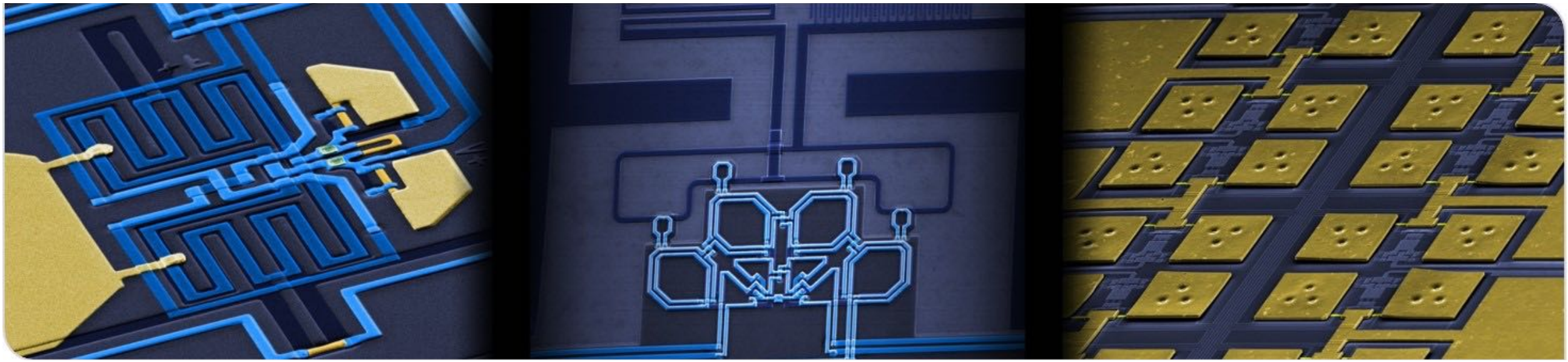
Karlsruhe Institute of Technology

Bauelemente der Elektrotechnik

Prof. Dr. rer. nat. Sebastian Kempf

Wintersemester 2021/22

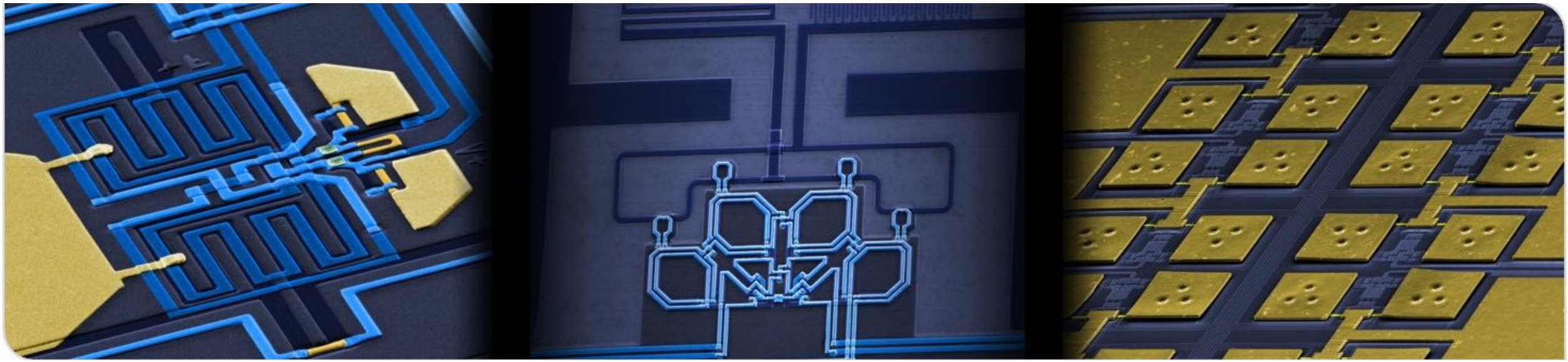


Karlsruhe Institute of Technology

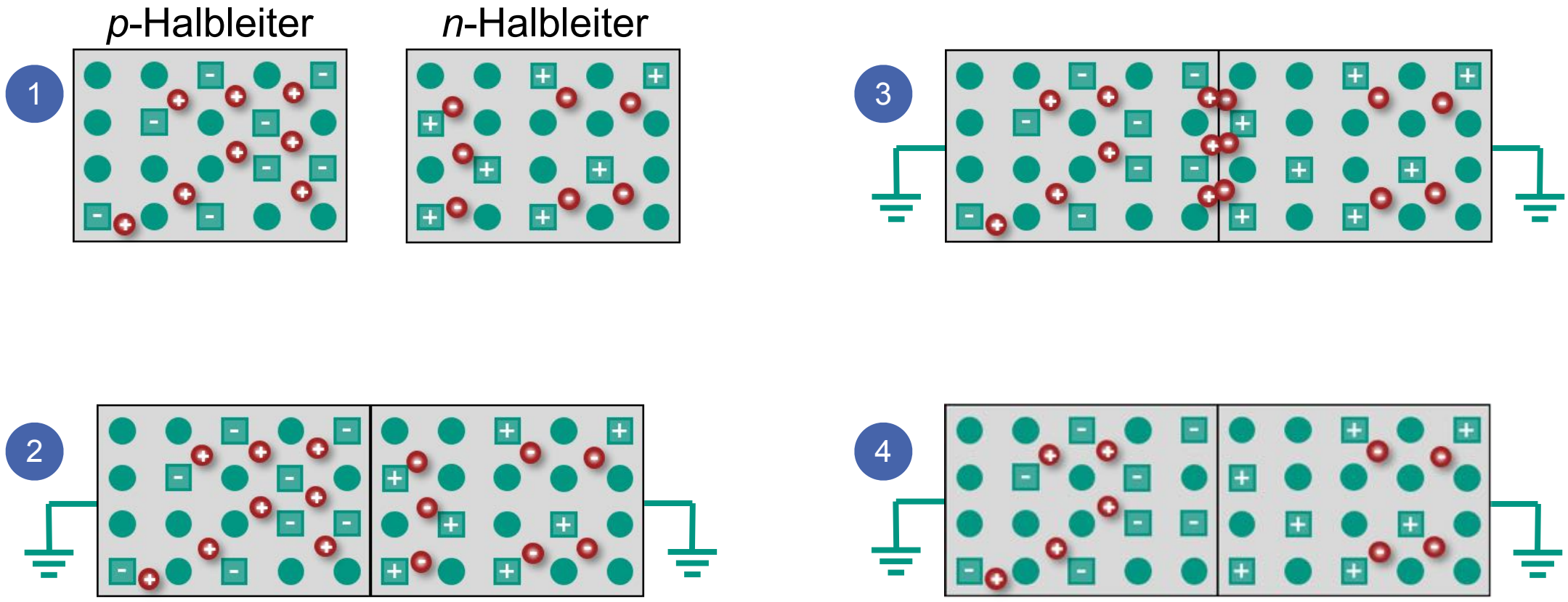
Bauelemente der Elektrotechnik

pn-Übergang und abgeleitete Bauelemente

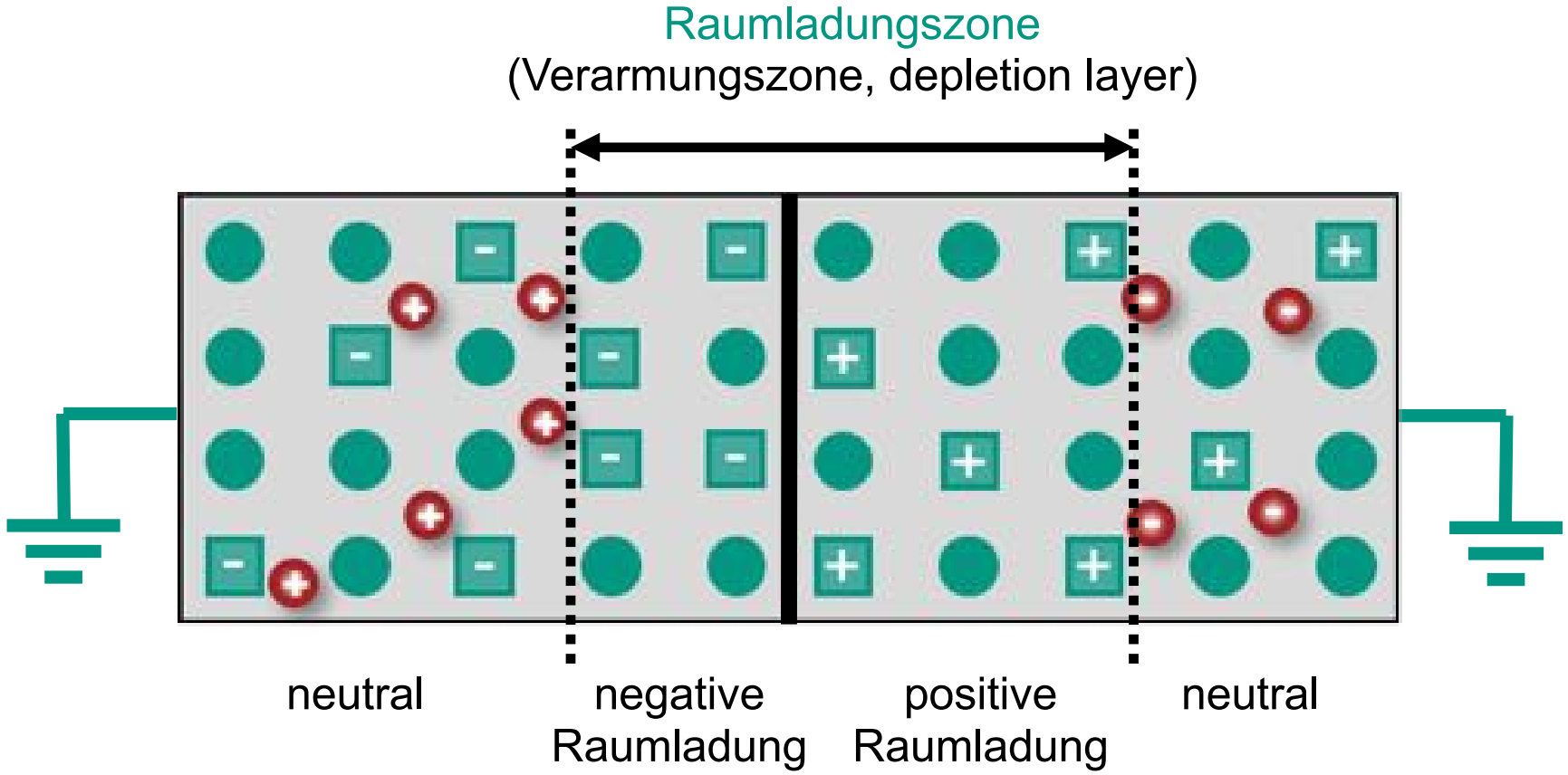
Wintersemester 2021/22



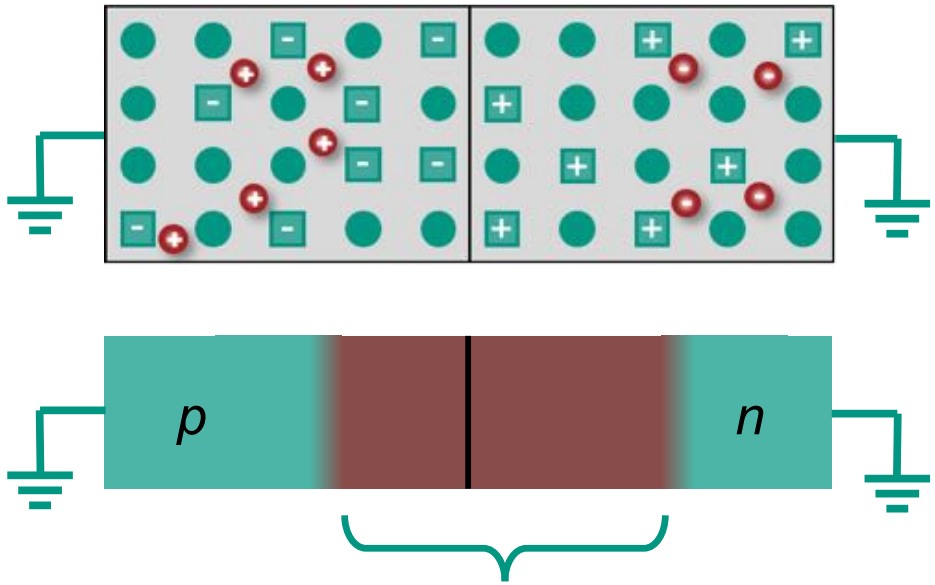
Ausbildung der Raumladungszone



Raumladungszone



Vereinfachte Darstellung der Raumladungszone



