Real heterojunctions

LECTURE 9

- Schottky barrier current
- CdS/CIGS
- Energy band alignment "rules"
- CdTe/Ge
- Surface reconstruction, dipoles
- Surface states
- Fermi-level pinning

Sec. 11.1

HJ1: Schottky barrier

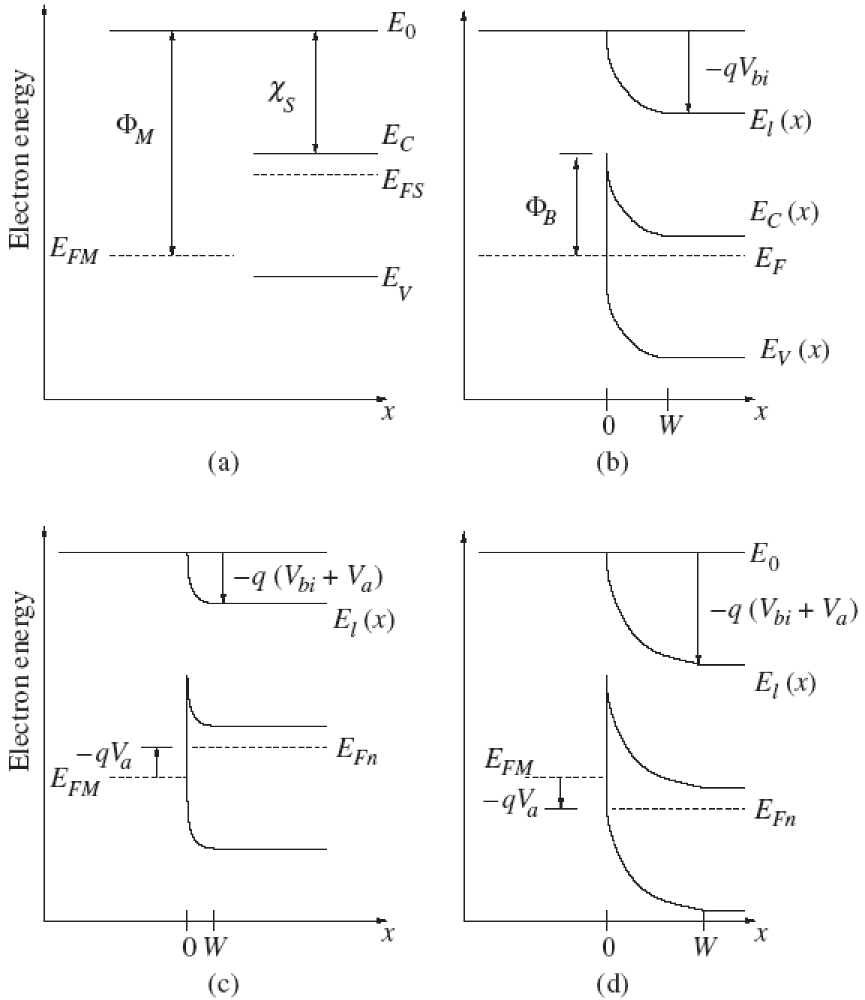
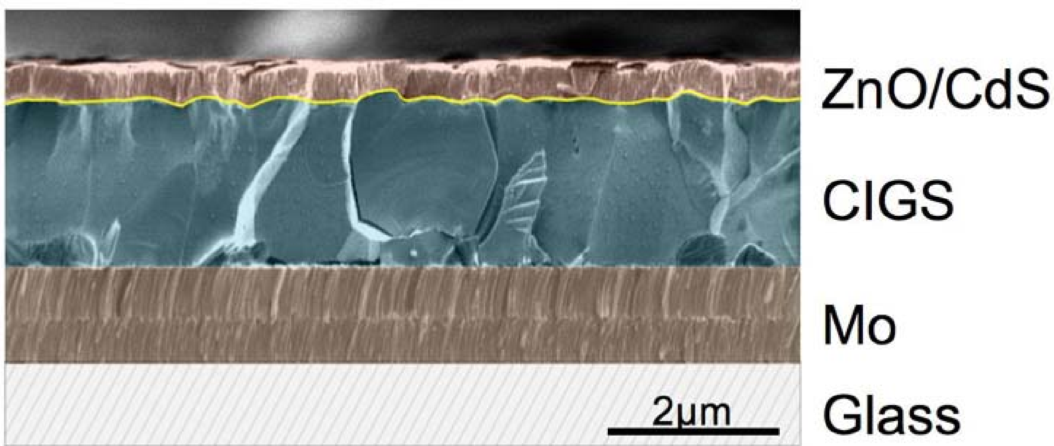


