**MOSFET**

Explain the following terms: accumulation, flatband voltage, depletion, threshold voltage, and inversion. Draw the minority charge distribution for forward active mode.

The following explanations are for n-channel enhancement mode MOSFETs. It’s just the other way around for p-channel enhancement mode MOSFETs: negative voltage → positive voltage, bands bend up → bands bend down, holes → electrons, acceptors → donors, …

**Accumulation**

When you put a voltage between the gate and the body that is less than the flatband voltage, you get into accumulation. So the fermi energy on the metal side will go up and the bands of the semiconductor will bend up.

The voltage accumulates positive charge carriers (majority carrier, holes) in the p-channel under the gate. This will result in an electric field in the oxide layer from the semiconductor to the metal.
Flatband voltage
The flatband voltage is the voltage that divides accumulation from depletion. With the flatband voltage applied, the bands are just flat and not bended either way. For this is usually a small negative voltage (less negative than with accumulation) needed. There is no depletion layer.
Depletion
When you put a voltage between the gate and the body that is higher than the flatband voltage, you get into depletion. So the fermi energy on the metal side will go down and the bands of the semiconductor will bend down.
The voltage depletes positive charge carriers (majority carrier, holes) from the p-channel under the gate. When the holes deplete, they leave behind the negative charged acceptors. Those immobile negative charged acceptors will generate an electric field from the metal to the semiconductor.
**Threshold voltage**

When you are in depletion and rise the voltage on the gate, the bands will bend further down. When the Fermi energy gets closer to the conduction band, the electron density (minority carrier) will rise (inversion). The Threshold voltage is the point where the mobile minority carrier have the same value as the doping at the semiconductor-oxide interface. This is the point where the MOSFET starts conducting between the source and the drain.

\[ n = N_A \]
Inversion
When you rise the voltage over the Threshold voltage you get into inversion. The bands will bend even further down and the minority carrier density (electrons) will rise over the doping level. That means that you get a high concentration and a good conducting channel from the source to the drain.
**Minority charge distribution for forward active mode**

Assuming we short the source and the body together, then in forward active mode we have a voltage between the drain and the source so that $V_{DS} < V_{GS} - V_{TH}$.

The voltage $V(y)$ between the gate and the body depends on the location under the gate, it increases linearly from the source voltage next to the source to the drain voltage next to the drain.

You can calculate the minority charge distribution with $Q(y) = -C_{ox}(V_{GS} - V(y) - V_{TH})$.

The plot looks something like this, where the minority charge concentration decreases from the source to the drain.

![Graph showing minority charge distribution](image)

The minority charge carrier concentration can be calculated with $n(y) = \frac{Q(y)}{e}$. That means that the plot has a different scale and positive sign but basically looks the same as the one for the charge distribution.