Neutraler *p*-Bereich

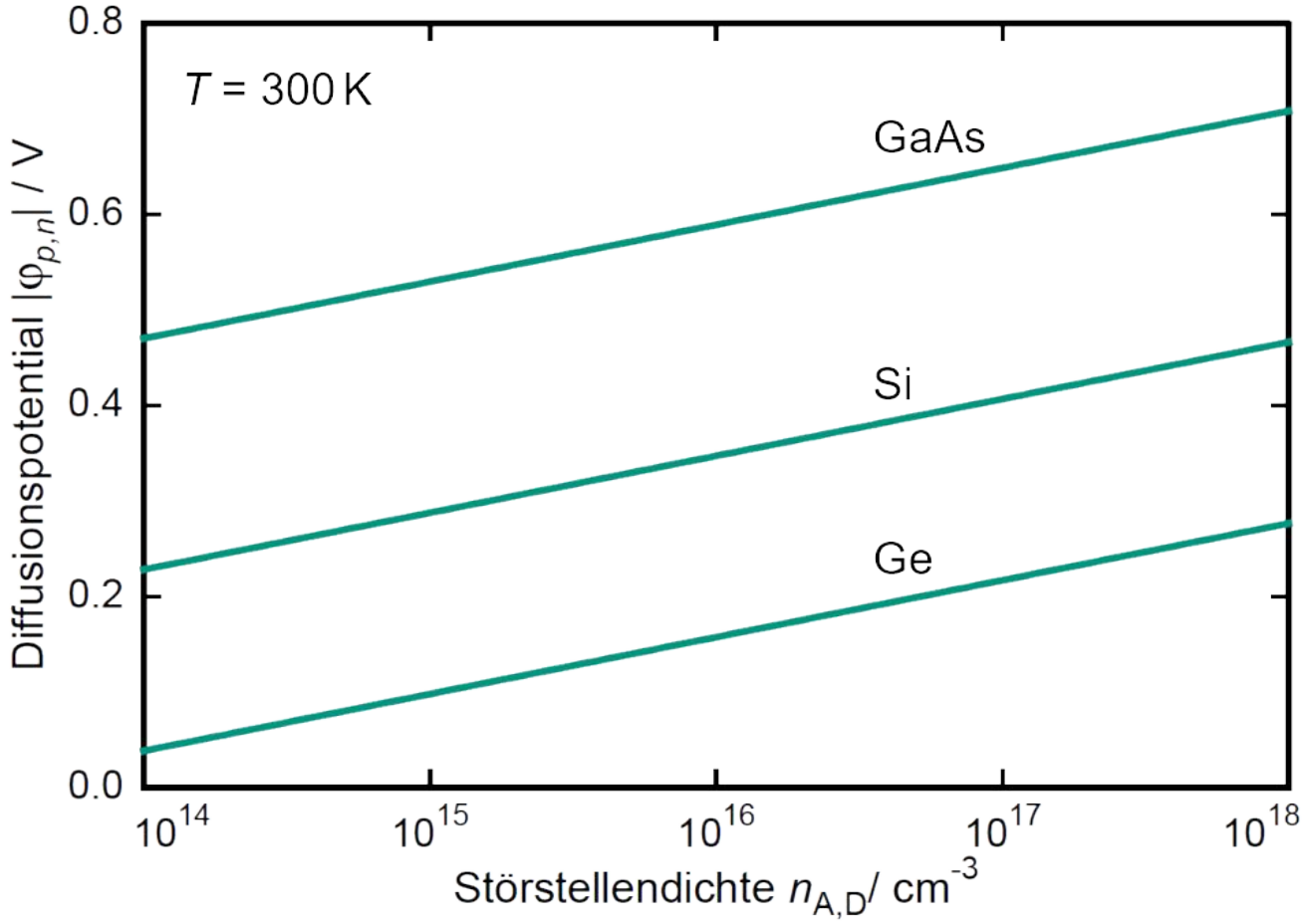
$n_{\mathrm{D}} = 0, p \gg n \approx 0$

Raumladungszone

Neutraler *n*-Bereich

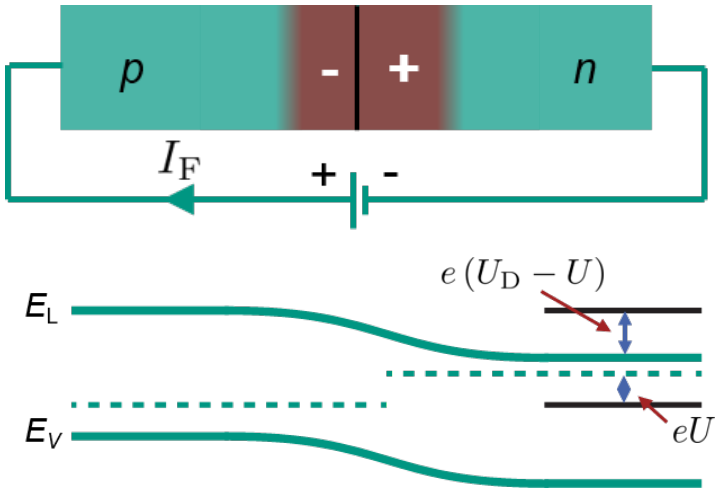
$n_{\mathrm{A}} = 0, n \gg p \approx 0$

Diffusionspotentiale

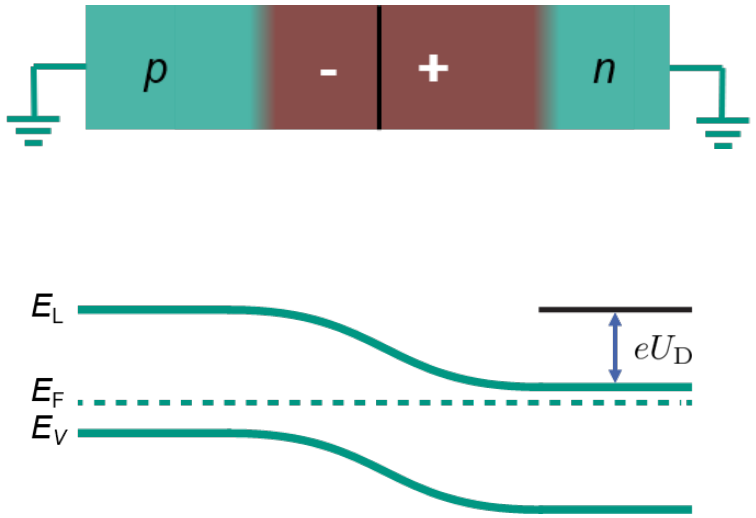


pn-Übergang mit äußerer Spannung

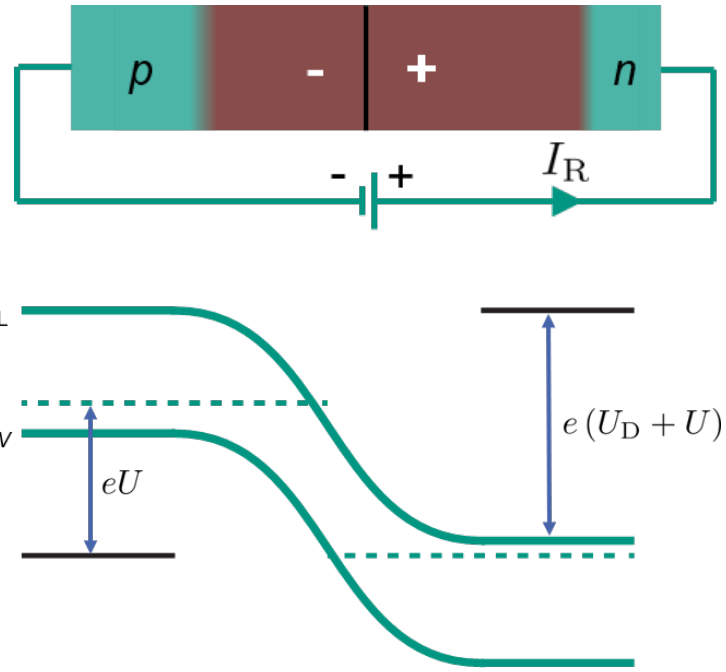
Durchlassrichtung
(forward bias)



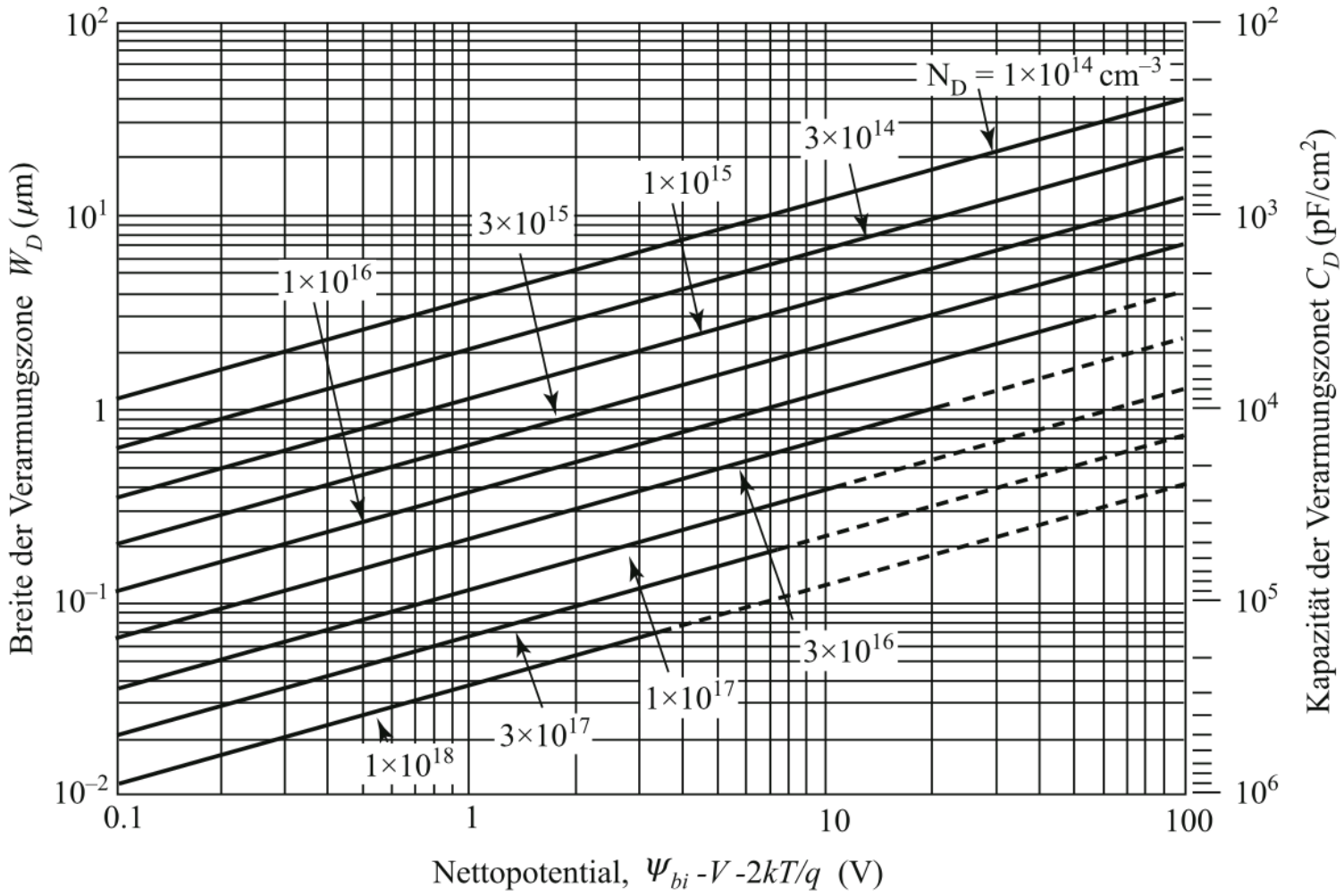
Thermisches Gleichgewicht



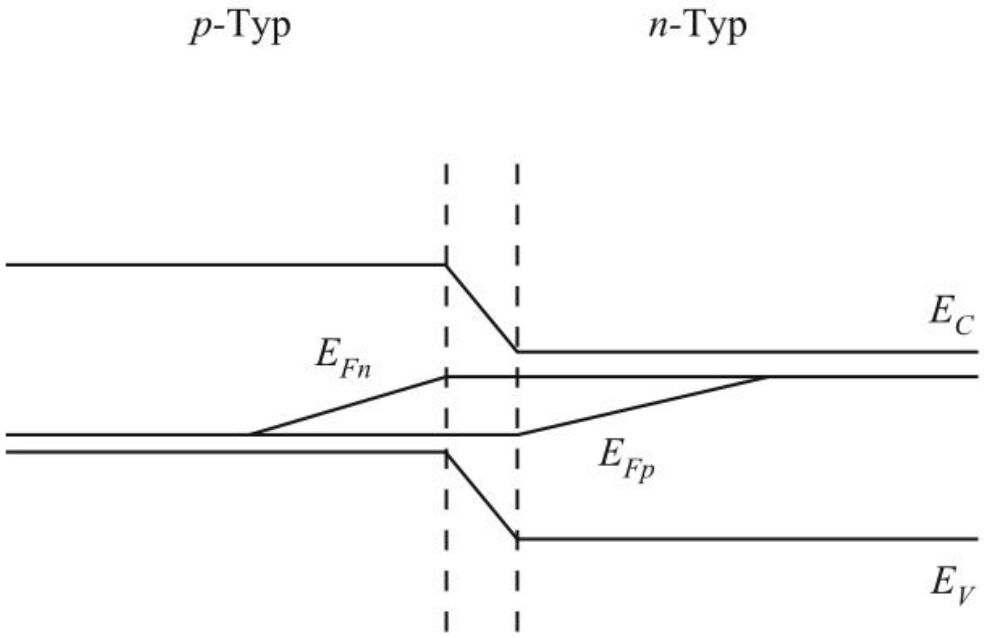
Sperrrichtung
(reverse bias)

