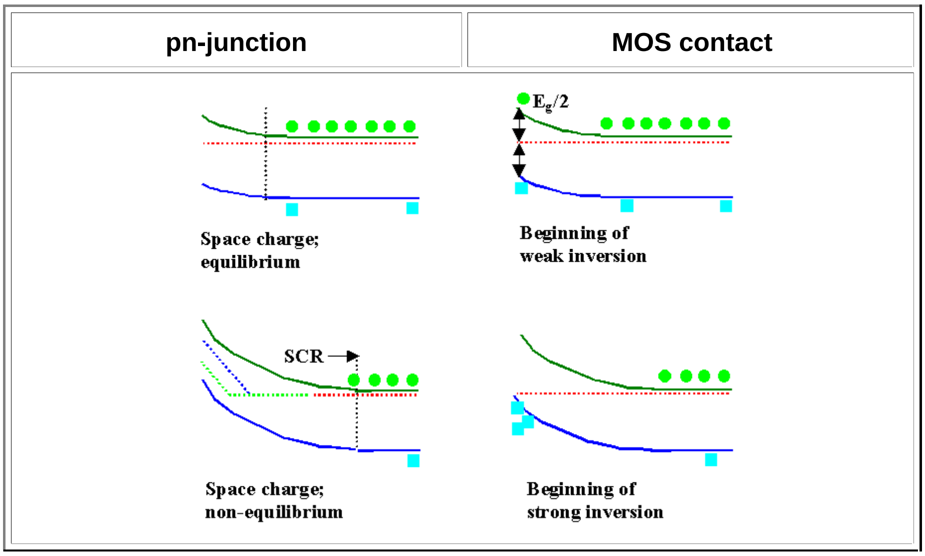
Inversion

Advanced

- Inversion is the working horse of all ***MOS*** devices. Its treatment is not only rather involved, but requires for realistic cases an inclusion of the "oxide" properties, i.e. the properties of the insulting layer needed to avoid current flow.
  - It is simply not particularly useful to discuss the case of an *fictive insulating layer with infinitesimal thickness* as before. It is necessary, to include *properties* of this layer, like its fixed or mobile volume charge density, and interface charge densities.
  - You might wonder why there should be charge in the insulating layer; after all, macroscopic objects normall do not carry net charge. The gate oxide of a transistor, however, is not a macroscopic object, and it does not take a lot of charge to influence the junction properties a lot. In fact, some devices (**EPROM**s, to be precise), completely depend on charge trapped in the oxide.
- **MOS** devices and inversion thus have a vocabulary of their own which exceeds the scope of this course considerably.
  - We will therefore not treat the inversion case in detail *but only discuss qualitatively* what happens.
- Let's look at band diagrams for polarities where the majority carriers are repulsed by the surface charge
  - We compare an **MOS** contact, where large voltages can be used without current flow, and thus band bending may occur for a constant Fermi energy (right), with a reversely biased **pn**-juction (left), where we also may apply large voltages but with a non-constant Fermi energy.



  - In the reversely biased **pn**-junction a large space charge region develops, totally devoid of carriers as indicated by the Quasi-Fermi energies.
  - For the **MOS** contact, the situation for small voltages is similar to the **pn**-junction, but for larger voltages a new situation occurs:
- The Fermi energy will be in mid-band position for some voltage, increasing the voltage somewhat will now lead to *inversion*, i.e, holes are now the majority carriers in a surface-near layer. The following distinctions are customary
  - **Weak inversion** begins when the Fermi energy at the surface in in the middle of the band gap. In this case, the hole concentration at the surface is identical to the electron concentration and equal n_i. If the voltage is increased, the hole concentration will now be larger than the electron concentration
  - **Strong inversion** commences as soon as the Fermi energy is equal to the level of the donor atoms in our example, i.e. is practically at the valence band edge. The concentration of holes will now be larger than the concentration of electrons in the bulk of the material and increase even further if the voltage is increased.