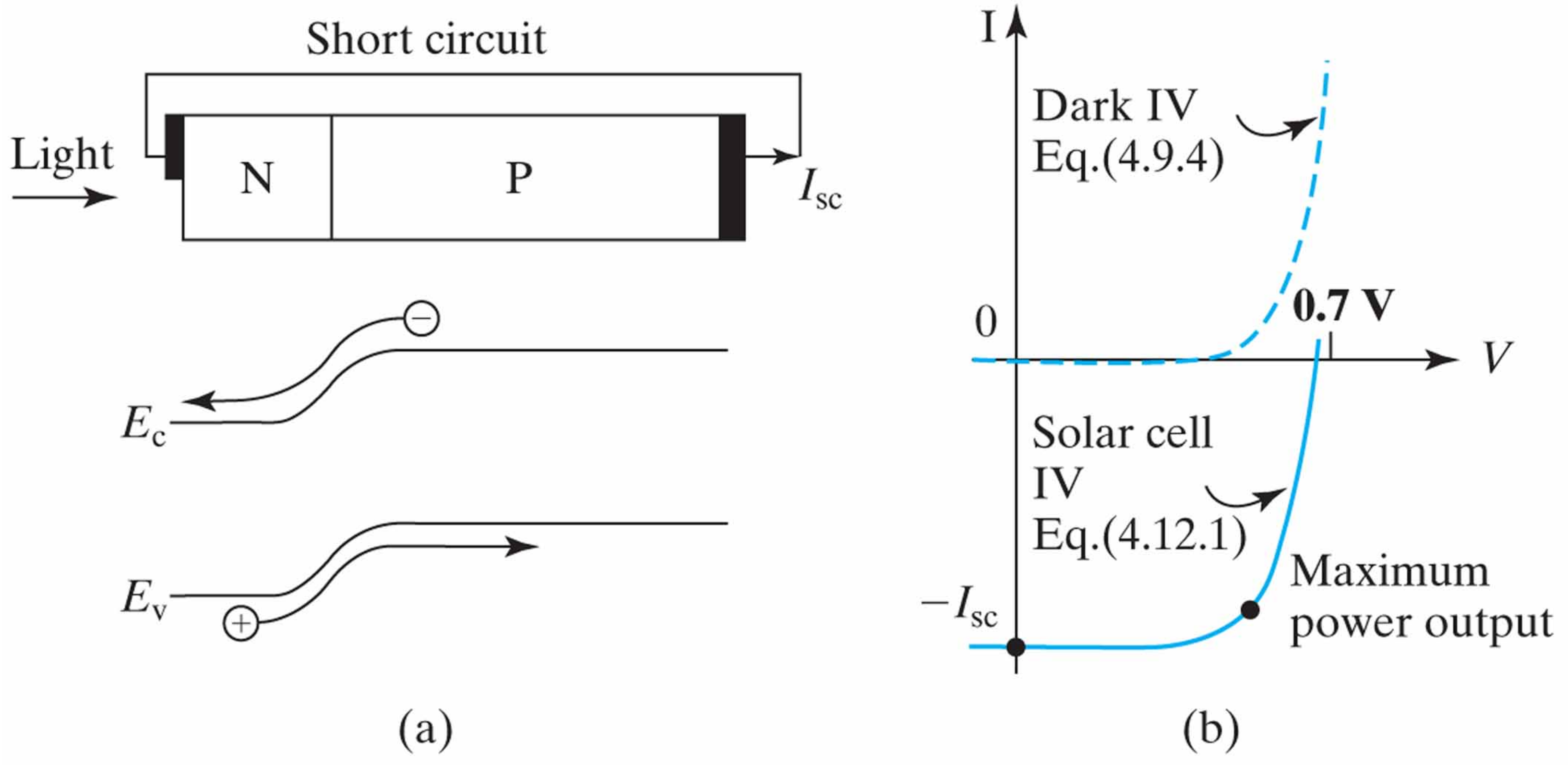

1.E−06
1.E−07
1.E−08
1.E−09
Specific contact resistance (Ω-cm^2)
5E+19
1.5E+20
2.5E+20
3.5E+20
4.5E+20
5.5E+20
Surface doping density (1/cm^3)
ϕ_B
0.6 V
0.5 V
0.4 V
0.3 V

Figure 4.25 (a) Light can produce a current in PN junction at $V = 0$. (b) Solar cell IV product is negative, indicating power generation. (After [4].)



