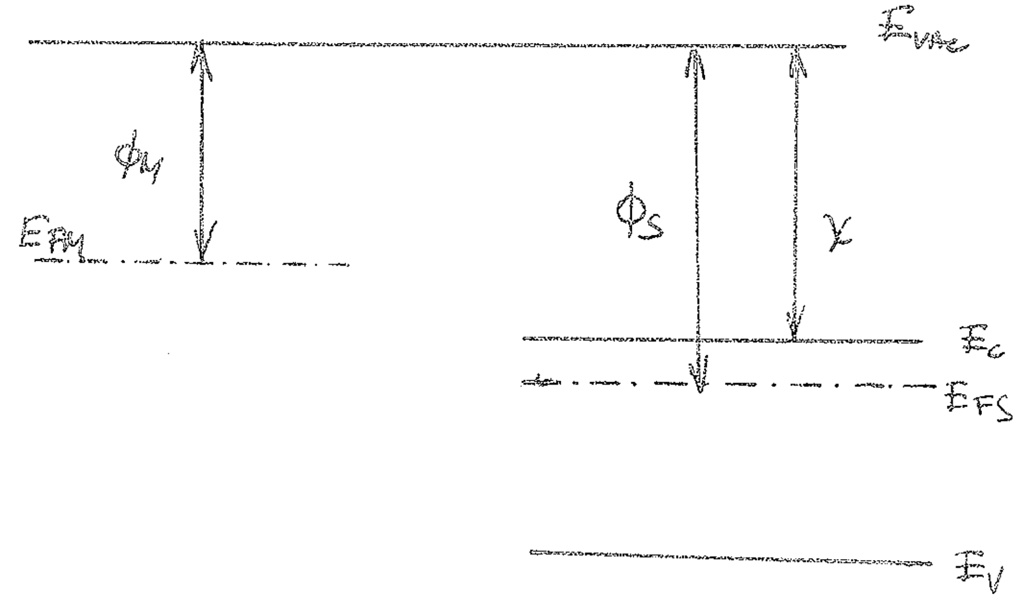
Contact Metal – Semiconductor

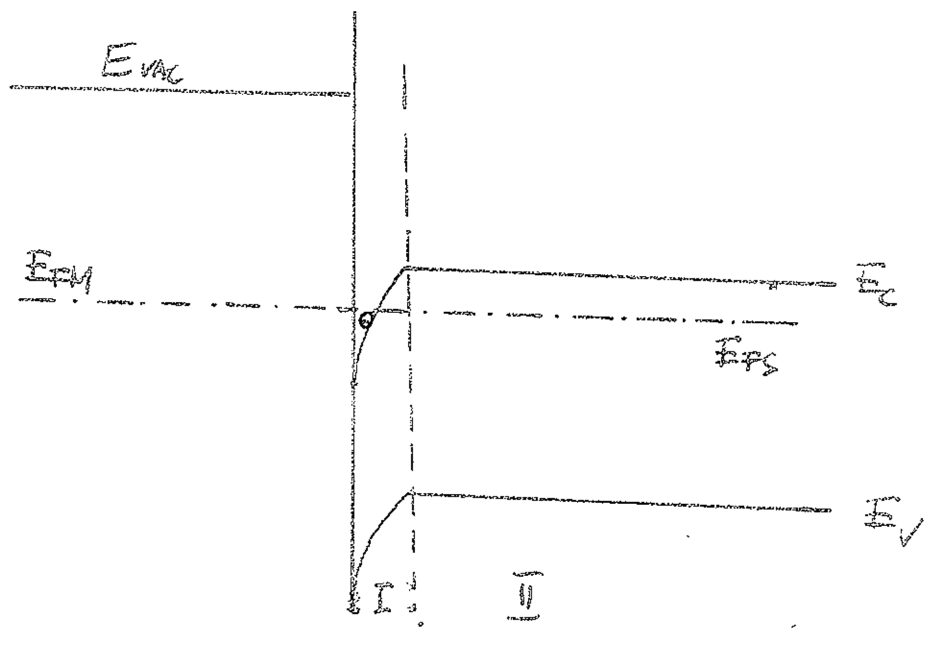
Contact metal-semiconductor represents another excample of inhomogeneous semiconductor structure. After depositing the metal it comes to charge transport between the metal and the semiconductor. As a result of this transfer the semiconductor becomes inhomogeneous. The charge transport and the properties of the M–S structure depend on difference between the work function of Metal and semiconductor and on the type (N or P) of the semiconductor. We will discuss all 4 possibilities and how the M–S structure behaves under bias.