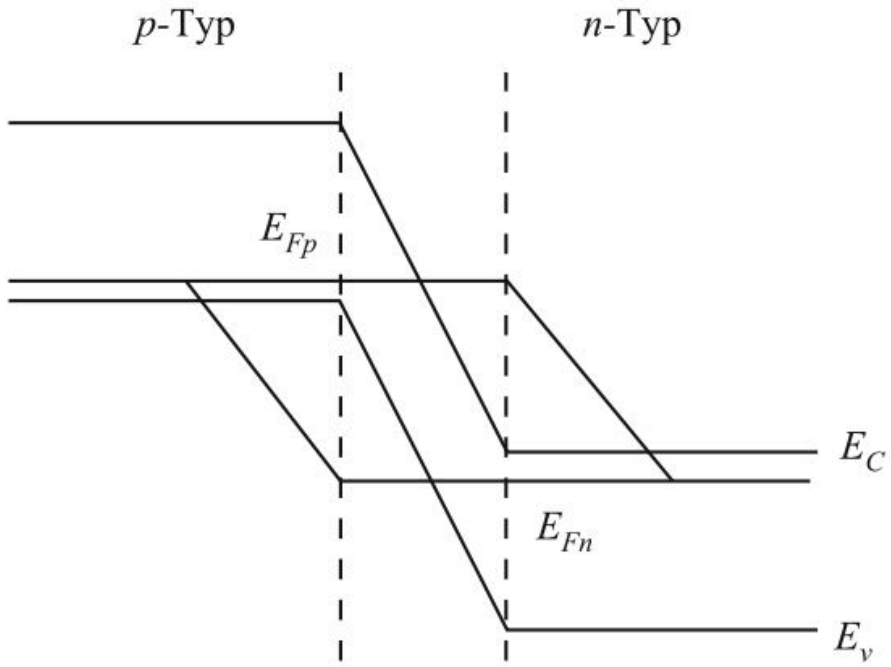


Breite und Kapazität der Verarmungszone

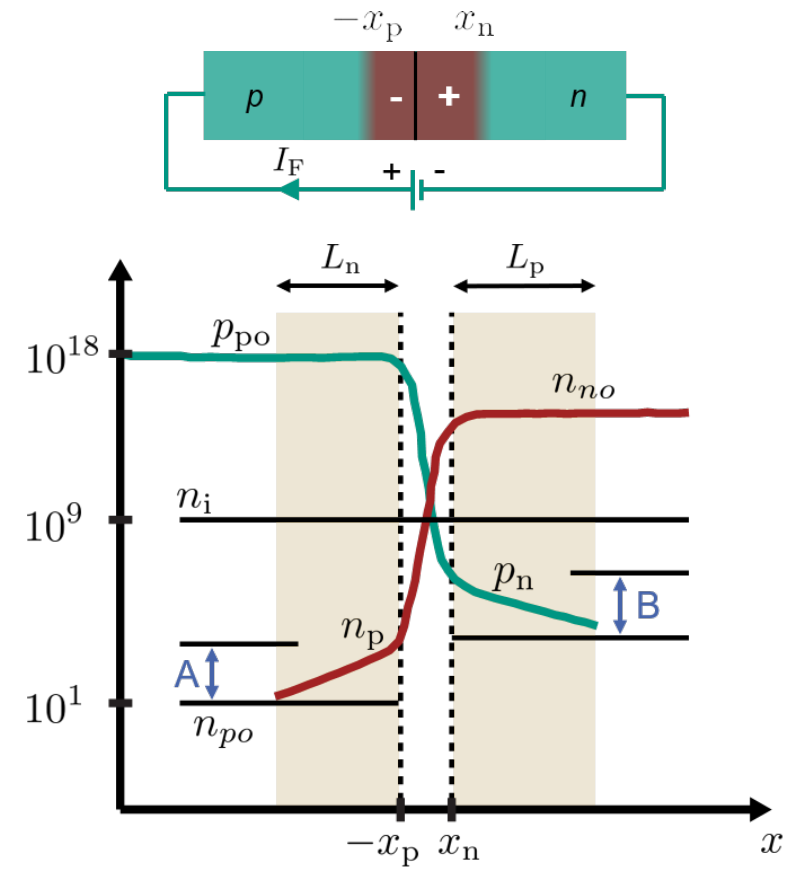


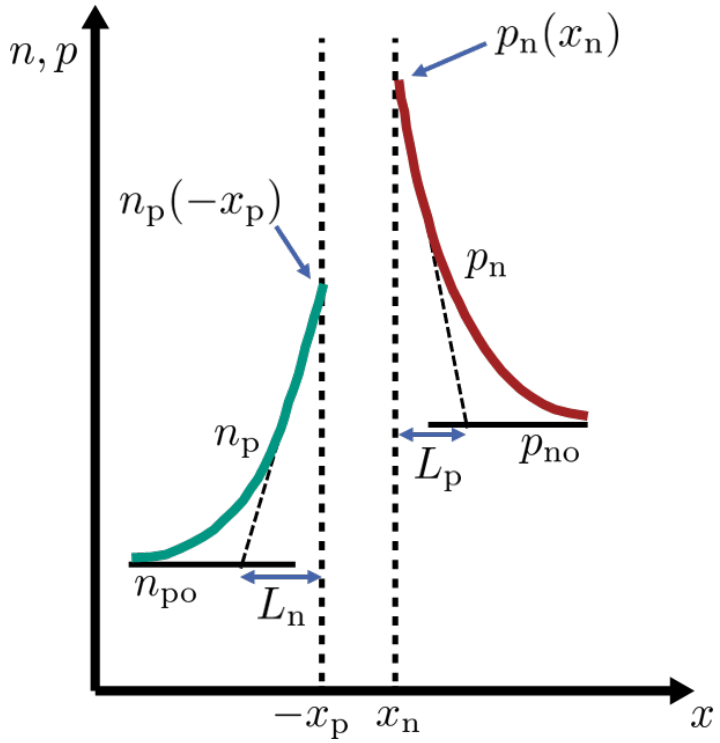
Potentialverteilung pn-Übergang

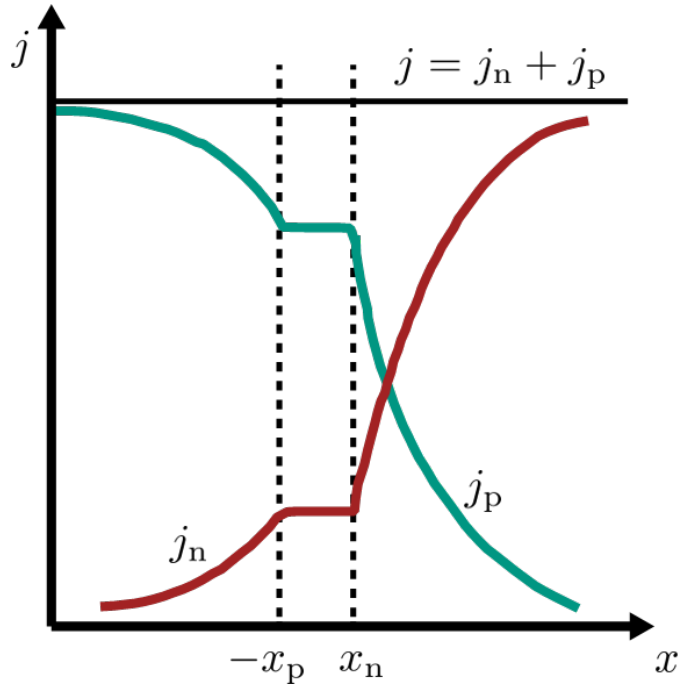




pn-Übergang in Durchlassrichtung

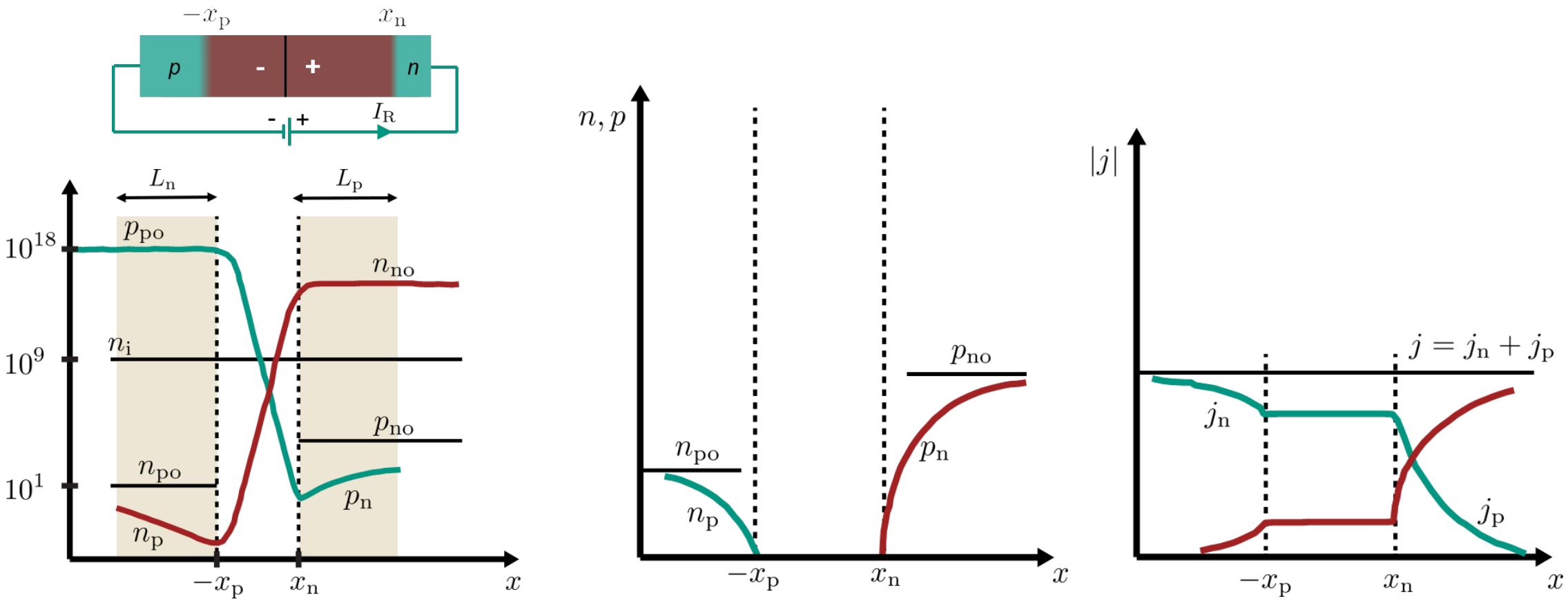






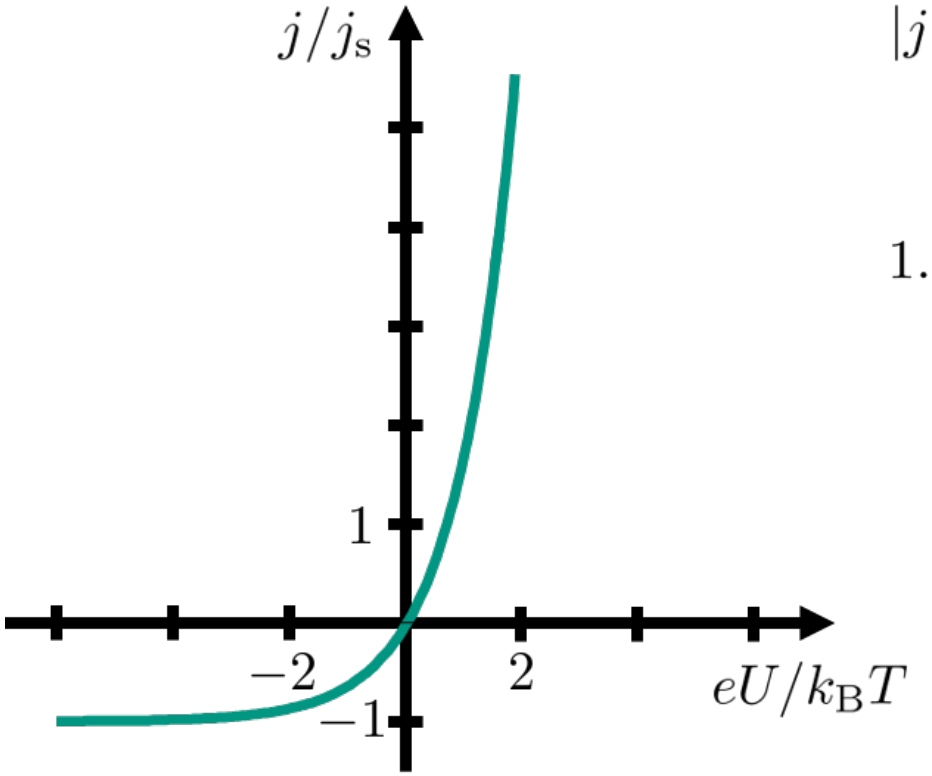
A: $n_{po}\left[\exp\left(\frac{eU}{k_B T}\right) - 1\right]$ B: $p_{no}\left[\exp\left(\frac{eU}{k_B T}\right) - 1\right]$