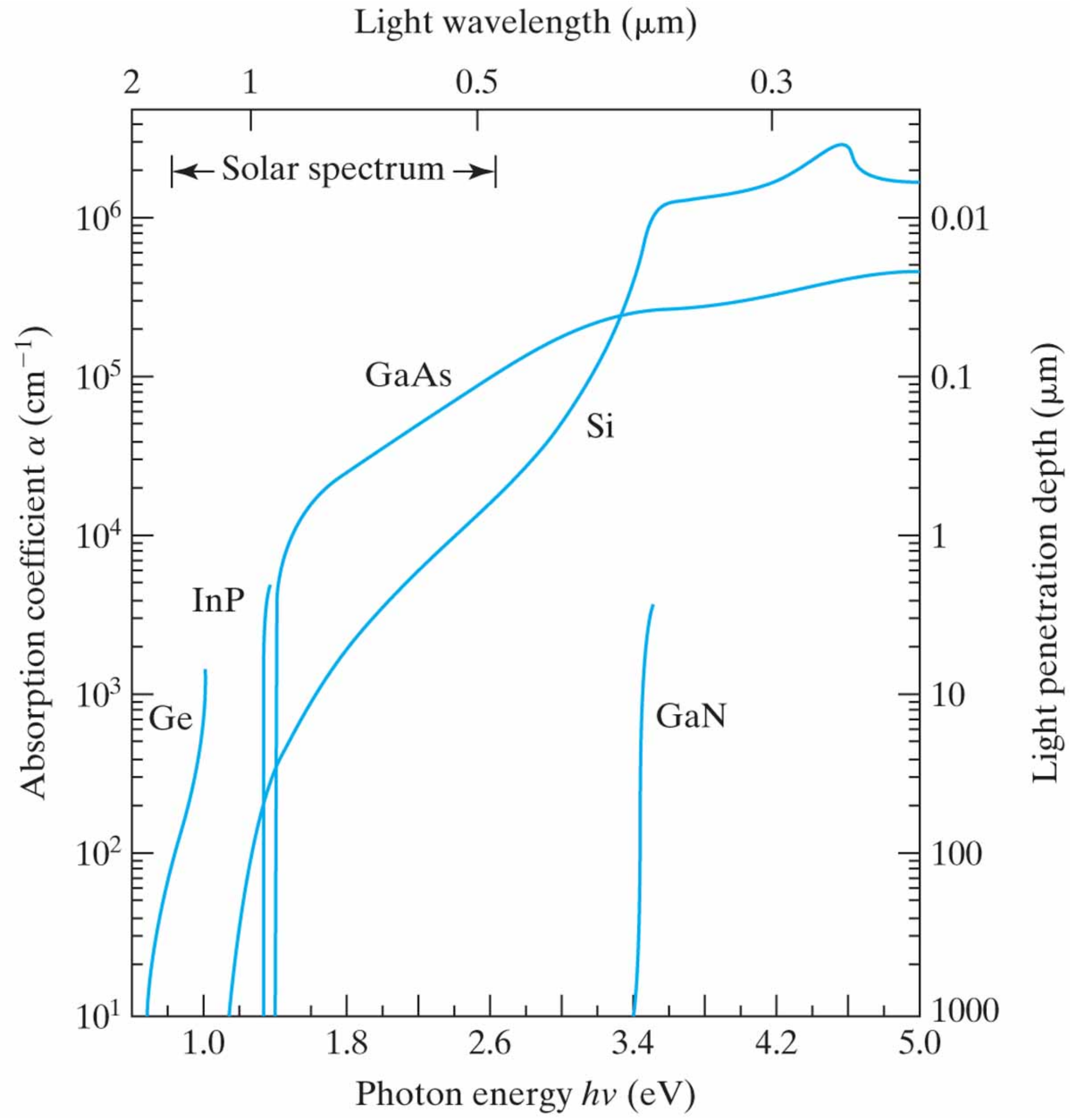

Light wavelength (μm)
2
1
0.5
0.3
Solar spectrum
10^6
10^5
10^4
10^3
10^2
10^1
Absorption coefficient α (cm^{-1})
0.01
0.1
1
10
100
1000
Light penetration depth (μm)
GaAs
Si
InP
Ge
GaN
1.0
1.8
2.6
3.4
4.2
5.0
Photon energy $h\nu$ (eV)

Figure 4.27 The *E–k* diagrams of (a) direct-gap semiconductor and (b) indirect-gap semiconductor.

