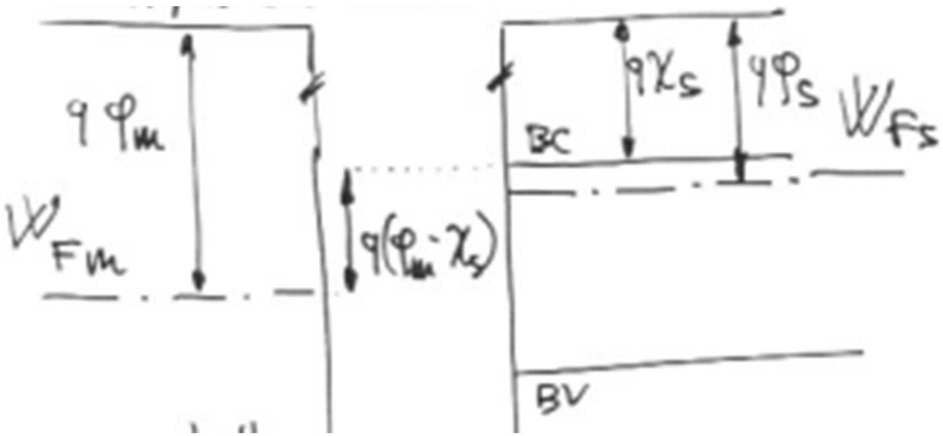
The Schottky junction [Singh]

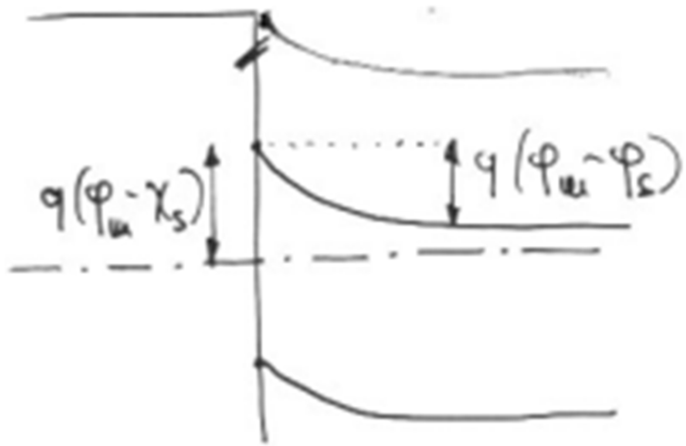
Ideal case, no surface states

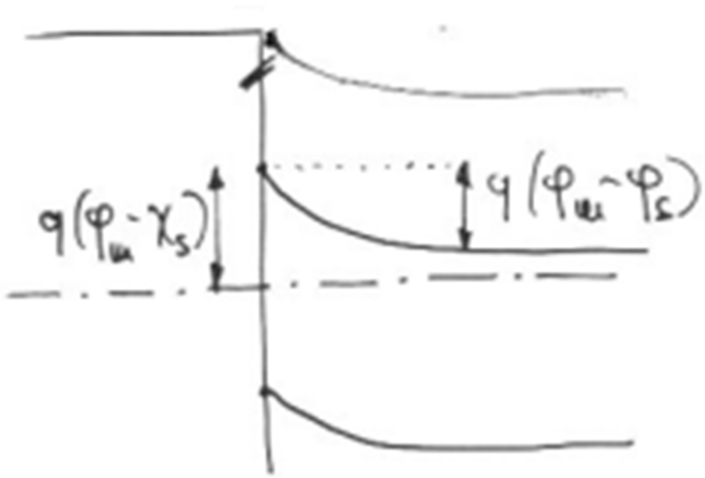


Let' consider n-silicon and a metal with $\varphi_m > \varphi_s$

χ_s is the electron affinity

When the junction is formed,
- W_F must be constant
- the vacuum energy levels, close to the junction, remain the same





So, there is band bending on the semiconductor side.
Charges:
- a *sheet* of electrons on the left
- a *layer* of positive ions on the right