Figure 11.3 Energy-band diagrams showing a metal/semiconductor junction. (a) Prior to joining the two components. (b) At equilibrium. (c) Forward bias. (d) Reverse bias.

- Note discontinuity in Fermi level
- What is the forward-bias current?

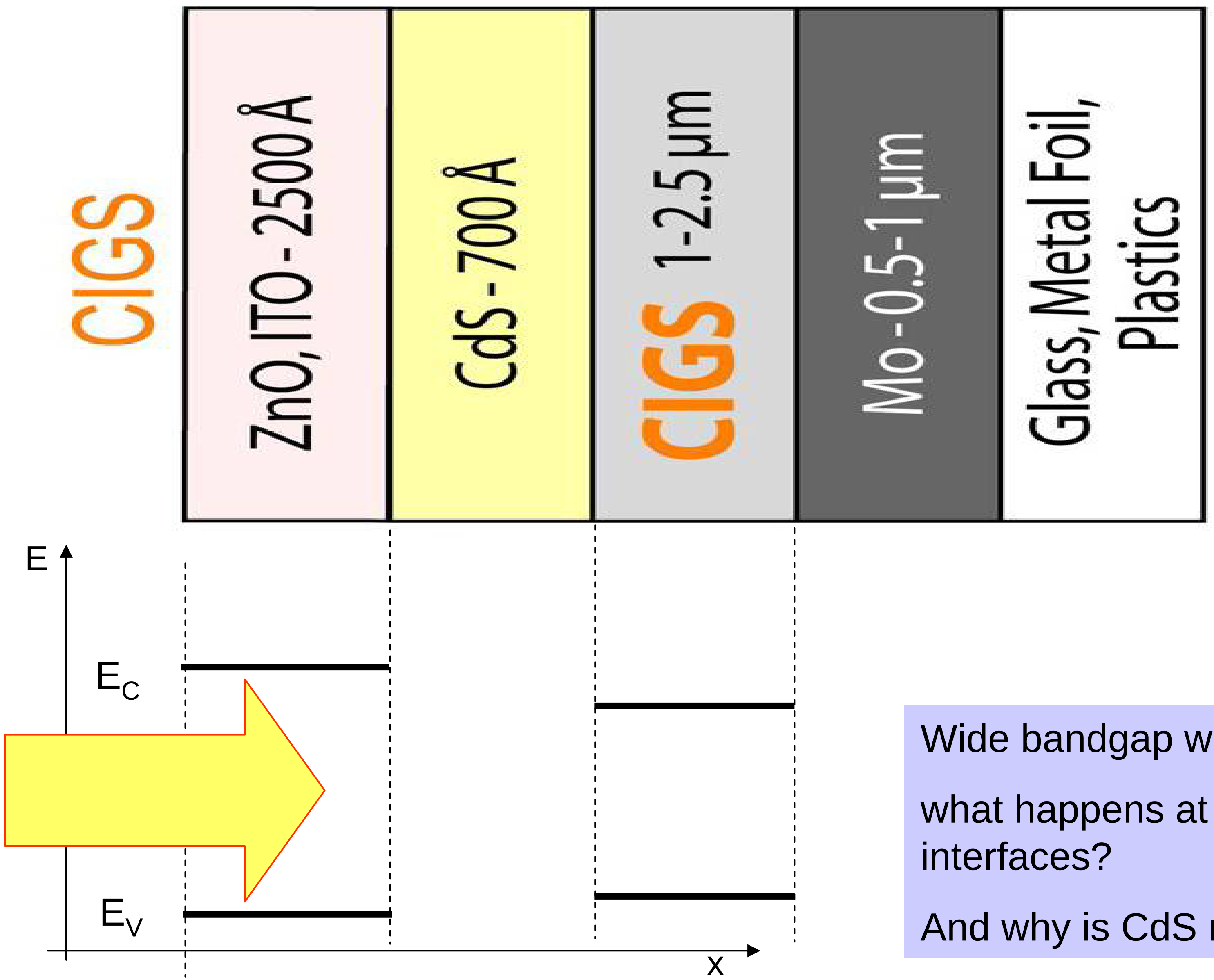
Sec. 7.6.1