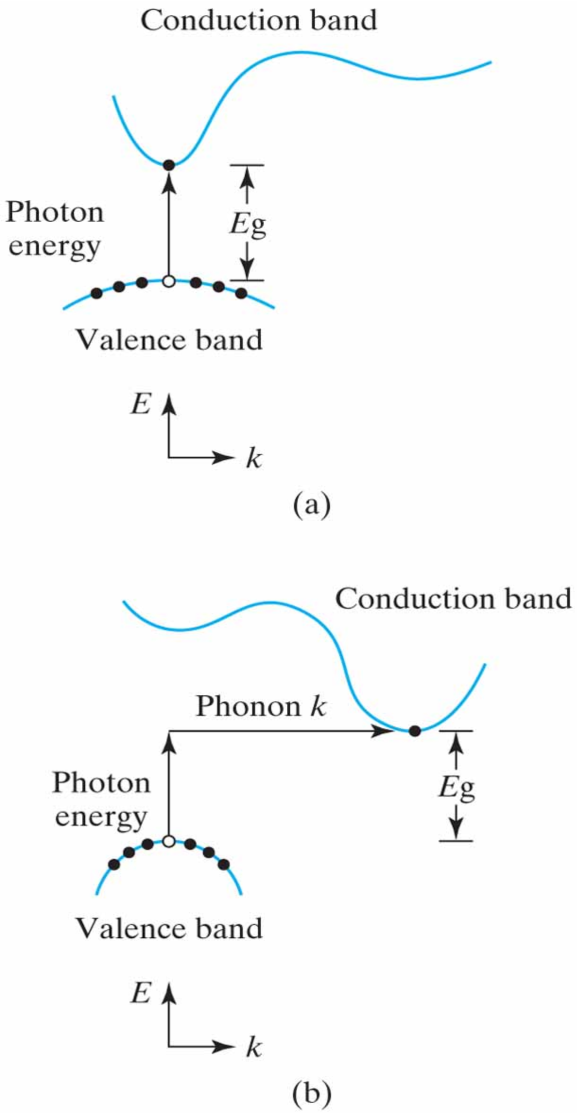
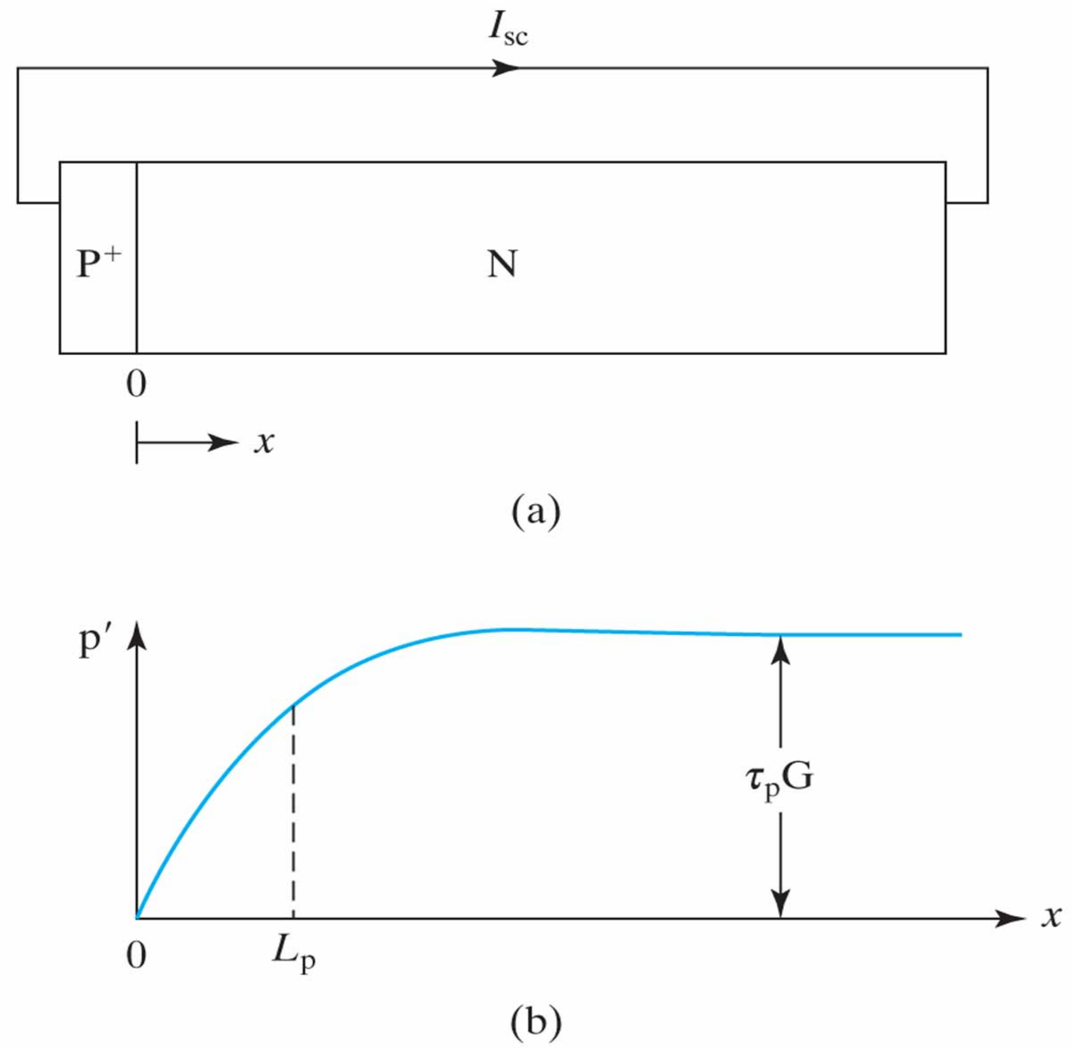