I. N type semiconductor, work function of metal is smaller than work function of the semiconductor ($\phi_M < \phi_S$)

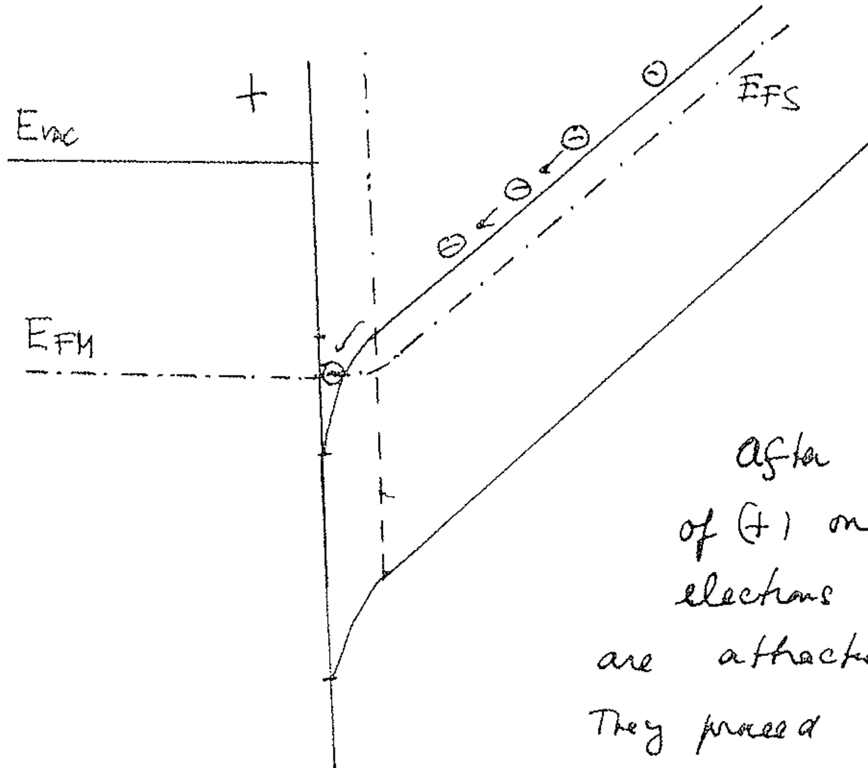
Due to the fact, that $\phi_M < \phi_S$, the Fermi level in the metal is higher at the absolute energy scale, than the Fermi level in the SC ($E_{FM} > E_{FS}$). After joining M and SC, electrons from M are transferred to SC. Because the SC is N-type (electrons are majority carriers), the new electrons from M form a highly conductive, enriched with electrons interface level.