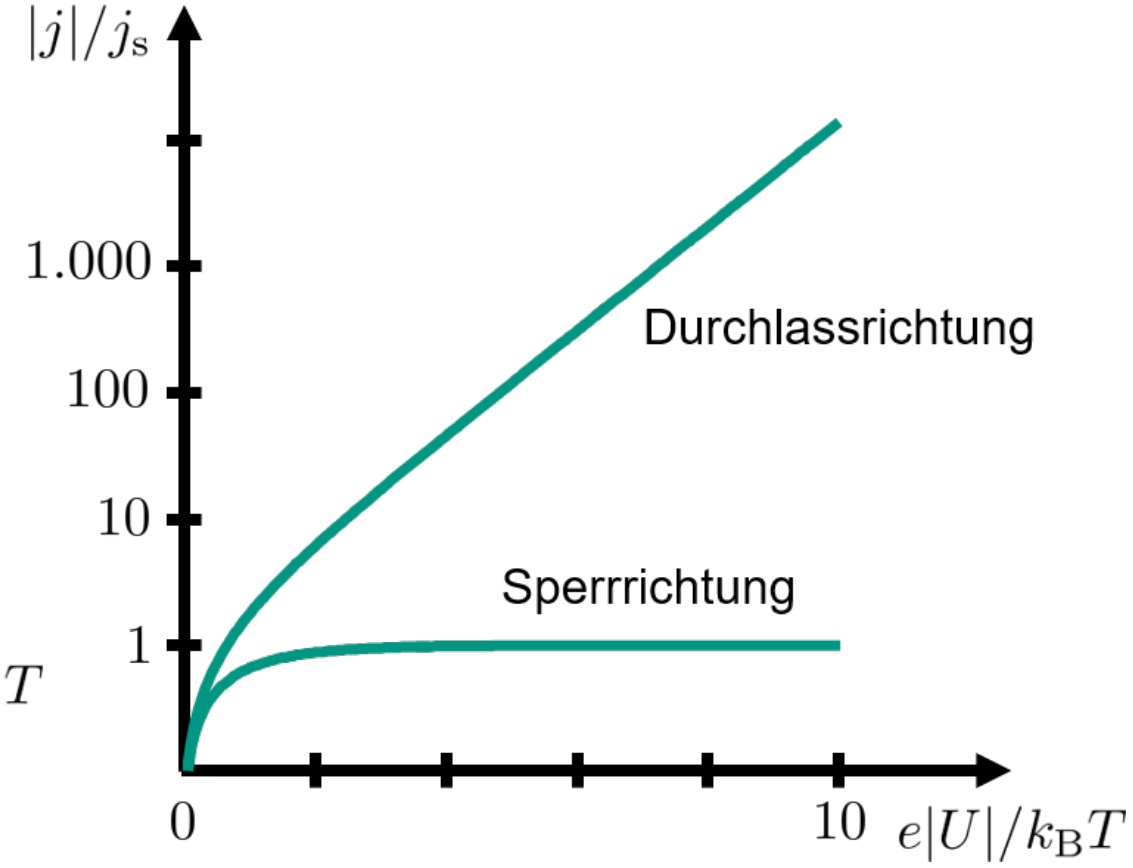
pn-Übergang in Sperrrichtung



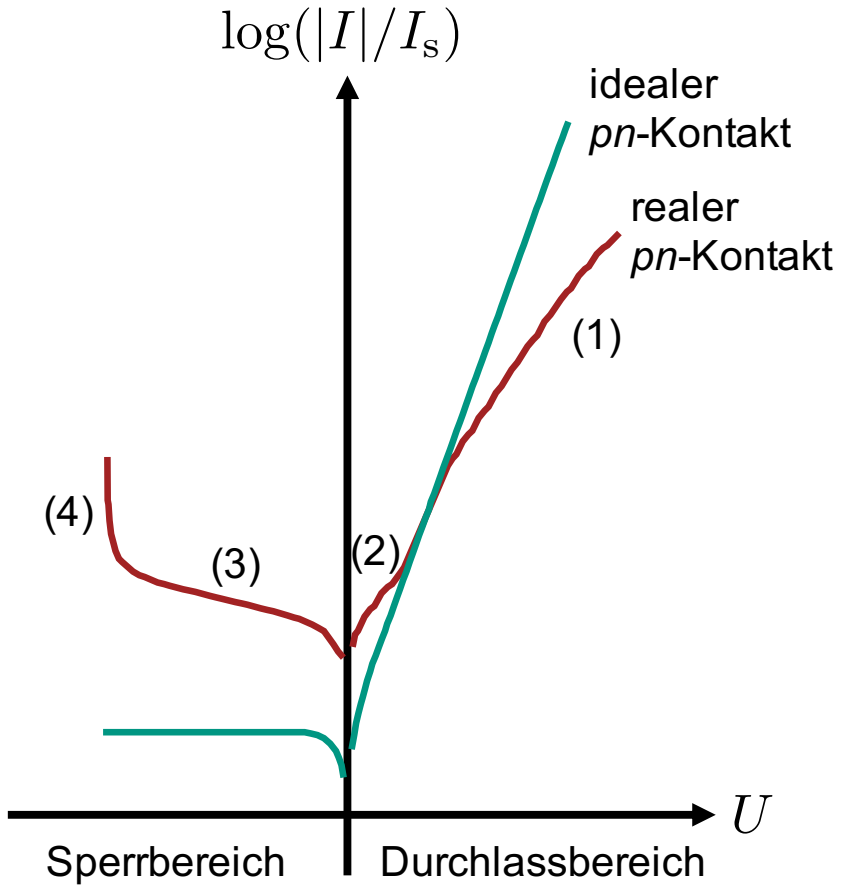
A: $n_\mathrm{po}\left[\exp\left(\frac{eU}{k_\mathrm{B}T}\right)-1\right]$ B: $p_\mathrm{no}\left[\exp\left(\frac{eU}{k_\mathrm{B}T}\right)-1\right]$