Figure 4.28 (a) A P⁺N solar cell under the short-circuit condition and (b) the excess carrier concentration profile. Effectively only the carriers generated within $x < L_p$ can diffuse to the junction and contribute to the short-circuit current.



(a)

(b)

Figure 4.29 Schematic drawing of an LED. Photons are generated when the electrons and holes injected by the PN junction recombine.

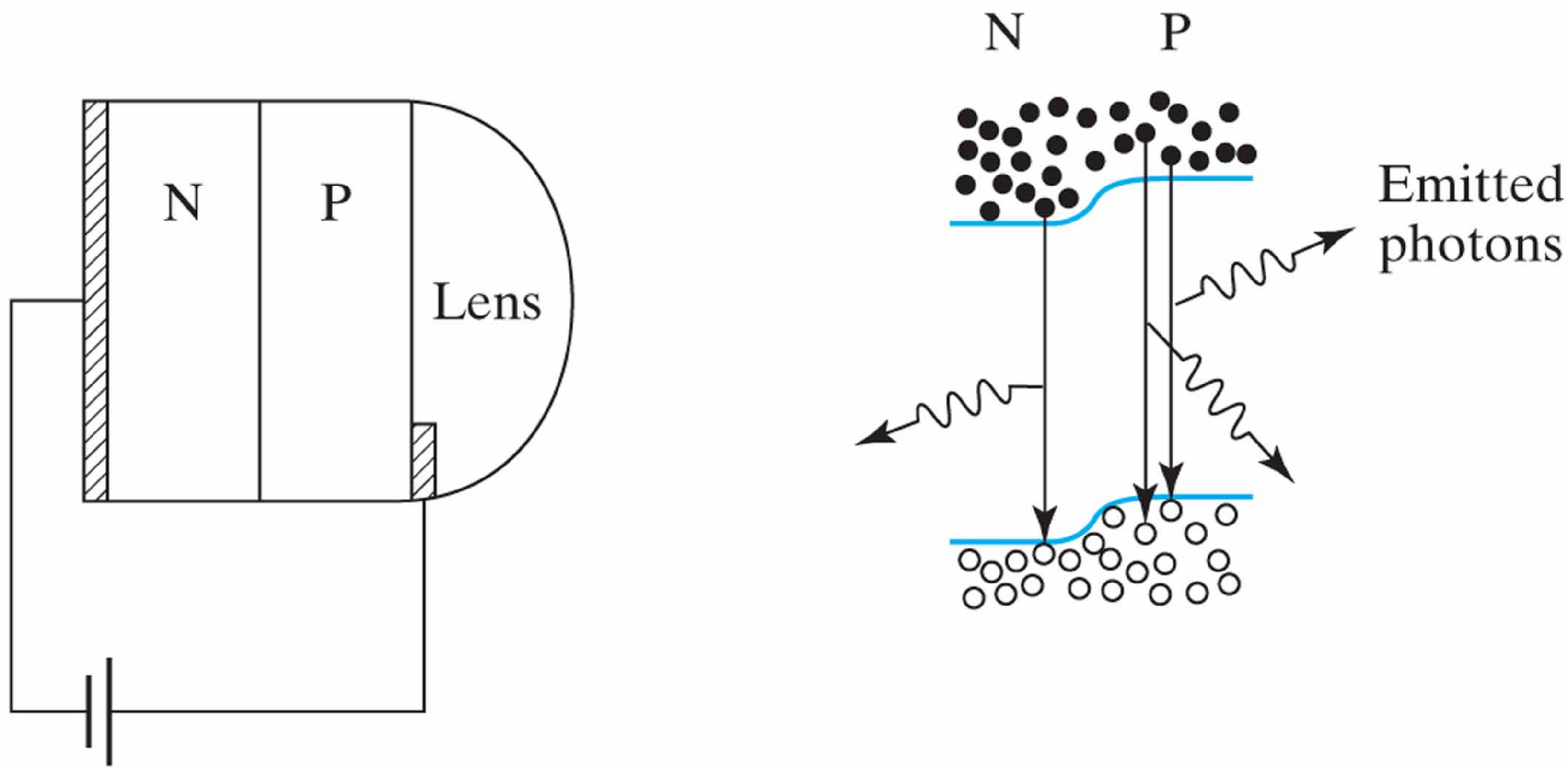


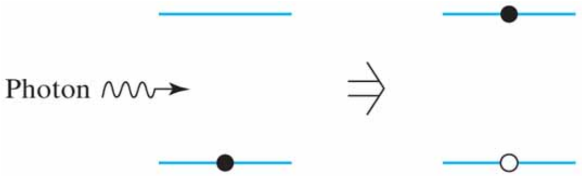
TABLE 4–1 Optoelectronic-device materials.

	$E_g(\mathrm{e}V)$	Wavelength (μm)	Color	Lattice constant (Å)
InAs	0.36	3.44		6.05