N-type semiconductor, $\phi_M < \phi_S$

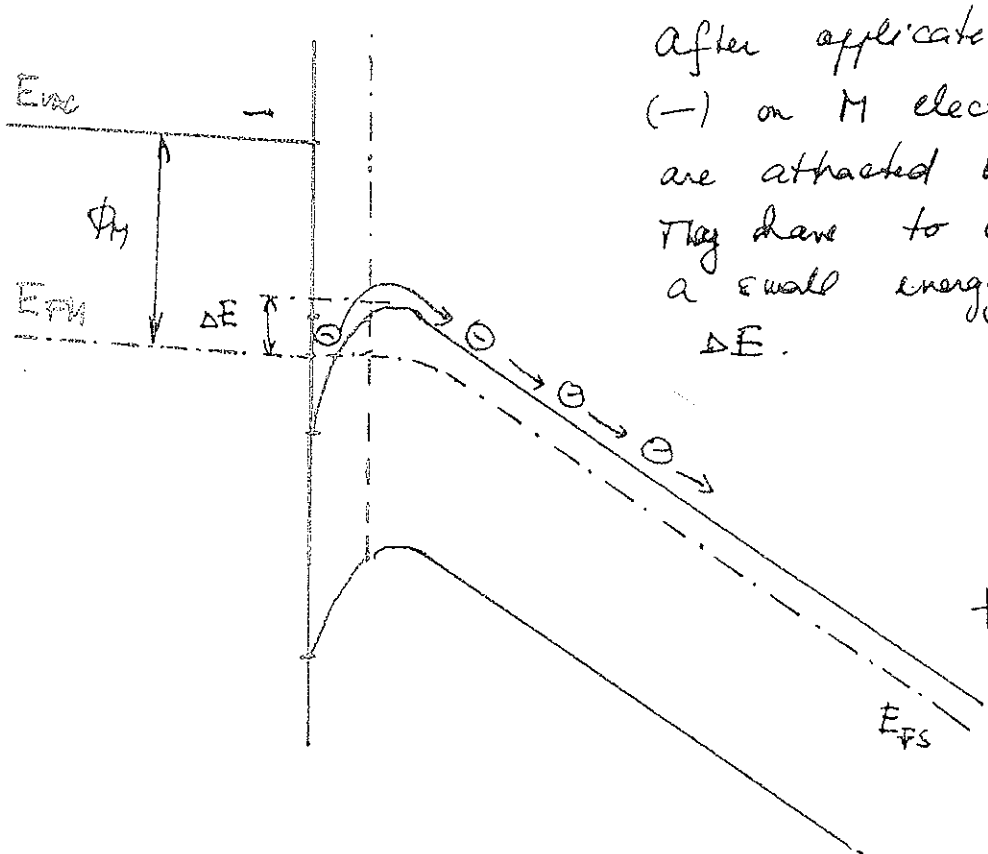




N-type, $\phi_M < \phi_S$ under bias



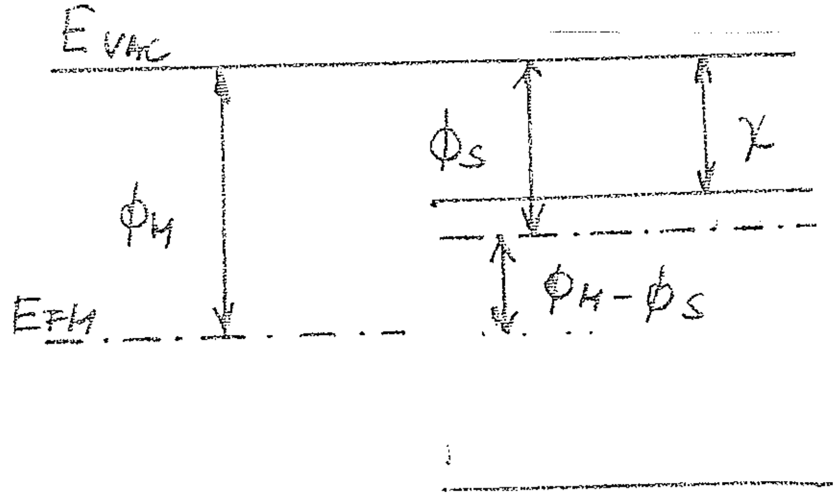
after application of (+) on metal electrons from SC are attracted to M. They proceed freely, there is no energy barrier



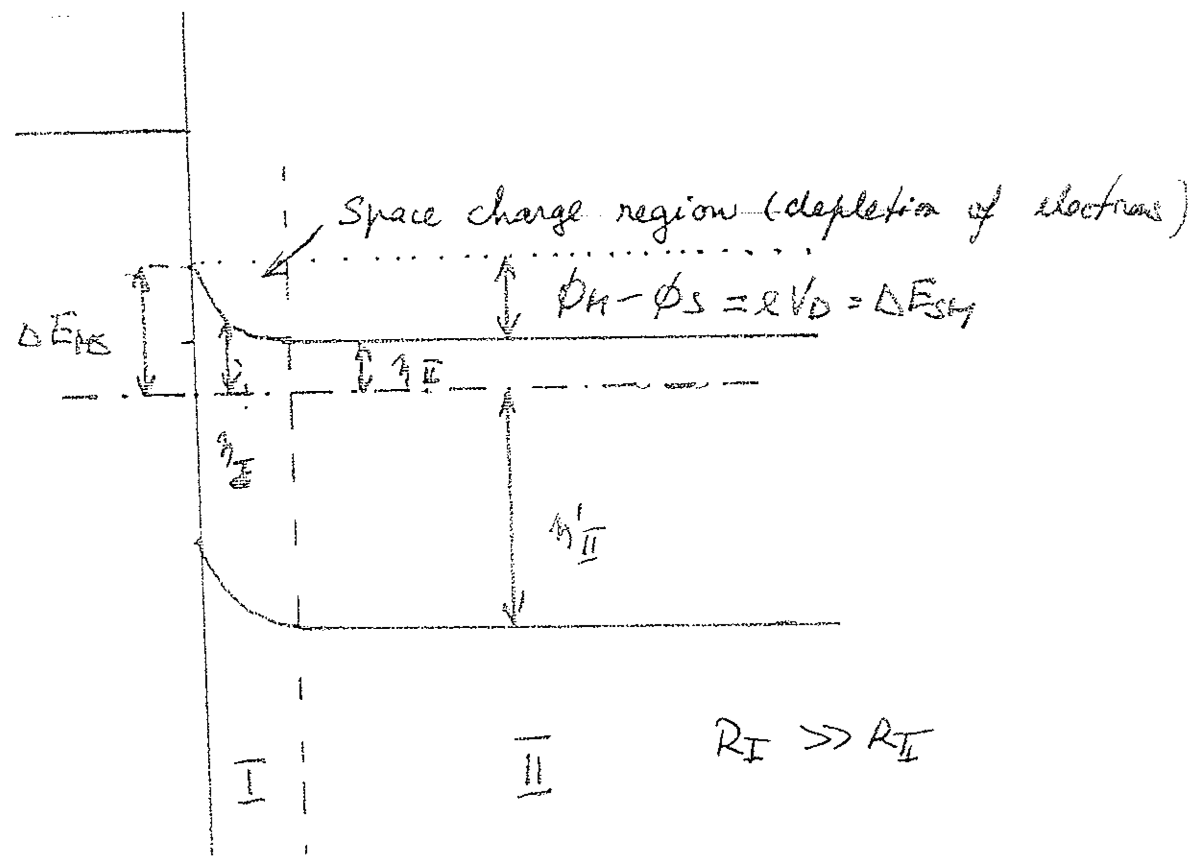
after application of (−) on M electrons are attracted to SC. They have to overcome a small energy barrier ΔE.