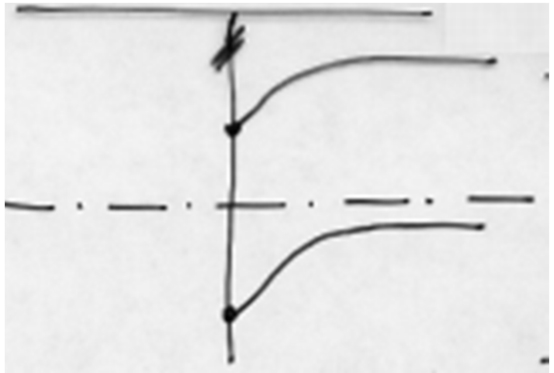
A Shottky barrier appears

$$q\varphi_b = q(\varphi_m - \chi_s)$$

together with a built-in potential

$$V_{bi} = \varphi_m - \varphi_s$$

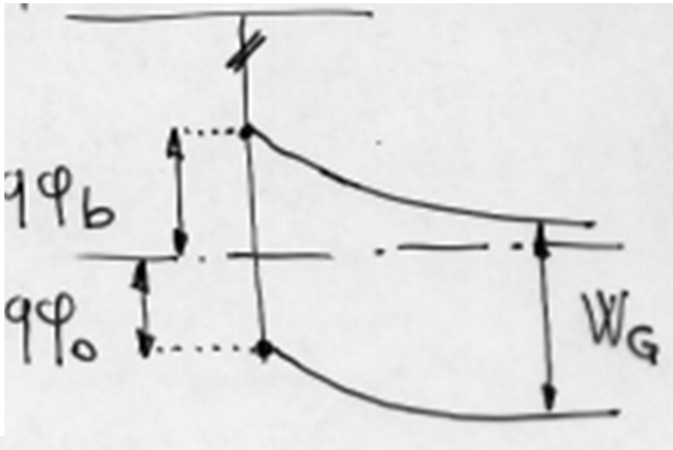
Similarly, for p-silicon and a metal with $\varphi_m<\varphi_s$



Real case

Actually, φ_b is almost independent on the type of metal; it mostly depends on the surface states (due to chemical defects, broken bonds...) at the interface.

So, W_F is blocked, “pinned”, at a certain level $q\varphi_0$ over BV



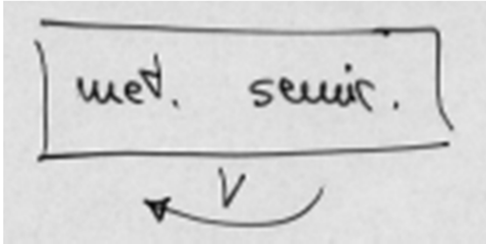
Then, the barrier is

$$q\varphi_b = W_G - q\varphi_0$$

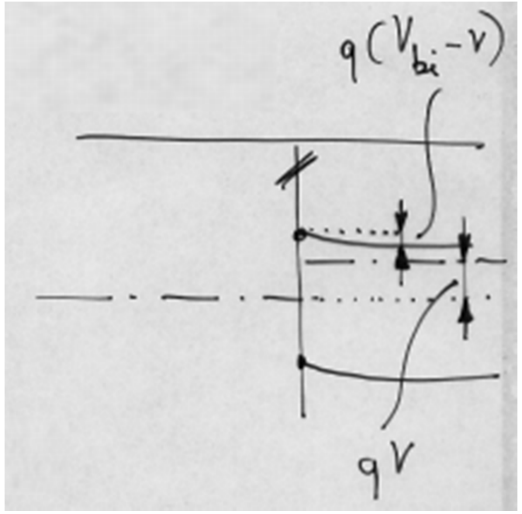
and is (almost) independent on the applied voltage.

Direct bias

The electrons of the semiconductors "see" a lower barrier



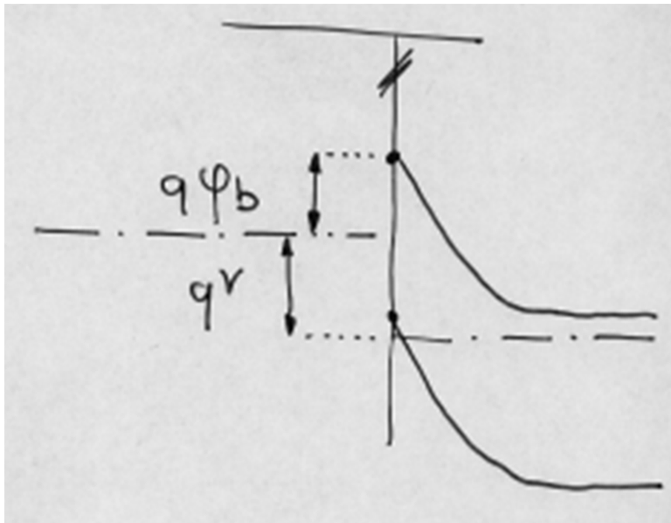
$$q(V_{bi} - V)$$



=> they can pass it
=> large current

Inverse bias

The electrons of the metal "see" the same (rather high) barrier
=> small, constant current



It may be found that

$$I = I_S \left(e^{V/V_T} - 1 \right)$$

with I_S larger than the typical I_0 of a pn junction.

Indeed, Schottky diodes
- have lower threshold
- have higher inverse saturation current
- are faster (there is no diffusion capacitance)

than pn diodes.