InN	0.65	1.91	infrared	3.45
InP	1.36	0.92		5.87
GaAs	1.42	0.87	↑	5.66
GaP	2.26	0.55	red yellow blue violet	5.46
AlP	3.39	0.51		5.45
GaN	2.45	0.37	↓	3.19
AlN	6.20	0.20	UV	3.11

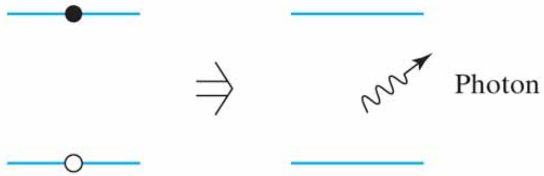
Fråga 82

- Vilket alternativ nedan ger lägst kontaktresistans mellan en metall och en halvledare?

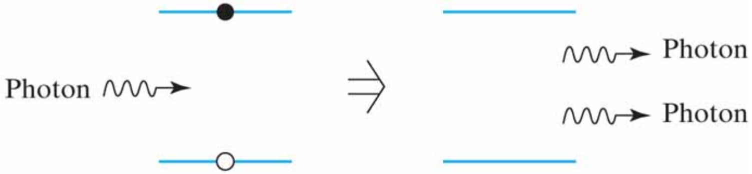
A) Hög Schottky barriär höjd och låg dopning i halvledaren
B) Låg Schottky barriär höjd och låg dopning i halvledaren
C) Låg Schottky barriär höjd och hög dopning i halvledaren
D) Hög Schottky barriär höjd och hög dopning i halvledaren