Heterostructure, thin film, cells: a lower cost alternative (?)



Noufi, Rommel; Ken Zweibel. HIGH-EFFICIENCY CDTE AND CIGS THIN-FILM SOLAR CELLS: HIGHLIGHTS AND CHALLENGES. National Renewable Energy Laboratory.

HJ2: CdS/CIGS

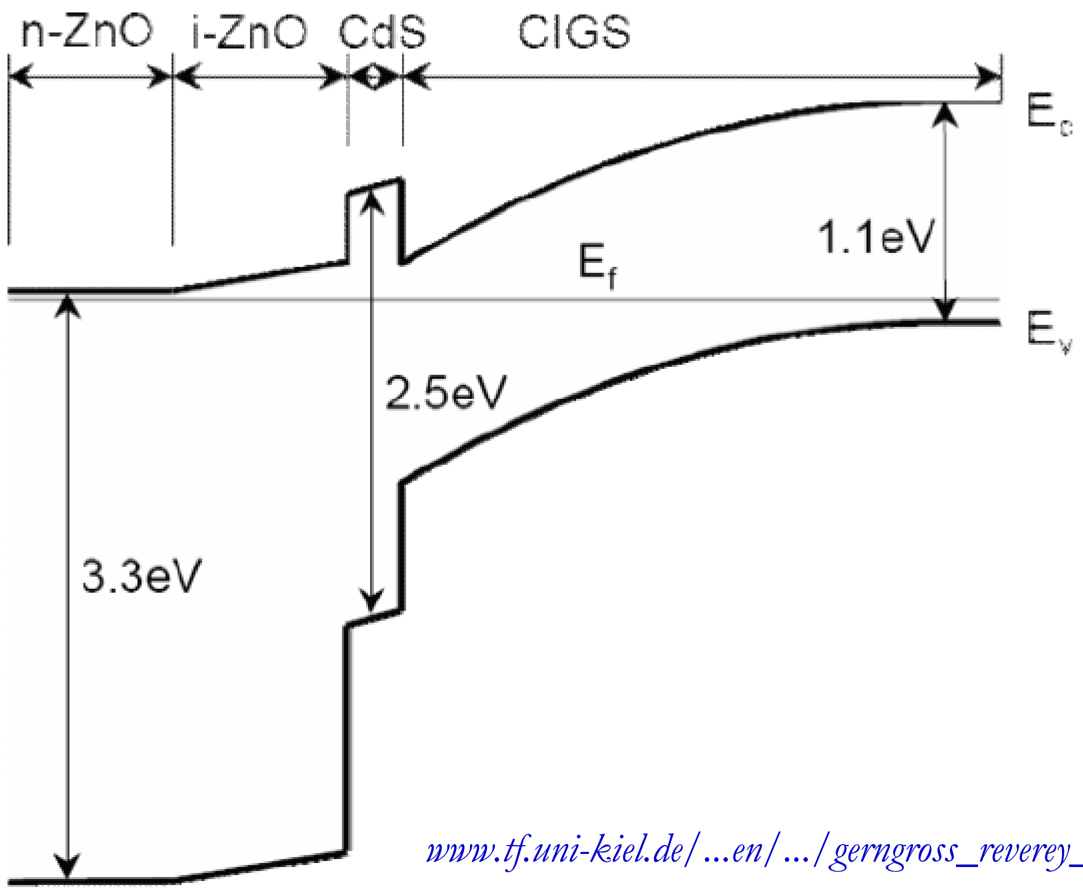


Wide bandgap window, but

what happens at the interfaces?