Ideale Strom-Spannung-Kennlinie

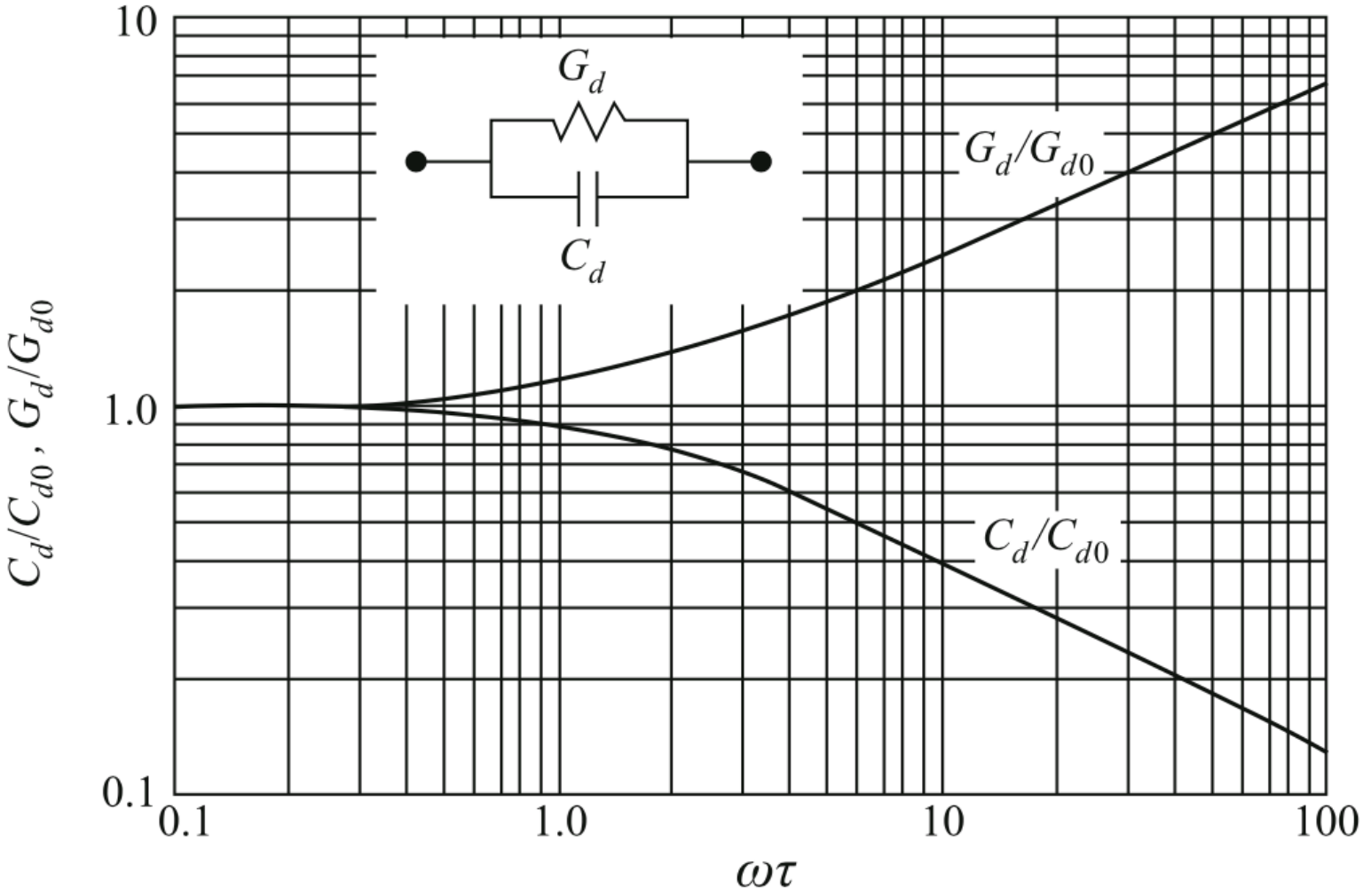




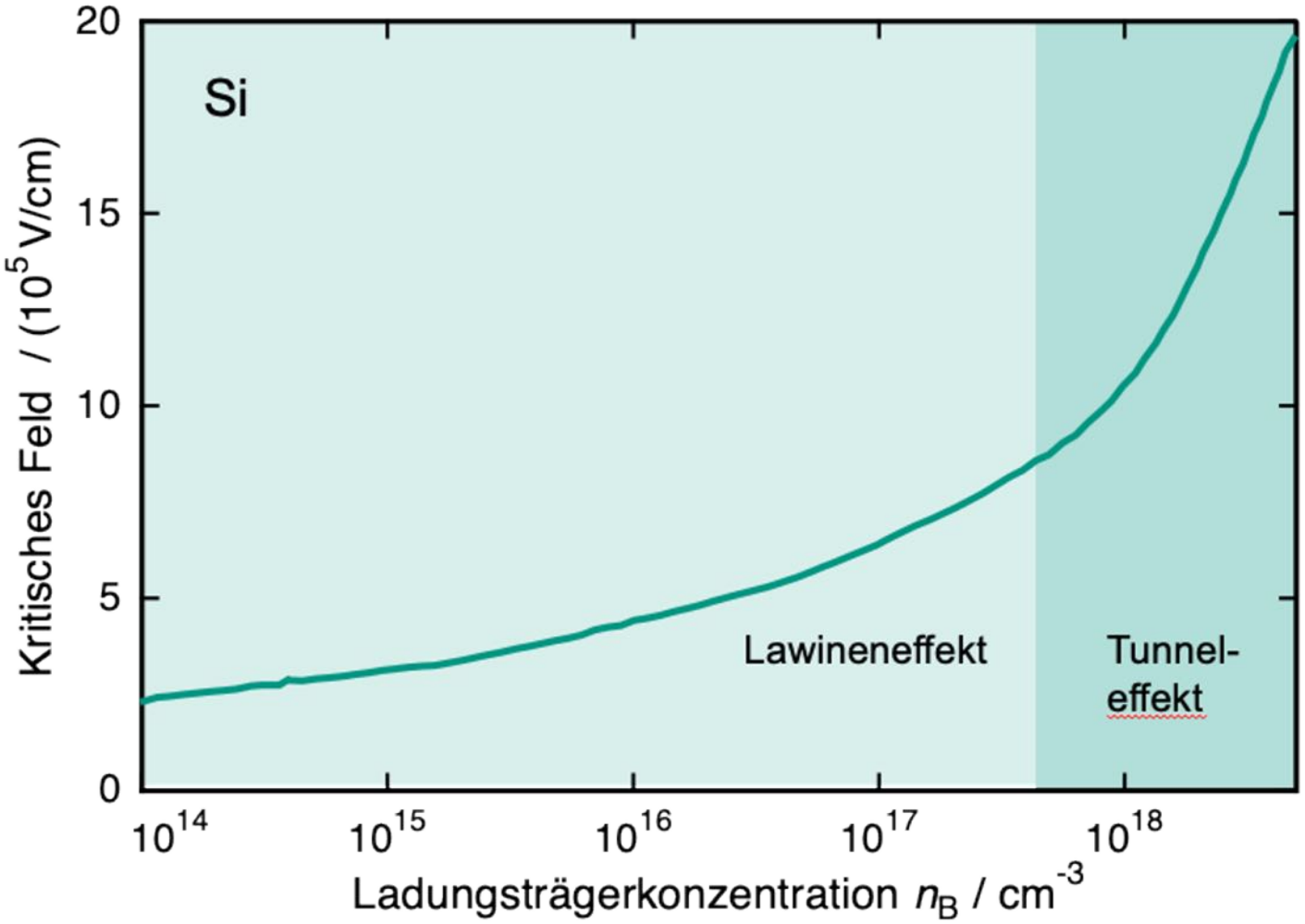
Reale Strom-Spannung-Kennlinie



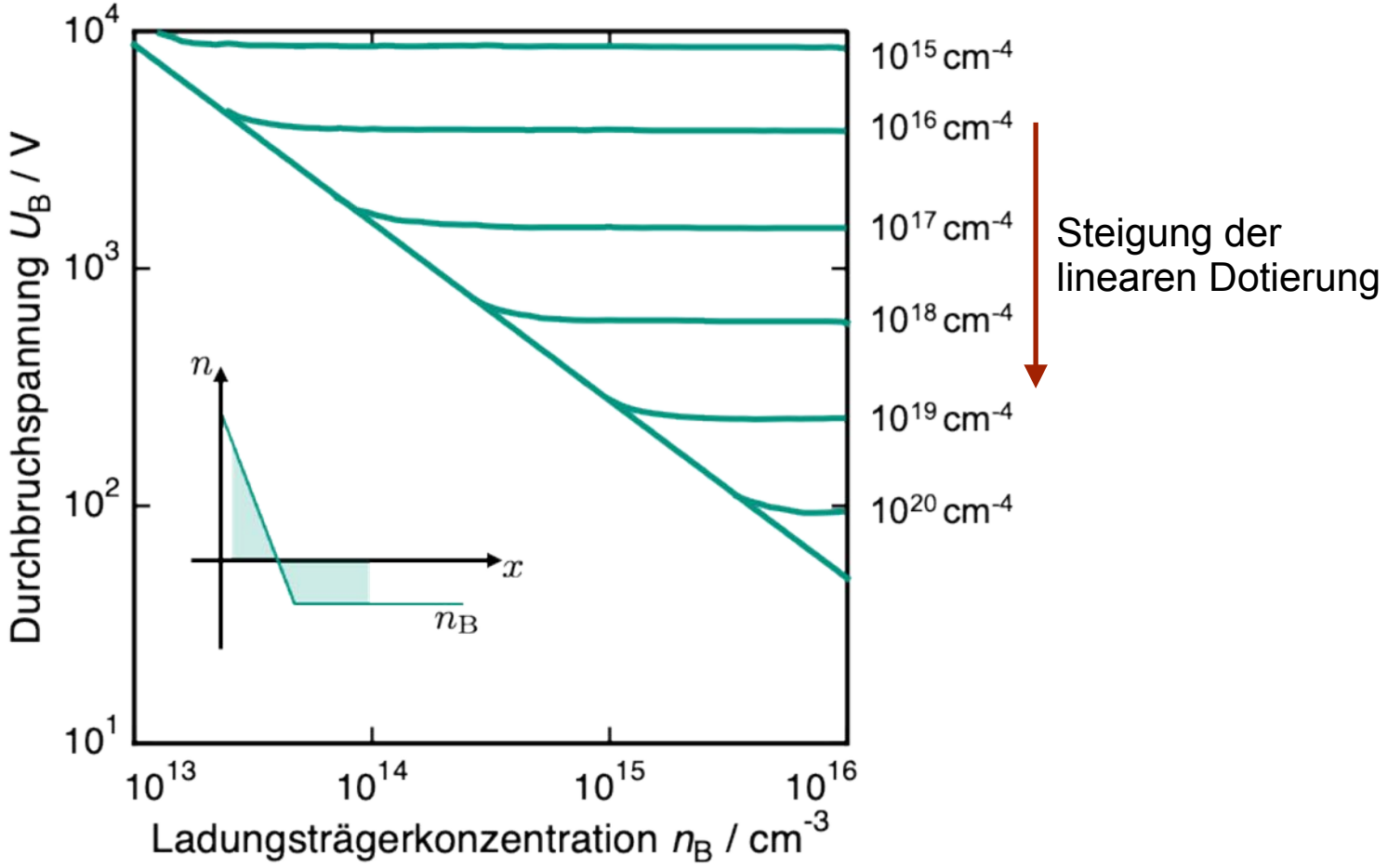
Diffusionsleitwert und Diffusionskapazität