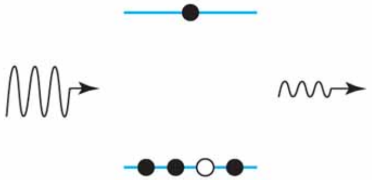
(a) Light absorption



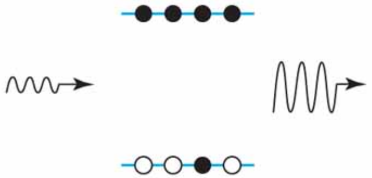
(b) Spontaneous emission



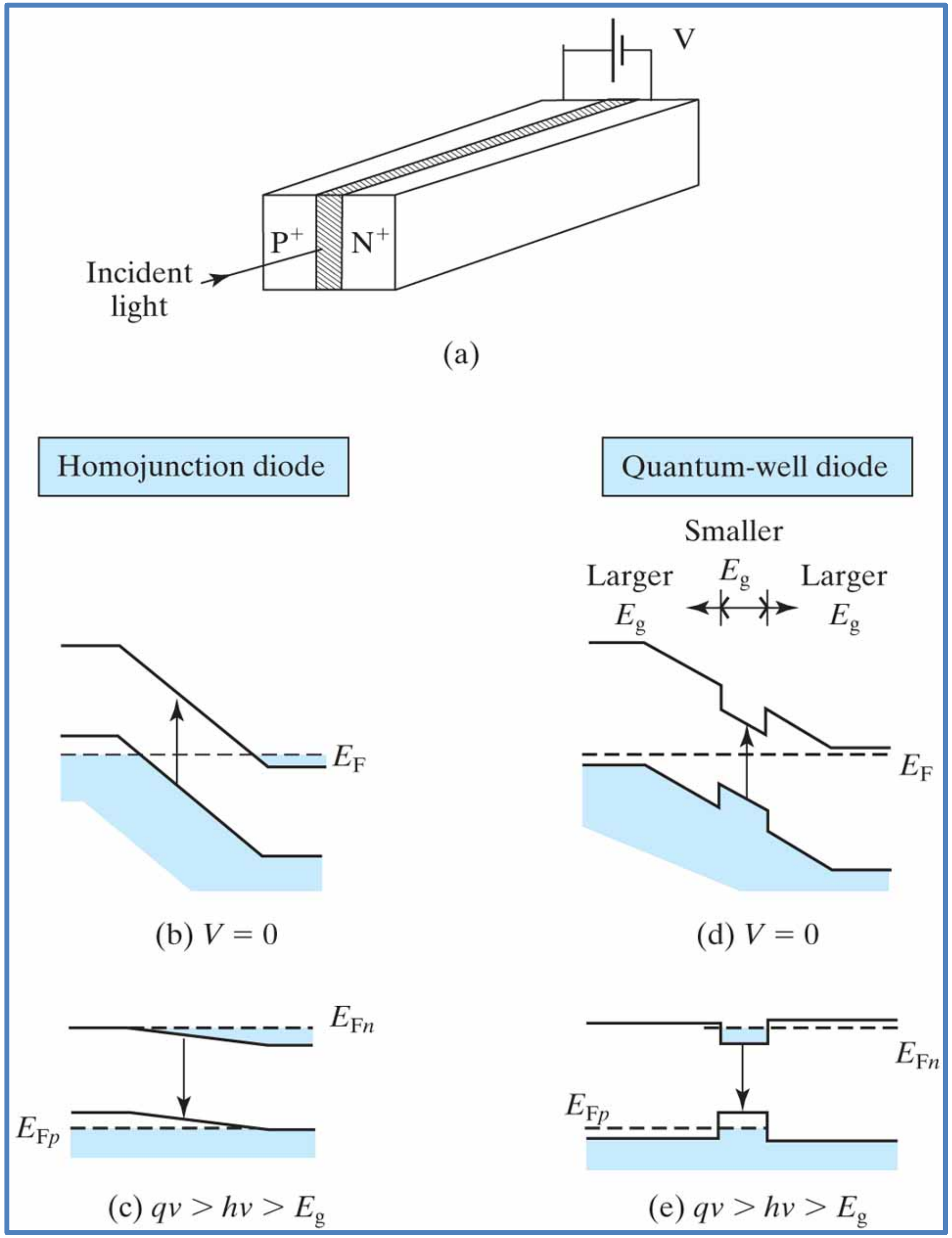
(c) Stimulated emission



(d) Net light absorption



(e) Net light amplification



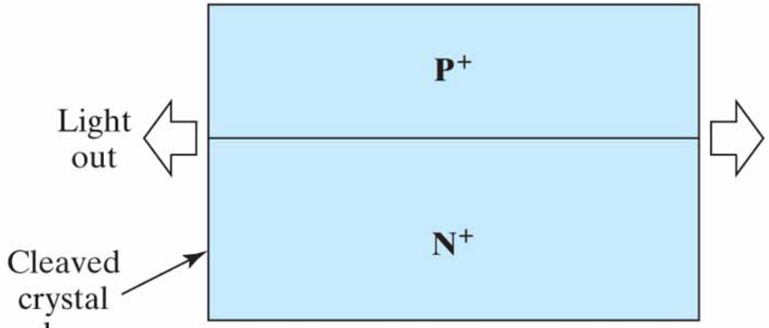
(a)