And why is CdS needed?

A proposed band diagram



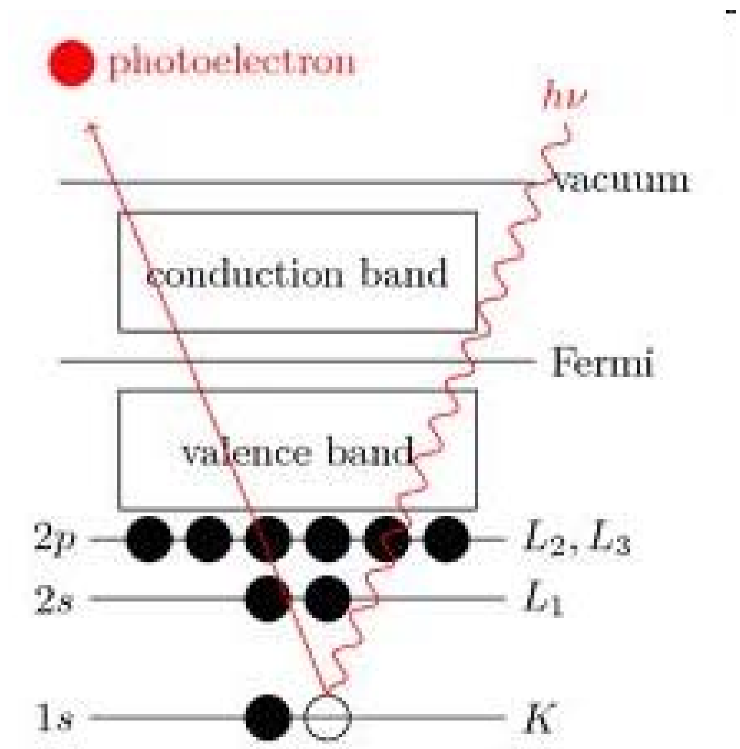
www.tf.uni-kiel.de/…en/…/gerngross_reverey_paper_ws_08_1.pdf

Figure 5: Band-gap structure of ZnO/CdS/CIGS module

How was the band alignment determined?