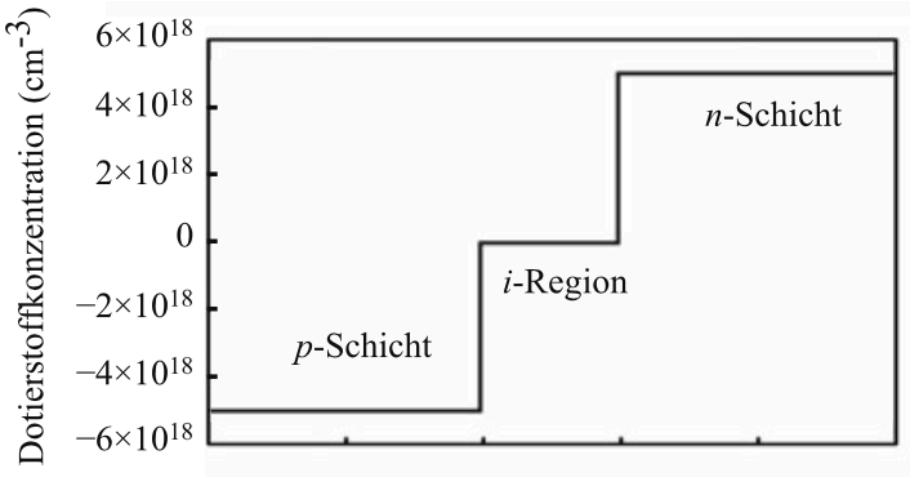
Kritische Feldstärke

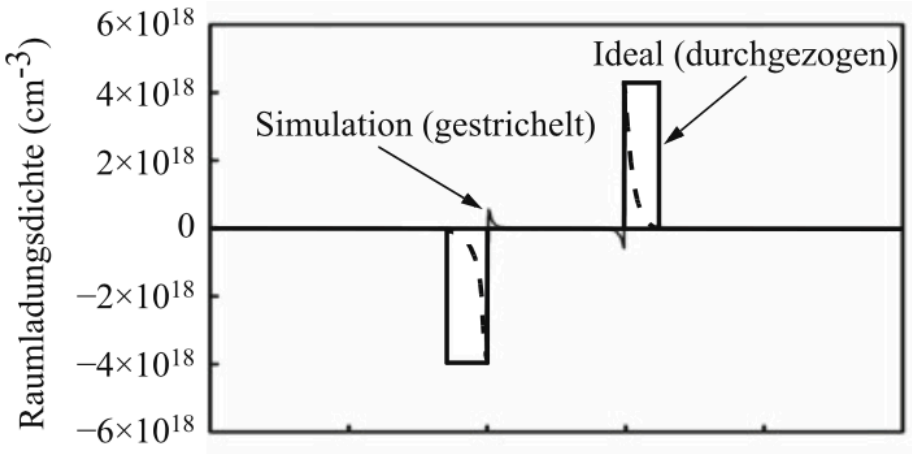


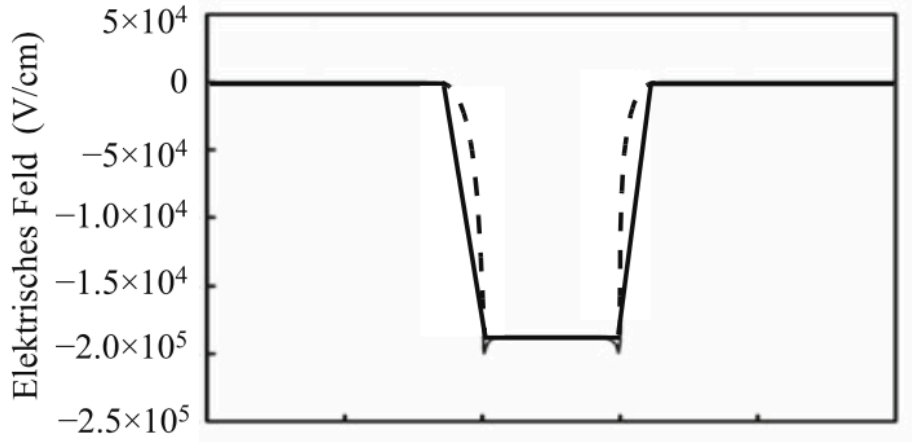
Durchbruchspannung

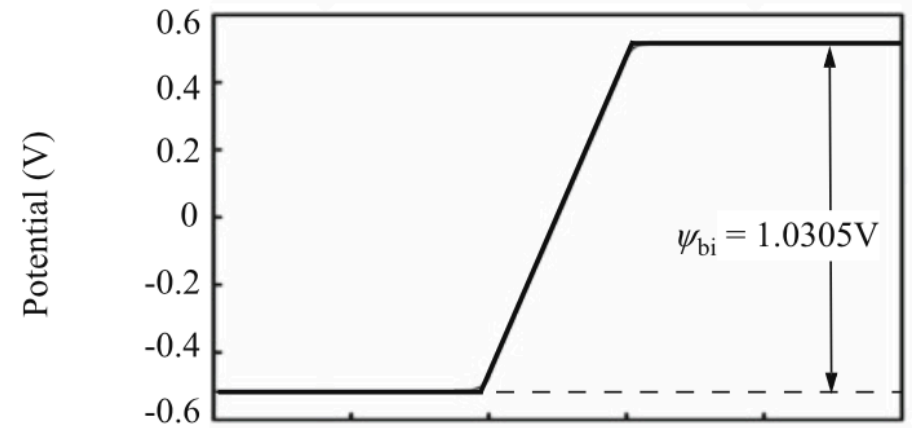


pin-Dioden

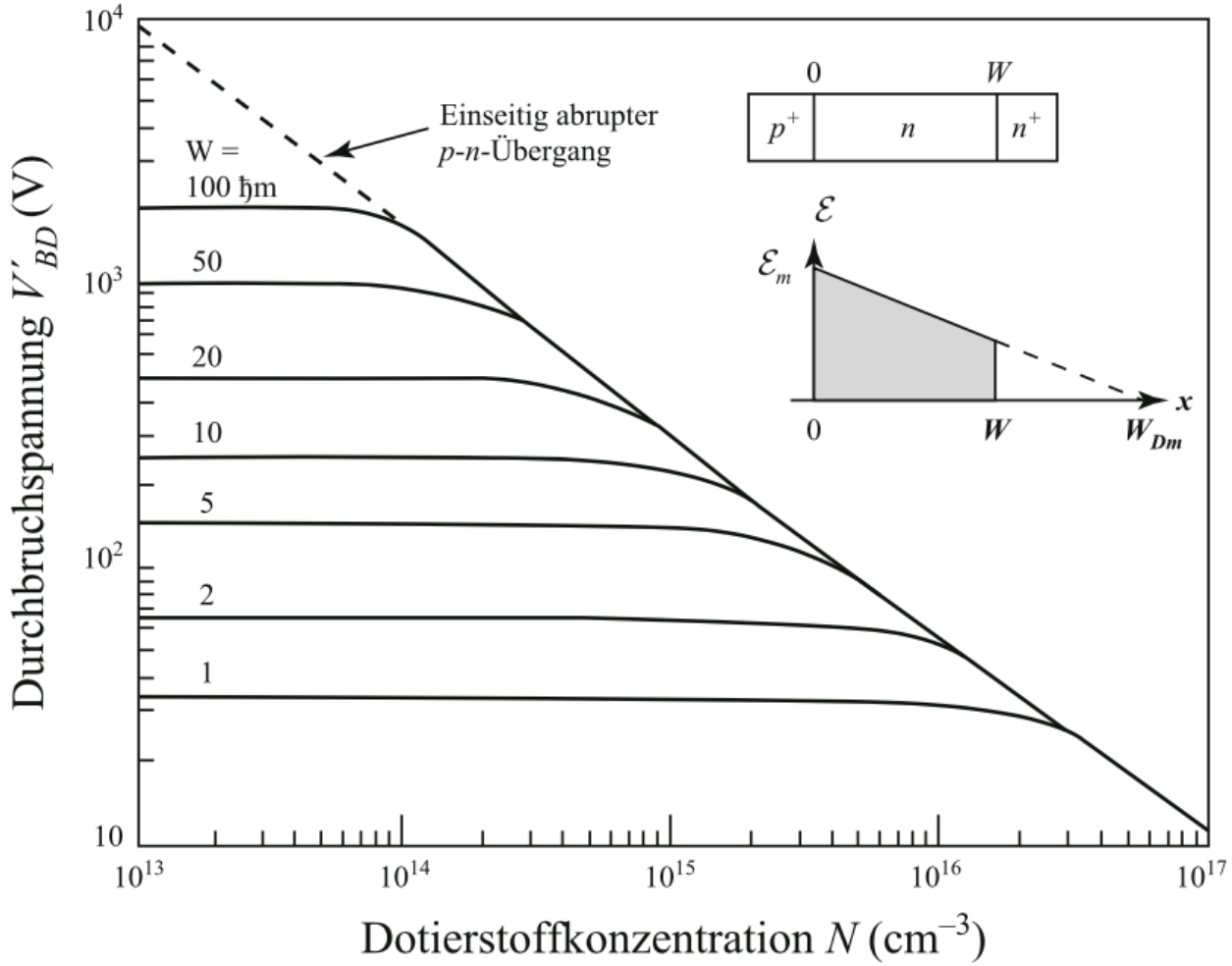

Dotierstoffkonzentration (cm^{-3})
6×10^{18}
4×10^{18}
2×10^{18}
0
−2×10^{18}
−4×10^{18}
−6×10^{18}
n-Schicht
i-Region
p-Schicht


Raumladungsdichte (cm^{-3})
6×10^{18}
4×10^{18}
2×10^{18}
0
−2×10^{18}
−4×10^{18}
−6×10^{18}
Ideal (durchgezogen)
Simulation (gestrichelt)

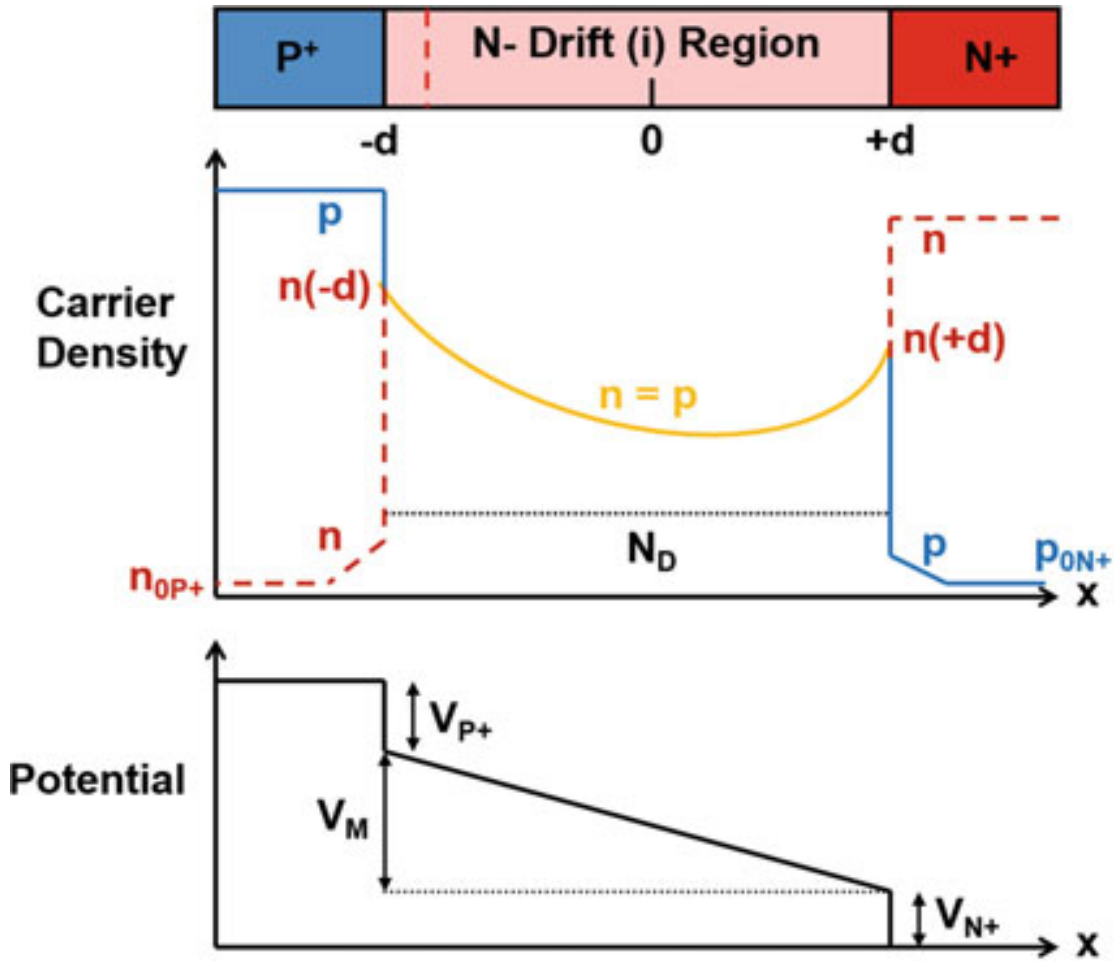

Elektrisches Feld (V/cm)
5×10^{4}
0
−5×10^{4}
−1.0×10^{4}
−1.5×10^{4}
−2.0×10^{5}
−2.5×10^{5}


Potential (V)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
ψ_{bi} = 1.0305V

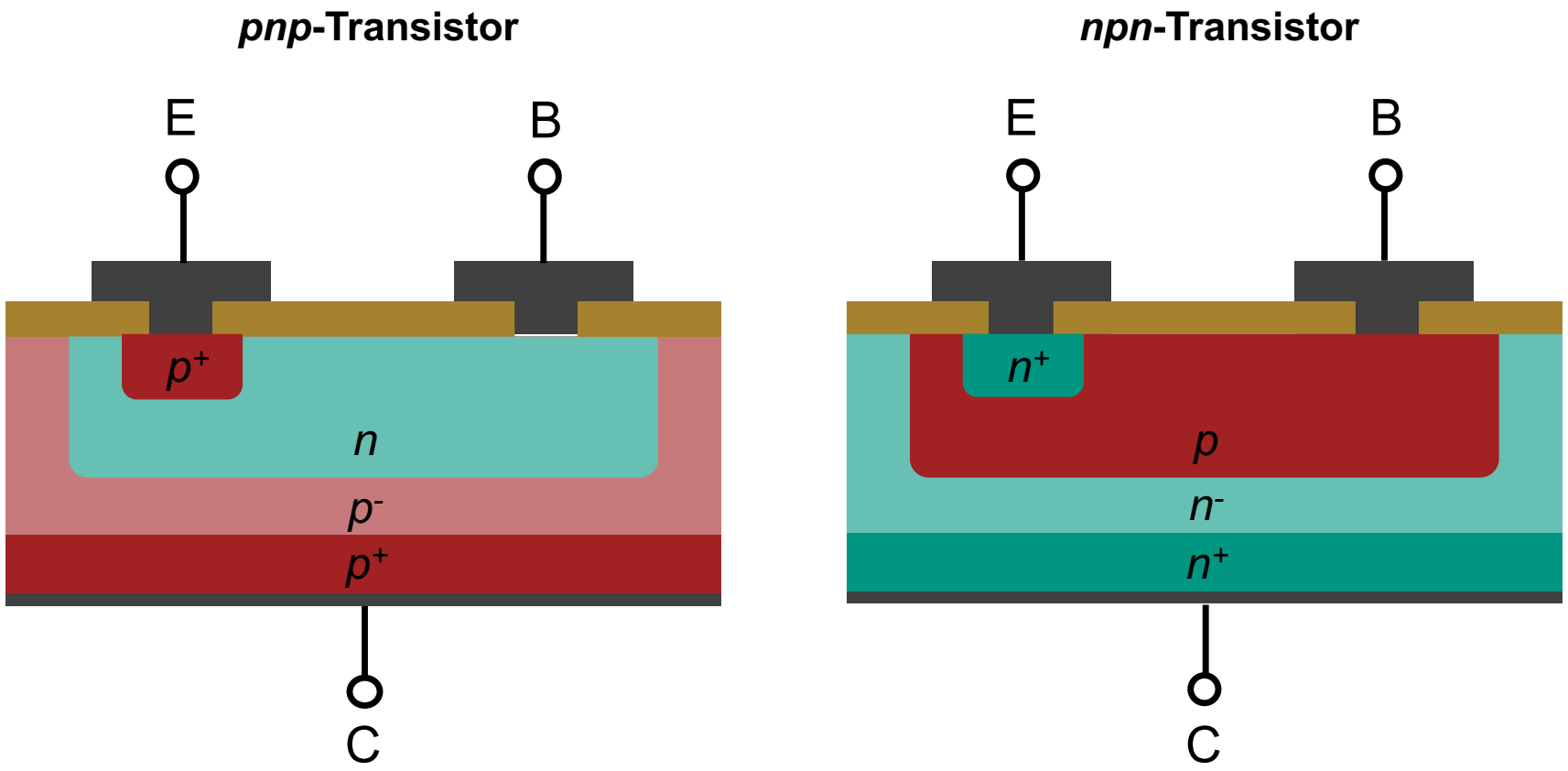
Durchbruchspannung von pin-Dioden



Ladungsträgerverteilung pin-Dioden im HL-Bereich



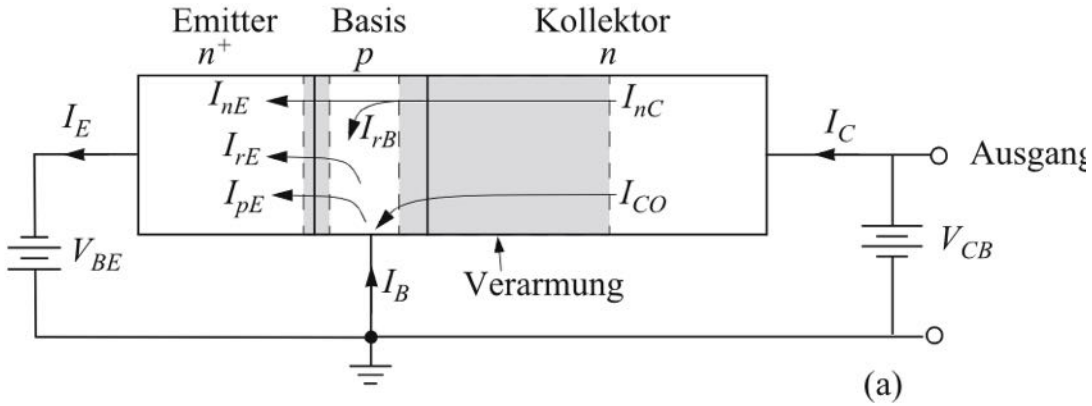
Bipolartransistoren in Epitaxial-Planar-Technik