Due to the fact, that there is no or only very small energy barrier, N-type SC with a deposited metal ($\phi_M < \phi_S$) has a linear or nearly linear I-V characteristics.
The metal / semiconductor interface behaves as an ohmic contact.

N-type semiconductor, $\phi_M > \phi_S$



Band scheme before deposition of the metal



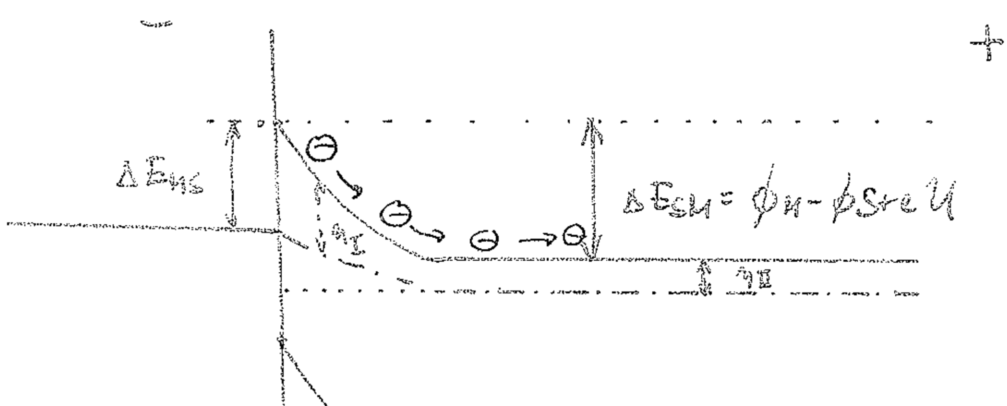
Band scheme after deposition of the metal. Space charge region of uncompensated ionized donors N_D^+ is formed at the interface.

N-type SC, $\phi_M > \phi_S$ under bias

The applied bias is almost completely concentrated on the space charge region ($R_I \gg R_{II}$)
$U = (R_I + R_{II}) I \approx R_I I$. The volume of the semiconductor is practically not influenced by the bias. Energy bands are nearly not tilted except of the SCR.

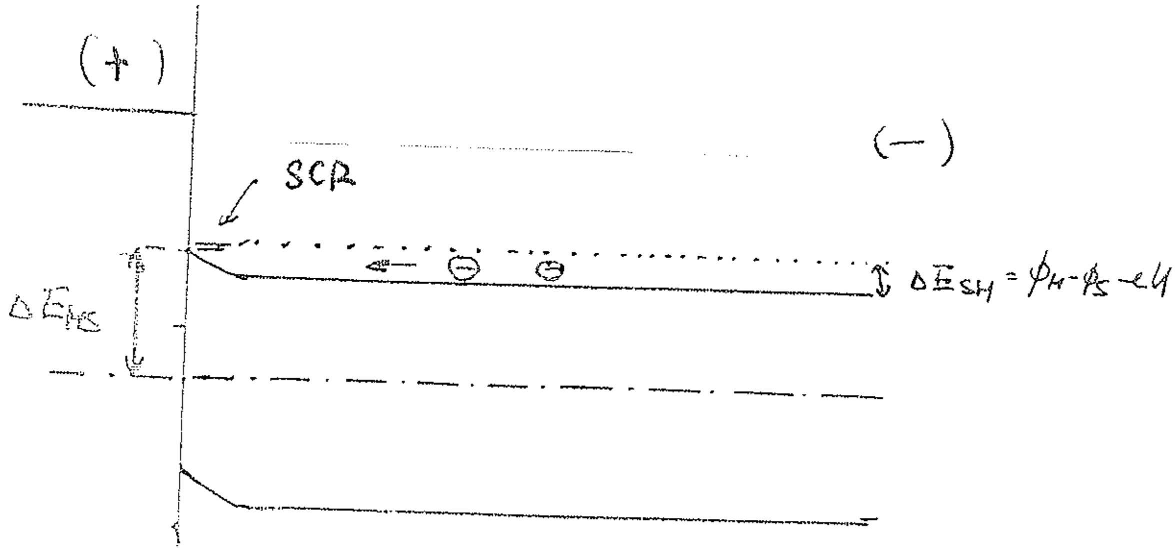
application of (−) on M, (+) on SC.

Electrons are attracted to the (+), the width of the SCR increases. Electrons have to overcome the barrier ΔE_{MS} before entering the SC.