The case p-silicon and $\varphi_m<\varphi_s$
is the same, but looking at the holes “from below”

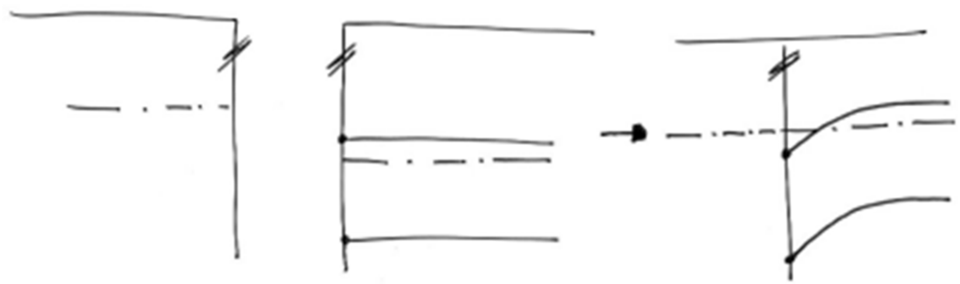
Ohmic contacts

An ohmic contact is obtained in the other two cases

- we have *accumulation*, instead of depletion, so we are plenty of carriers in both directions

For example, for n-silicon and

$\varphi_m < \varphi_s$



The four cases are summarised here →

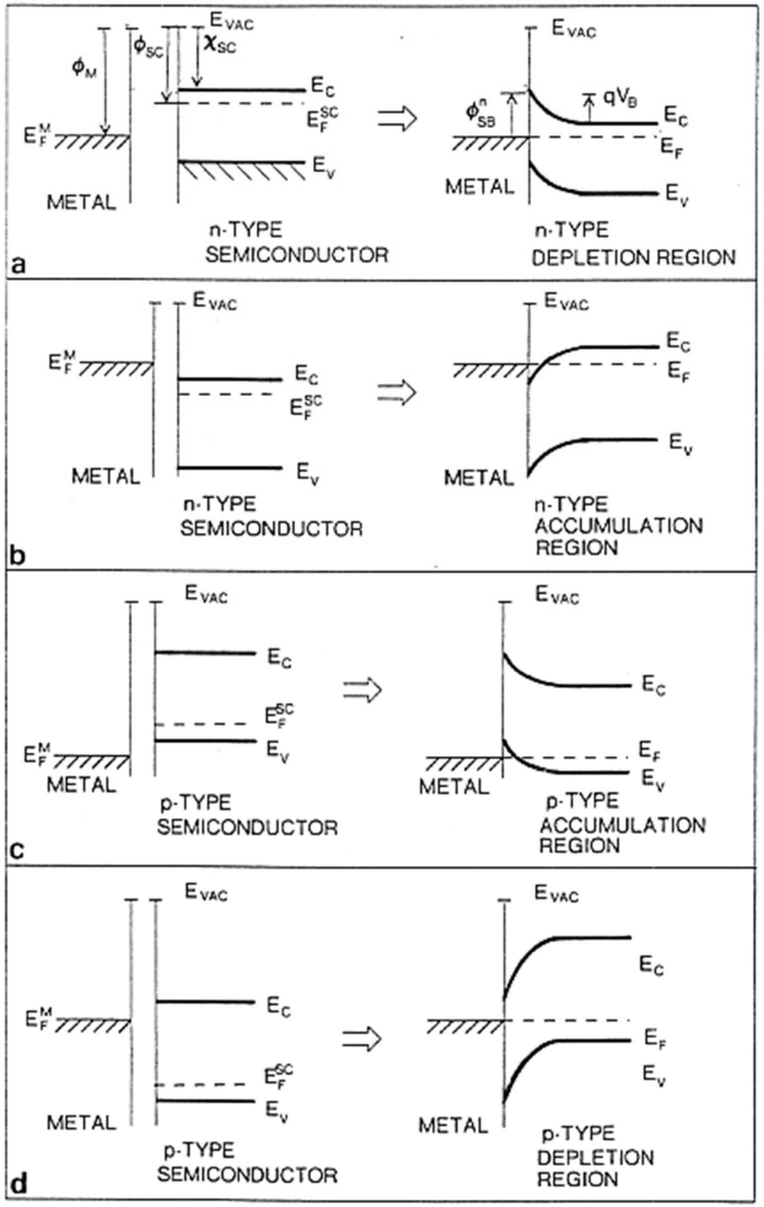


Fig. 1. Schematic diagrams of band bending before and after metal–semiconductor contact for (a) high work function metal and n-type semiconductor, (b) low work function metal and n-type semiconductor, (c) high work function metal and p-type semiconductor, and (d) low work function metal and p-type semiconductor.

Ohmic contacts

With commonly used metals and semiconductors, we would have rectifying contacts (case *a* and *d*).

If however the semiconductor is highly doped, the depletion zone is very thin

=> possible tunnel effect

=> current in both directions