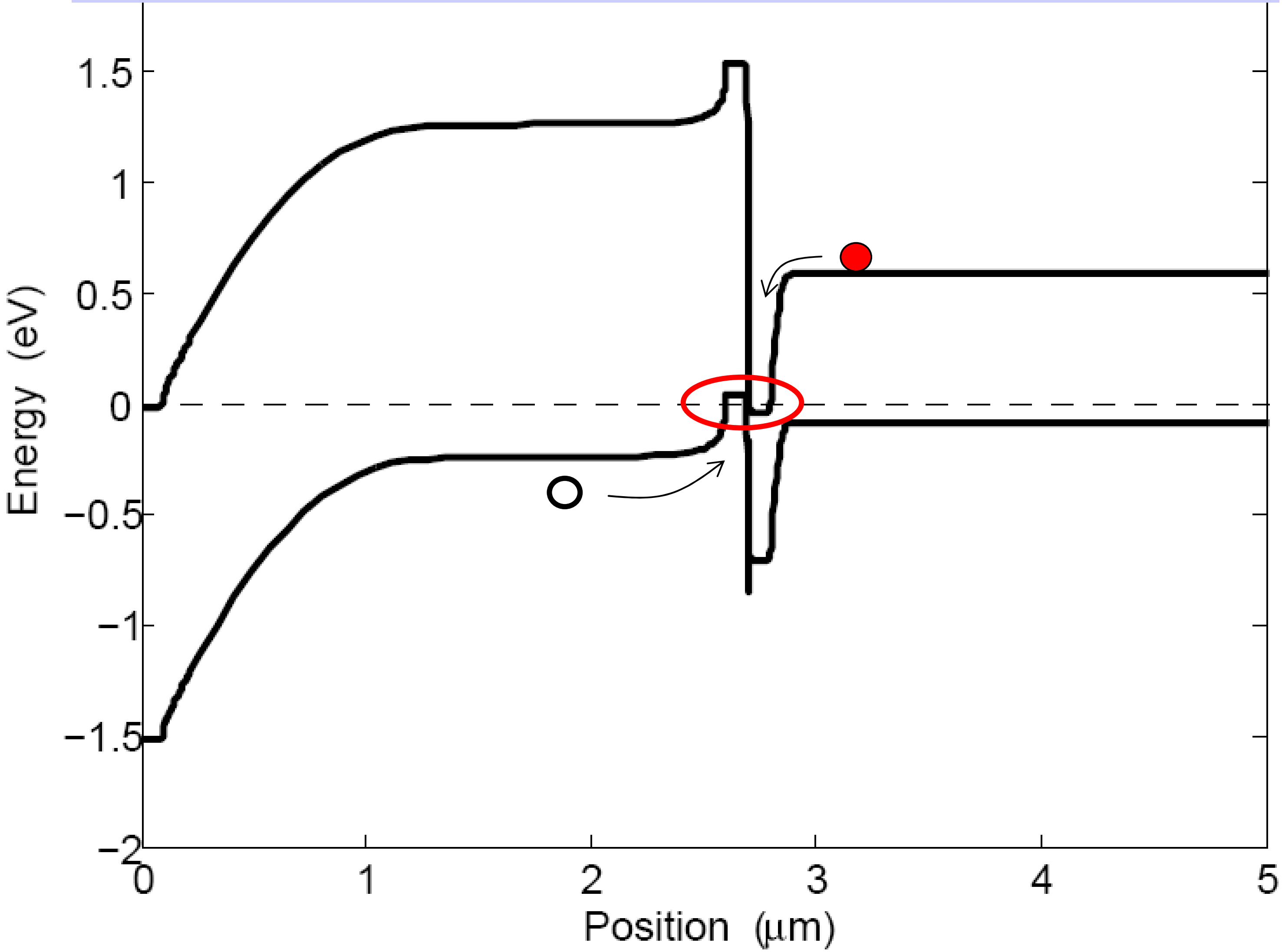
Band alignment

1. Anderson Rule: alignment via electron affinities.
2. "Kroemer Rule": alignment via valence-band offset.



X-ray photoelectron spectroscopy

HJ3: Band discontinuity at CdTe/Ge interface



Real heterostructures

Some practical factors affecting band alignment:

- surface reconstruction
- dipole formation
- interruption of the periodicity of the semiconductor
- surface states