The M-S contact is in the reverse direction

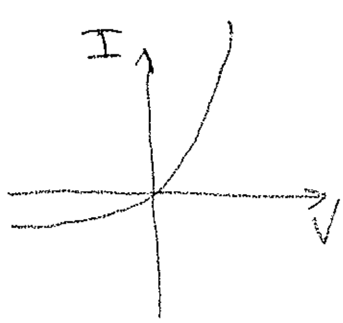
The width of the SCR decreases



Electrons drift from the SC to the metal. They have to overcome a small barrier ΔE_{SM}

The M-S contact is in the forward direction

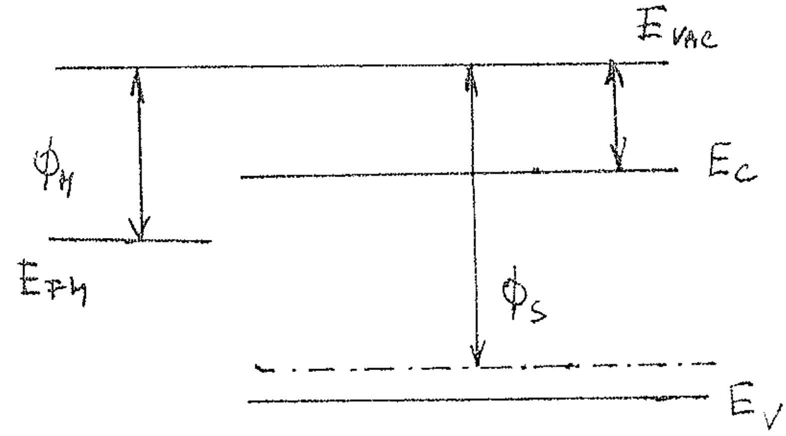
The I-V characteristics is asymmetric, the M-S interface in this case behaves as a rectifying contact and is similar as in case of the P-N junction.

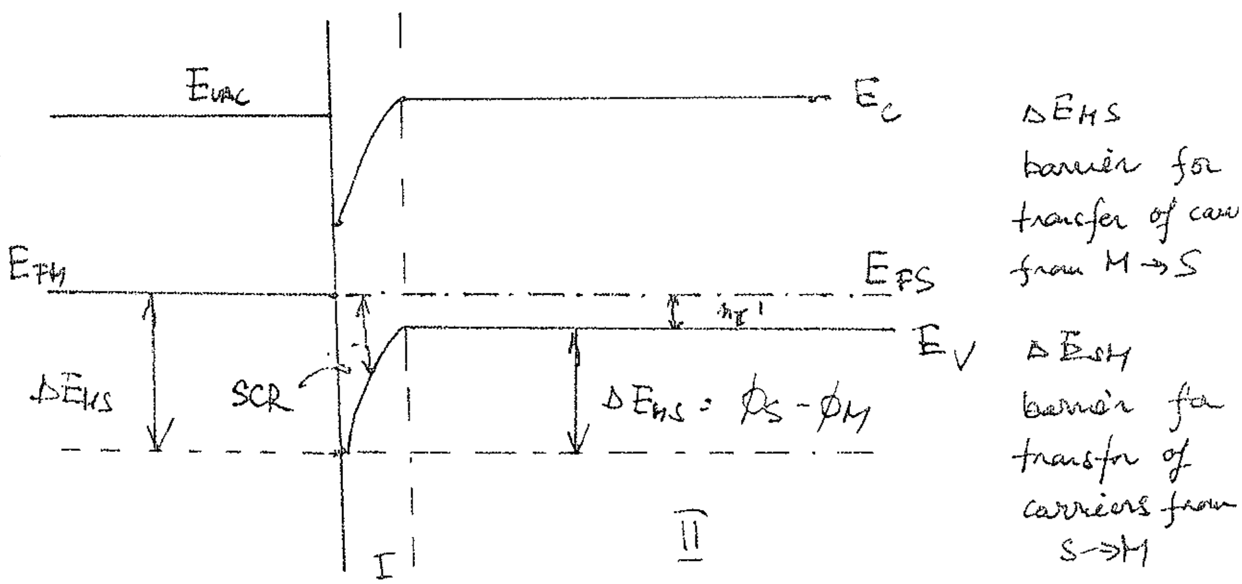


P-type semiconductor, $\phi_M < \phi_S$

No we discuss the case, when the SC is p-type, $\phi_M < \phi_S$. Because $E_{FM} > E_{FS}$, electrons go from M to SC when M is deposited on SC. The majority carriers in the SC are holes - they recombine with the electrons coming from the metal. Negatively charged acceptors remain uncompensated at the interface, a space charge region is formed. The resistivity of the space charge region is high when compared to the SC bulk. Therefore, after application of the bias most of it is concentrated on the SCR (space charge region)