(b) $V = 0$

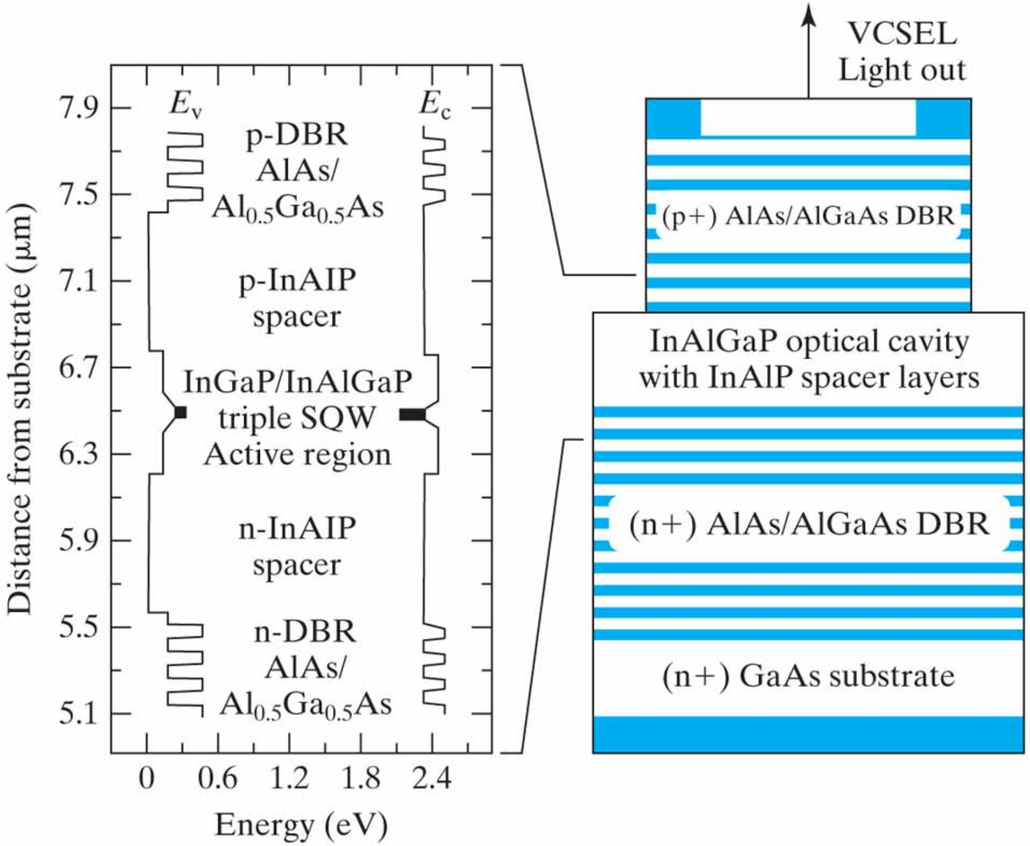
(d) $V = 0$

(c) $qv > hv > E_g$

(e) $qv > hv > E_g$


P$^+$
N$^+$
Light
out
Cleaved
crystal
plane

(a)


VCSEL
Light out
(p+) AlAs/AlGaAs DBR
InAlGaP optical cavity
with InAlP spacer layers
(n+) AlAs/AlGaAs DBR
(n+) GaAs substrate
E_v
E_c
p-DBR
AlAs/
$Al_{0.5}Ga_{0.5}As$
p-InAlP
spacer
InGaP/InAlGaP
triple SQW
Active region
n-InAlP
spacer
n-DBR
AlAs/
$Al_{0.5}Ga_{0.5}As$
7.9
7.5
7.1
6.7
6.3
5.9
5.5
5.1
Distance from substrate (μm)
0
0.6
1.2
1.8
2.4
Energy (eV)

(b)