Surface reconstruction

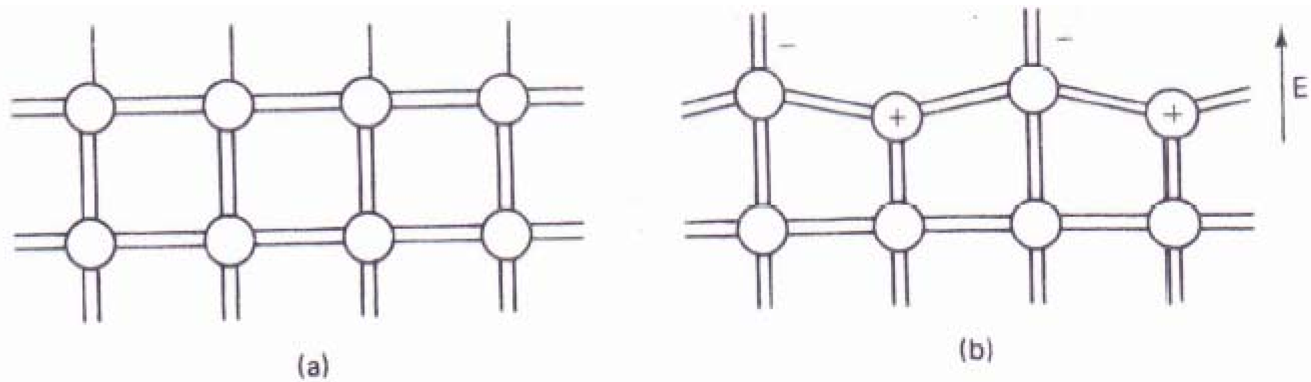


Figure 10.2 Schematic illustration of surface dipole formation. In (a) each neutral surface atom has one dangling bond. In (b) the dangling bonds pair and produce a shift in atomic positions.

What is the magnitude of the surface field?

How does it affect the band diagram?

Wolfe et al., Physical Properties of Semiconductors, Chap. 10, Prentice-Hall, 1989