P- type semiconductor, $\phi_M < \phi_S$

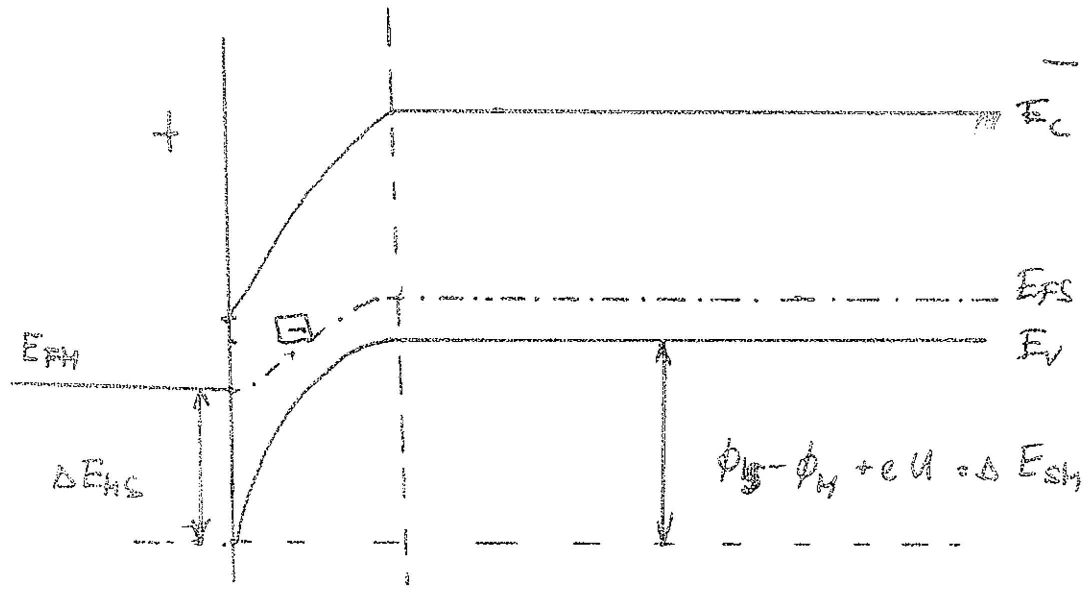


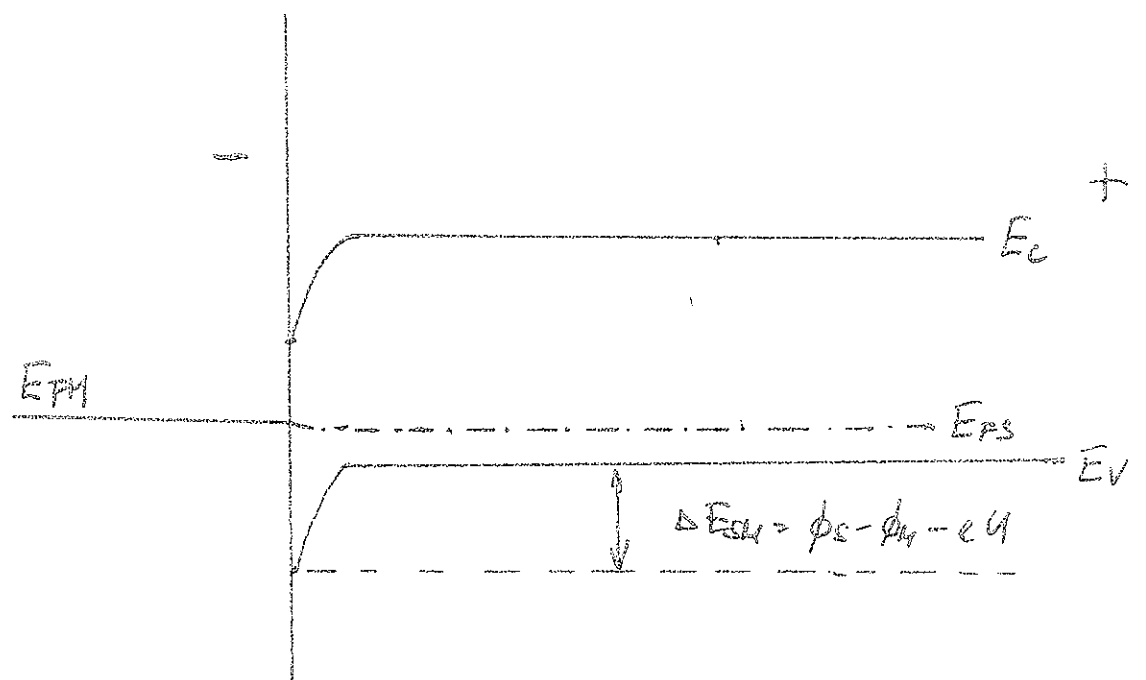


SCR .. space charge region (N_A^-)

after application of (+) on M, the majority holes are repulsed from the M-S interface, the Space charge region width increases. We have basically a very similar situation like in the case of P-N junction in the reverse direction.