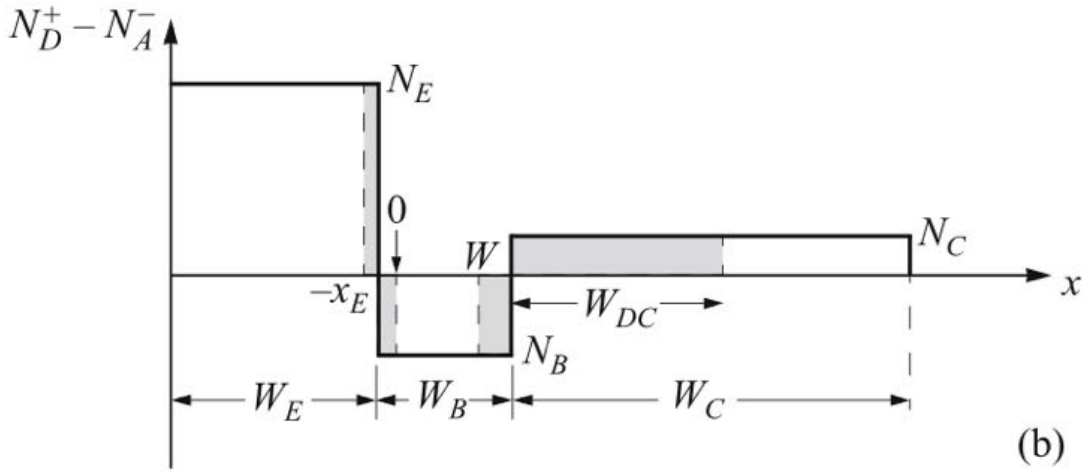


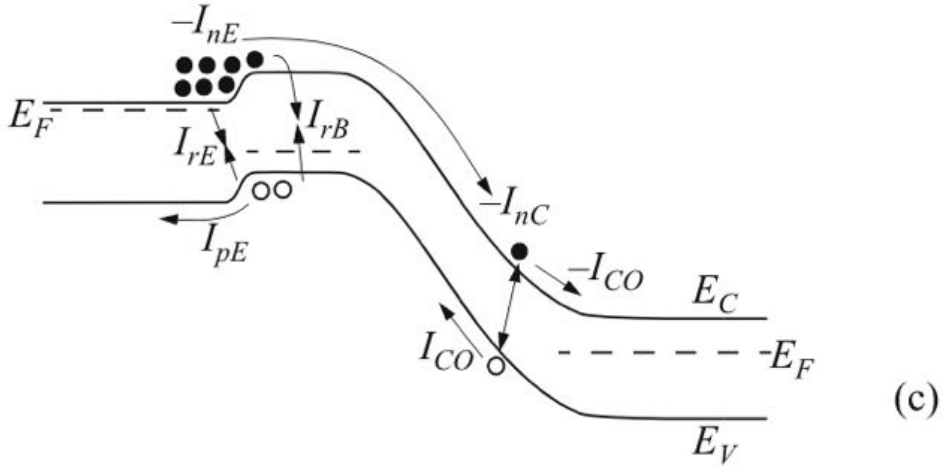
Betriebsmodi Bipolartransistor

	Spannung	Emitter-Diode (B-E)	Kollektor-Diode (B-C)	Modus
npn	E < B < C	Durchlass	Gesperrt	Verstärkungsbereich
	E < B > C	Durchlass	Durchlass	Sättigungsbereich
	E > B < C	Gesperrt	Gesperrt	Sperrbereich
	E > B > C	Gesperrt	Durchlass	Inversbereich
pnp	E < B < C	Gesperrt	Durchlass	Inversbereich
	E < B > C	Gesperrt	Gesperrt	Sperrbereich
	E > B < C	Durchlass	Durchlass	Sättigungsbereich
	E > B > C	Durchlass	Gesperrt	Verstärkungsbereich