Effect of surface dipoles

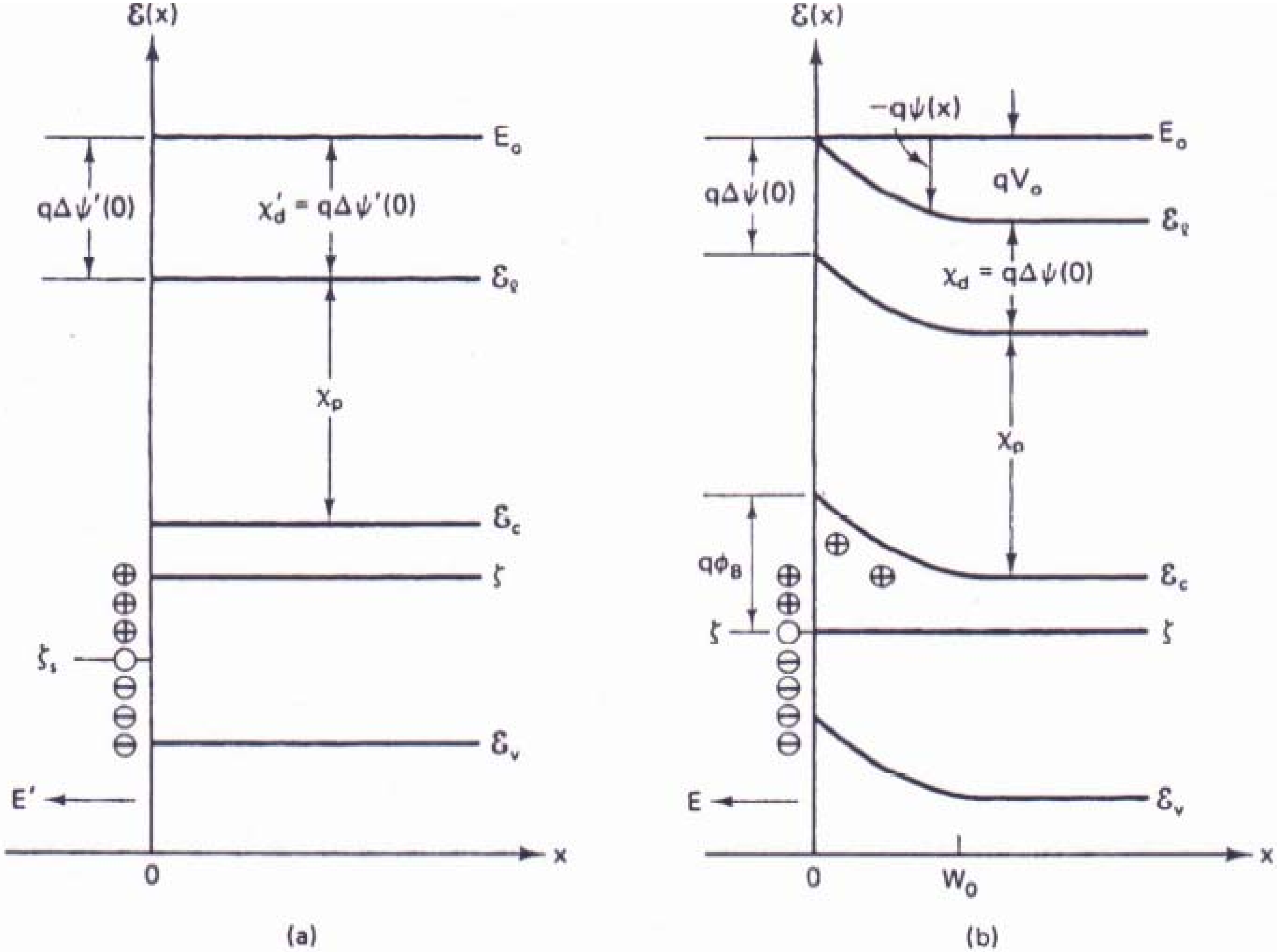


Figure 10.3 Effects of surface dipoles on energy band structure (a) before and (b) after charge transfer between the surface and the bulk material.

Wolfe et al., Physical Properties of Semiconductors, Chap. 10, Prentice-Hall, 1989

Lattice mismatch

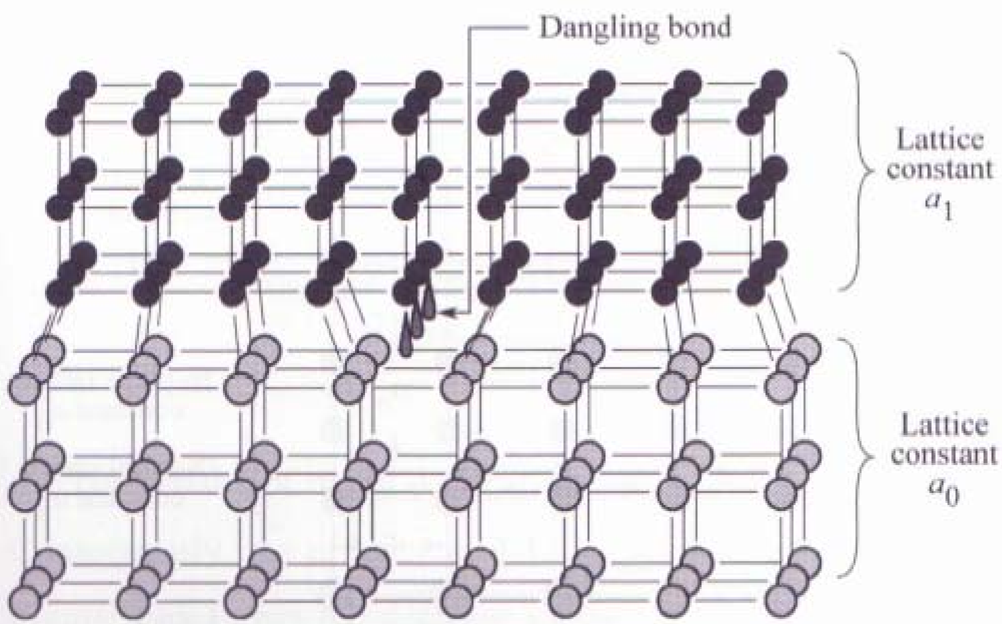


Fig. 7.12. Illustration of two crystals with mismatched lattice constant resulting in dislocations at or near the interface between the two semiconductors.

E.F. Schubert, LEDs, CUP, 2007

Dislocations cause intra-gap states, and non-radiative recombination.