P-type SC, $\phi_M < \phi_S$

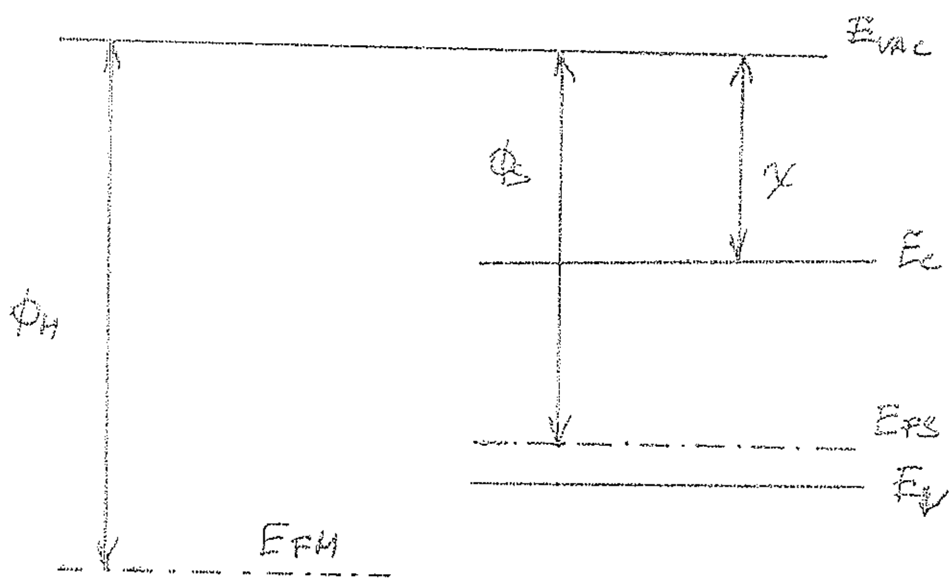




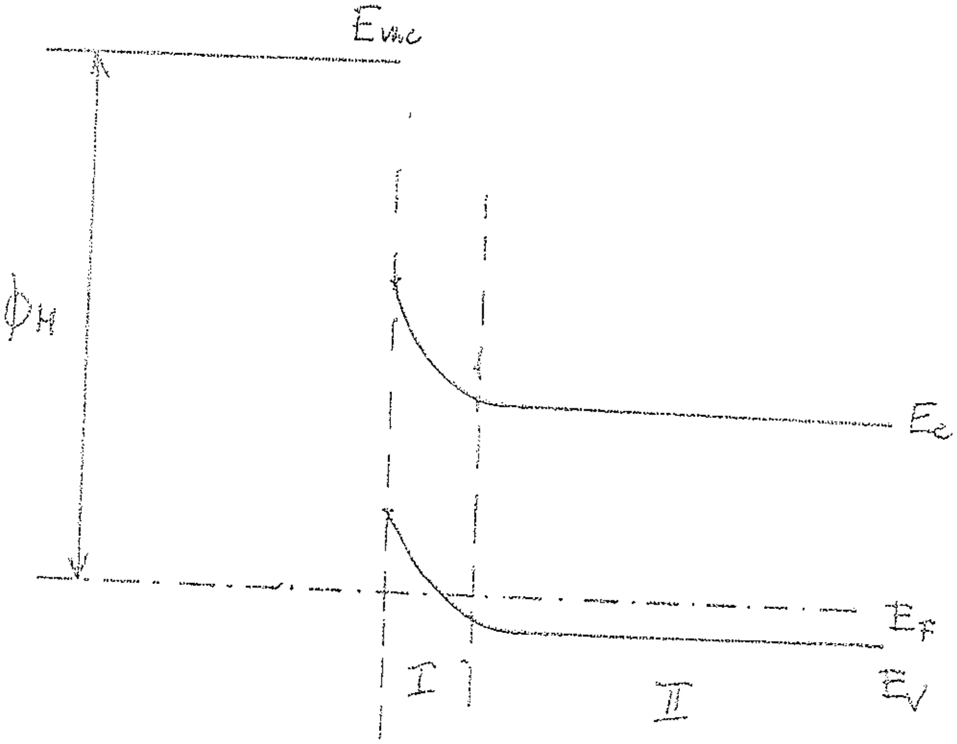
after application of (−) on the metal are the majority holes attracted to SCR which becomes thinner. The M-S interface is in forward direction.

The I-V characteristic is asymmetric, the contact is rectifying.