Effect of surface states

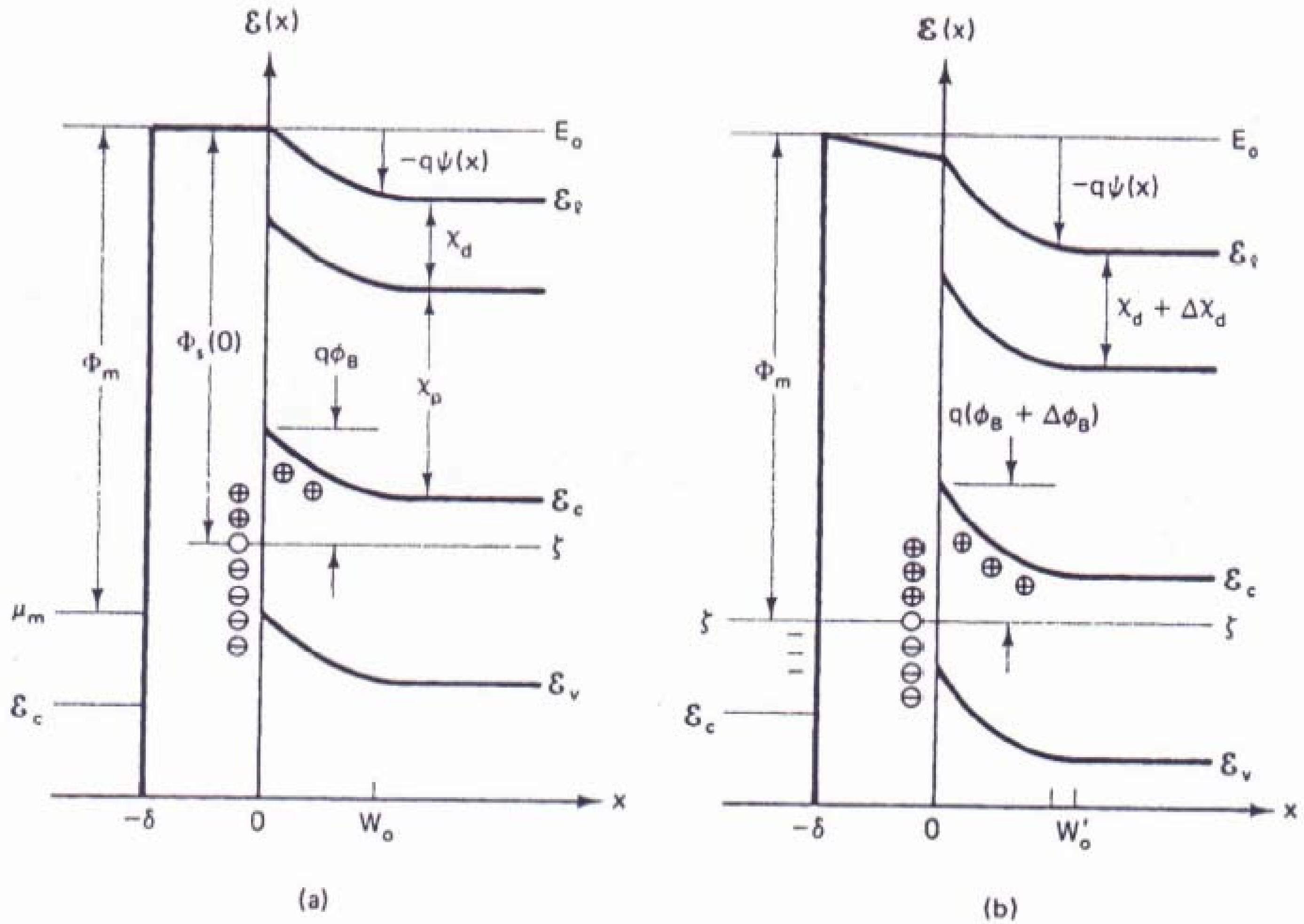


Figure 10.6 Energy band diagrams of a metal–semiconductor pair with $\Phi_m > \Phi_s$ and surface states (a) before and (b) after thermal equilibrium.

Wolfe et al., Physical Properties of Semiconductors, Chap. 10, Prentice-Hall, 1989