P-type semiconductor, $\phi_M > \phi_S$



Band scheme before deposition of the metal

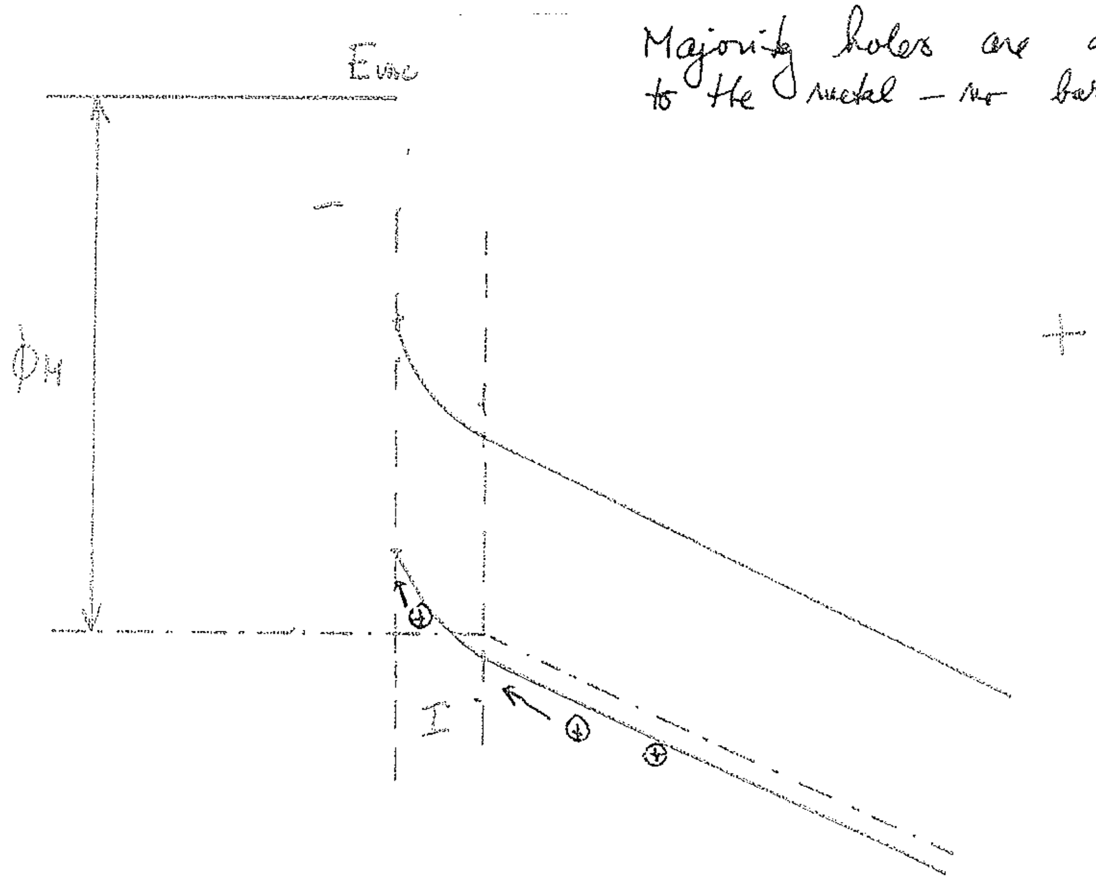


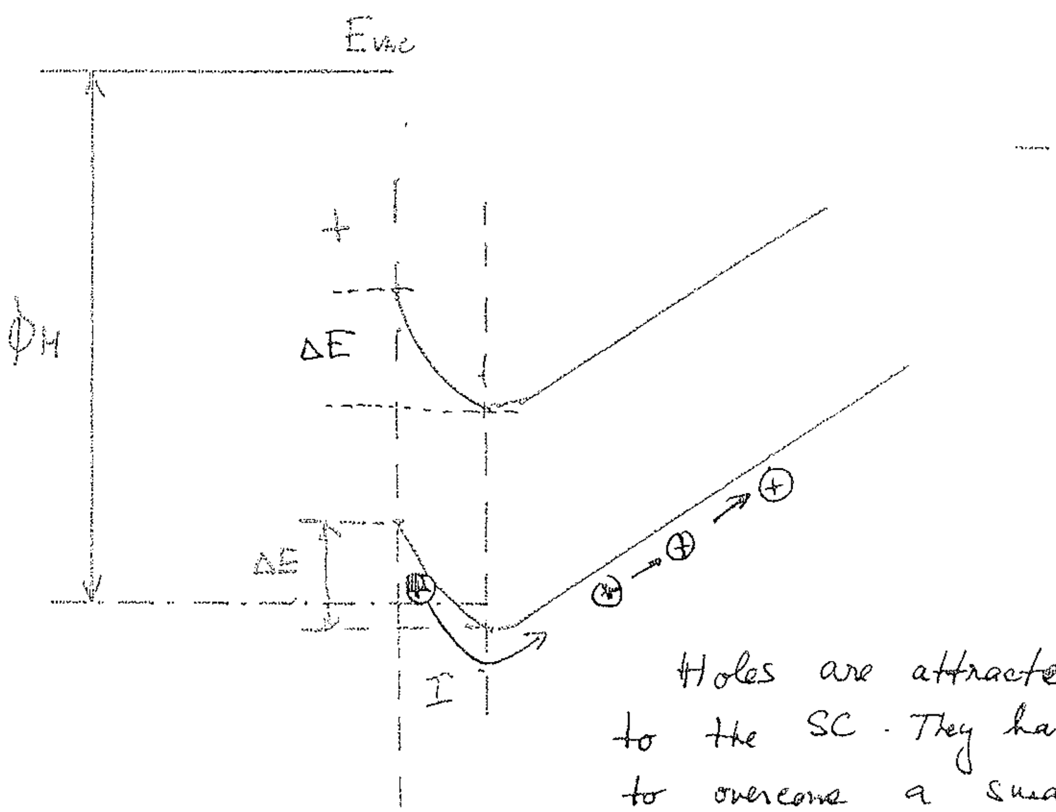
Band scheme after deposition of the metal. Electrons flow from SC to M. The interface area is enriched with holes, its resistivity is smaller than the resistivity of the bulk of the semiconductor.

$(P_I > P_{II})$ $R_I < R_{II}$

p-type SC, $\phi_M > \phi_S$, under bias

Majority holes are attracted to the metal – no barrier.





Holes are attracted to the SC. They have to overcome a small barrier ΔE.

The contact behaves as ohmic or nearly ohmic.