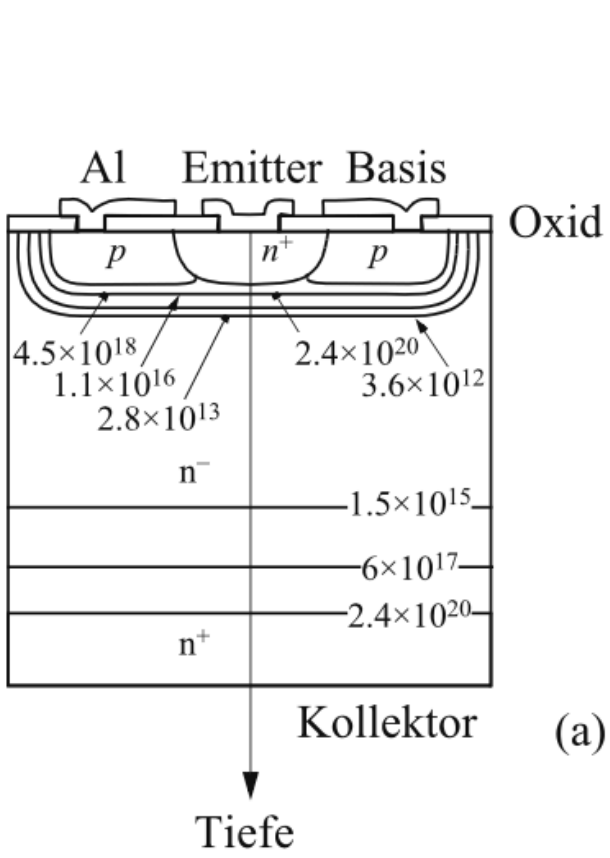
Dotierung und Bandstruktur eines BJT

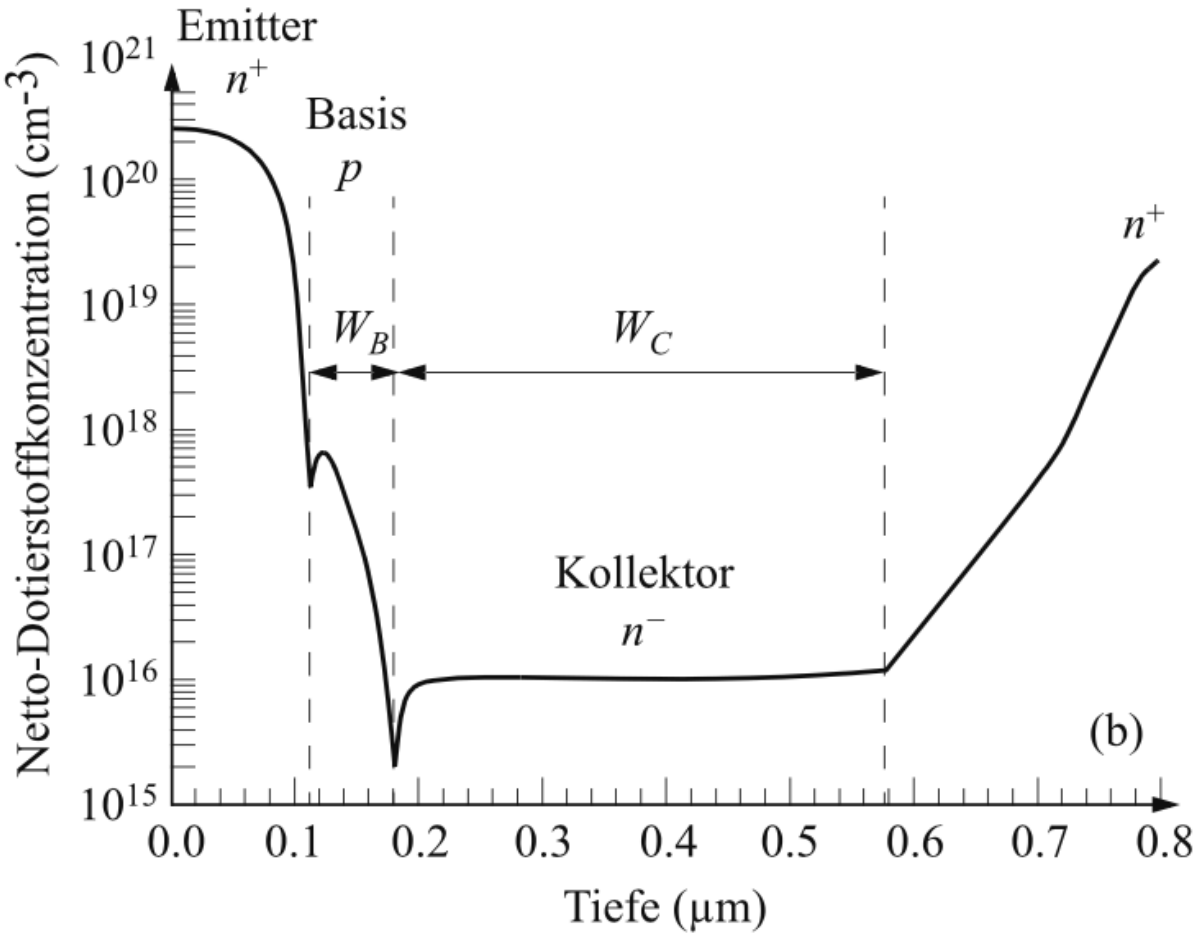




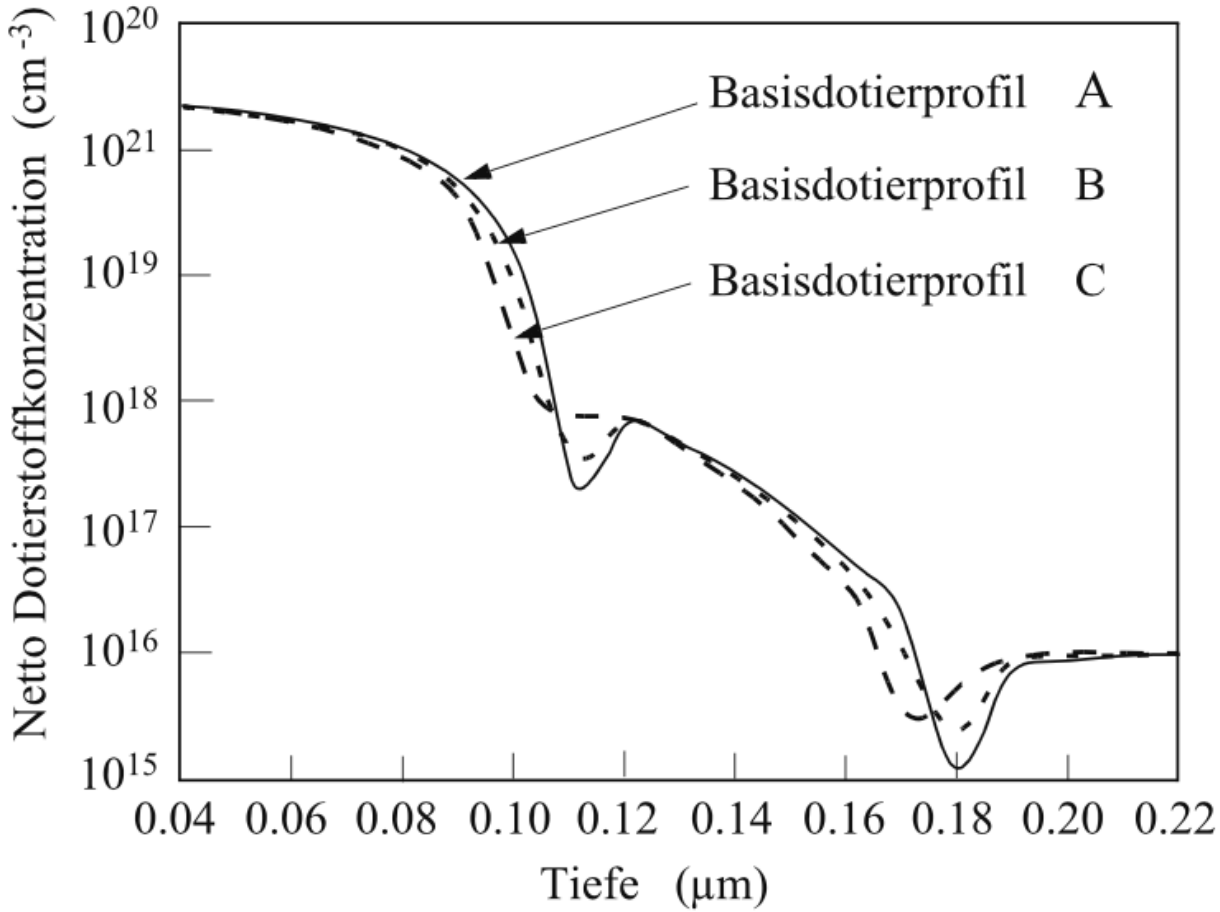


Verbesserung Basistransportfaktor



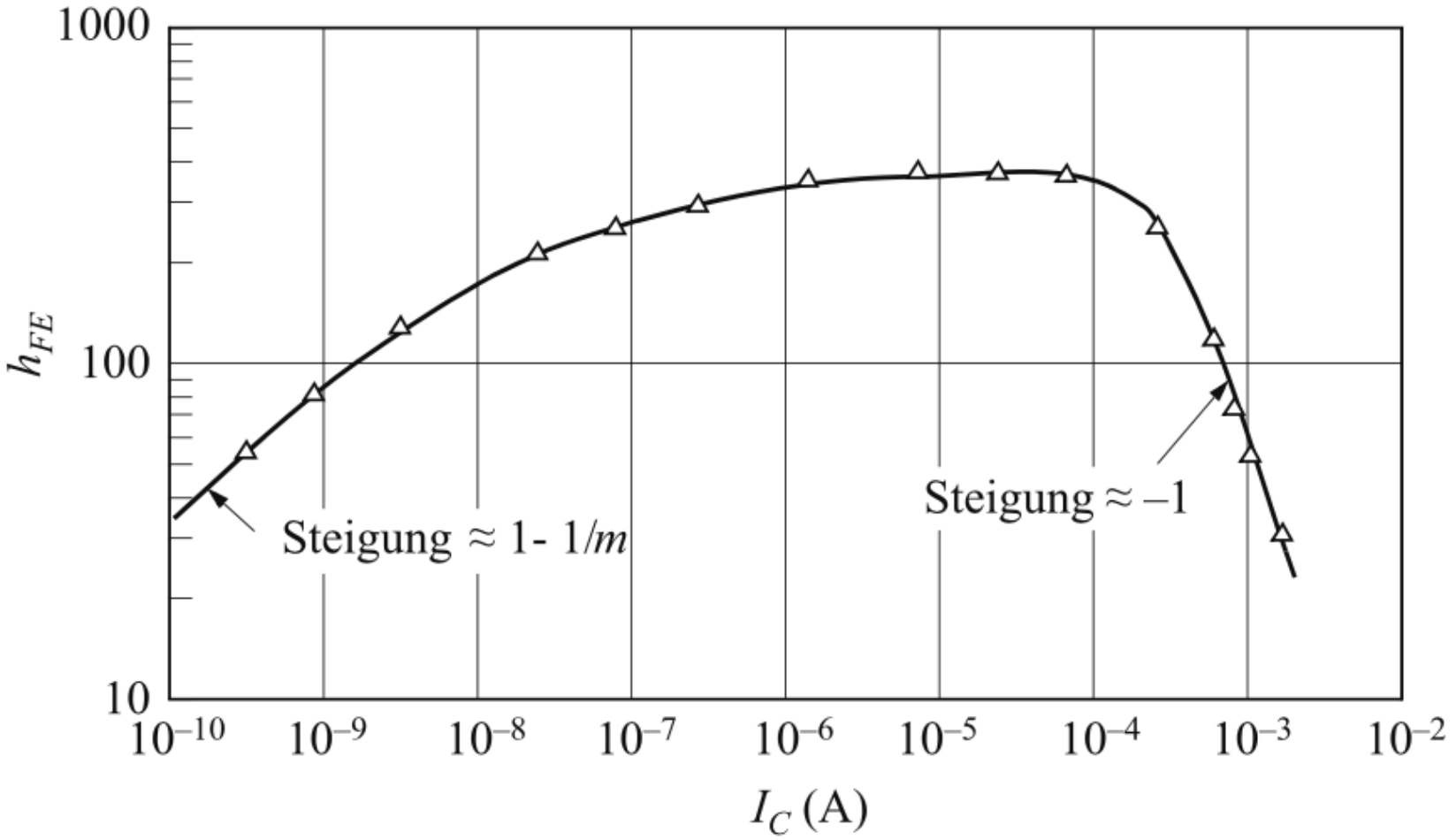


Einfluss Dotierprofil auf Stromverstärkung

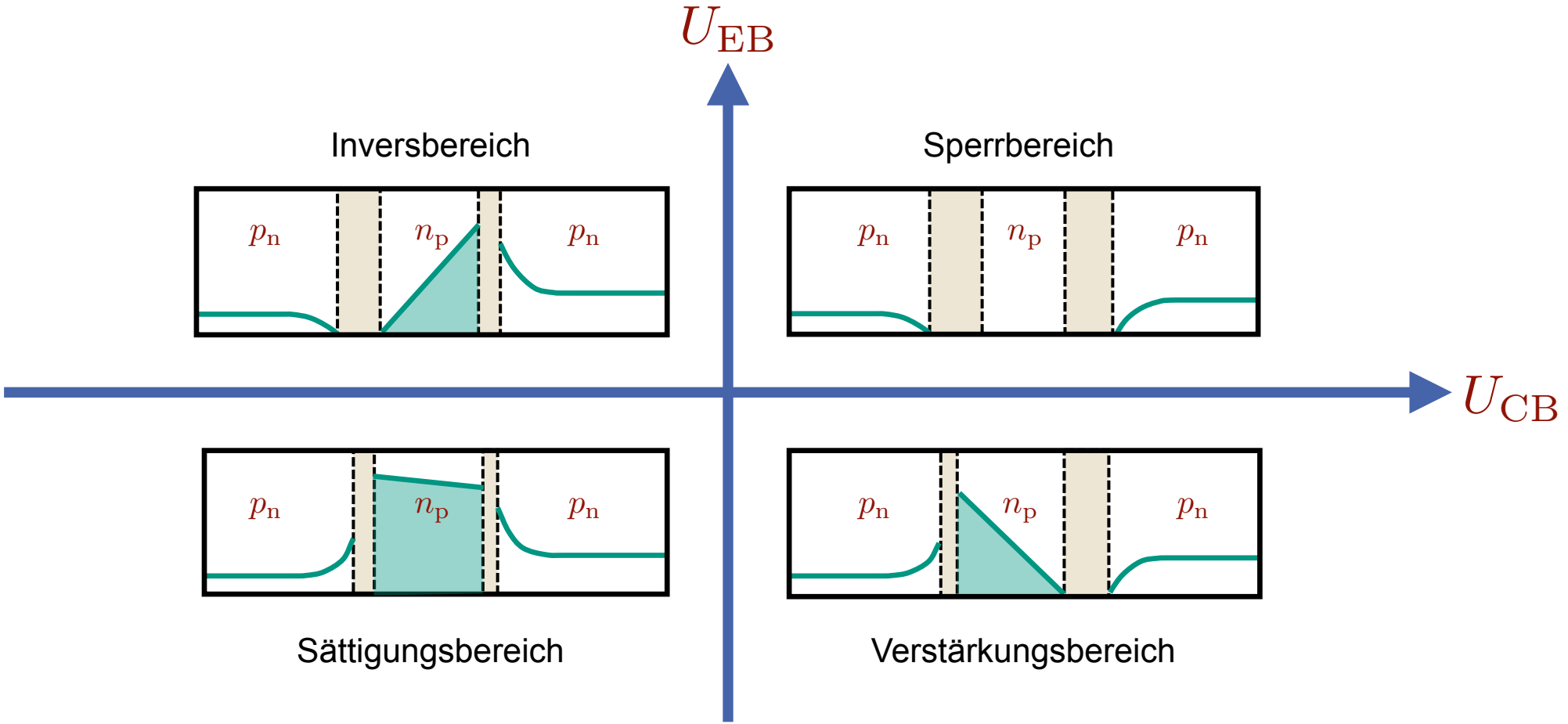


Dotierprofil	Maximale Stromverstärkung
A	125
B	100
C	85

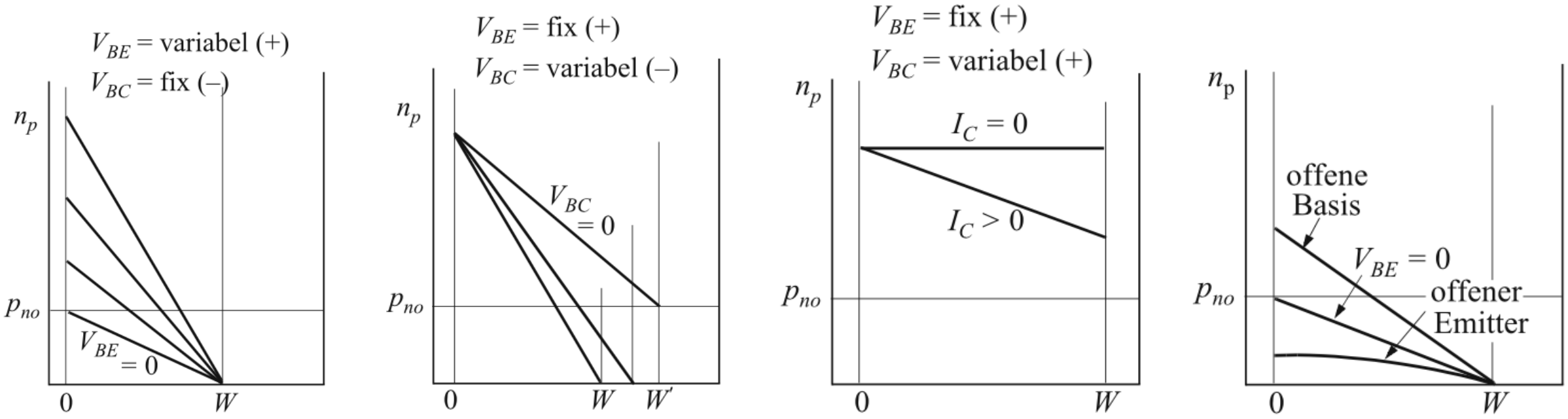
Variation der Stromverstärkung



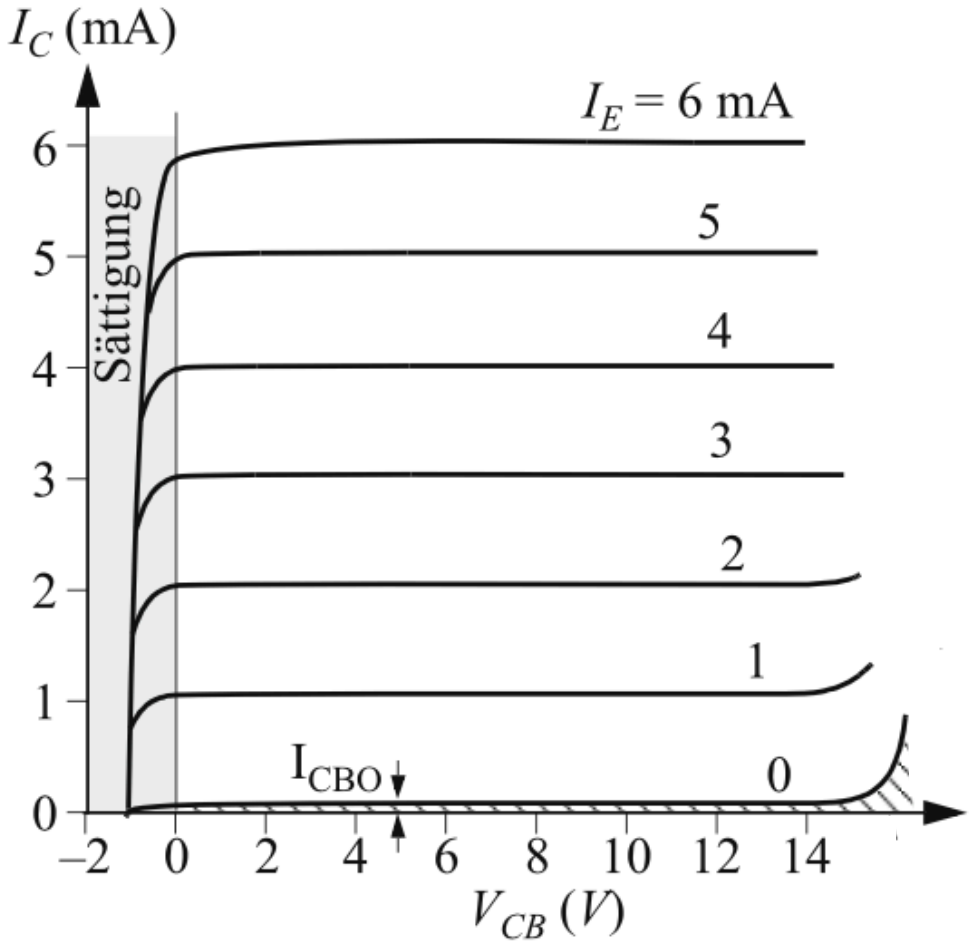
Betriebsmodi eines npn-Transistors



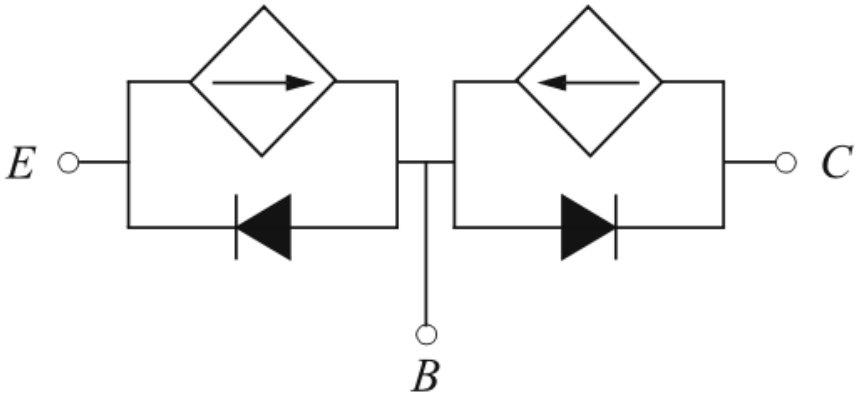
Ladungsträgerverteilung in der Basis

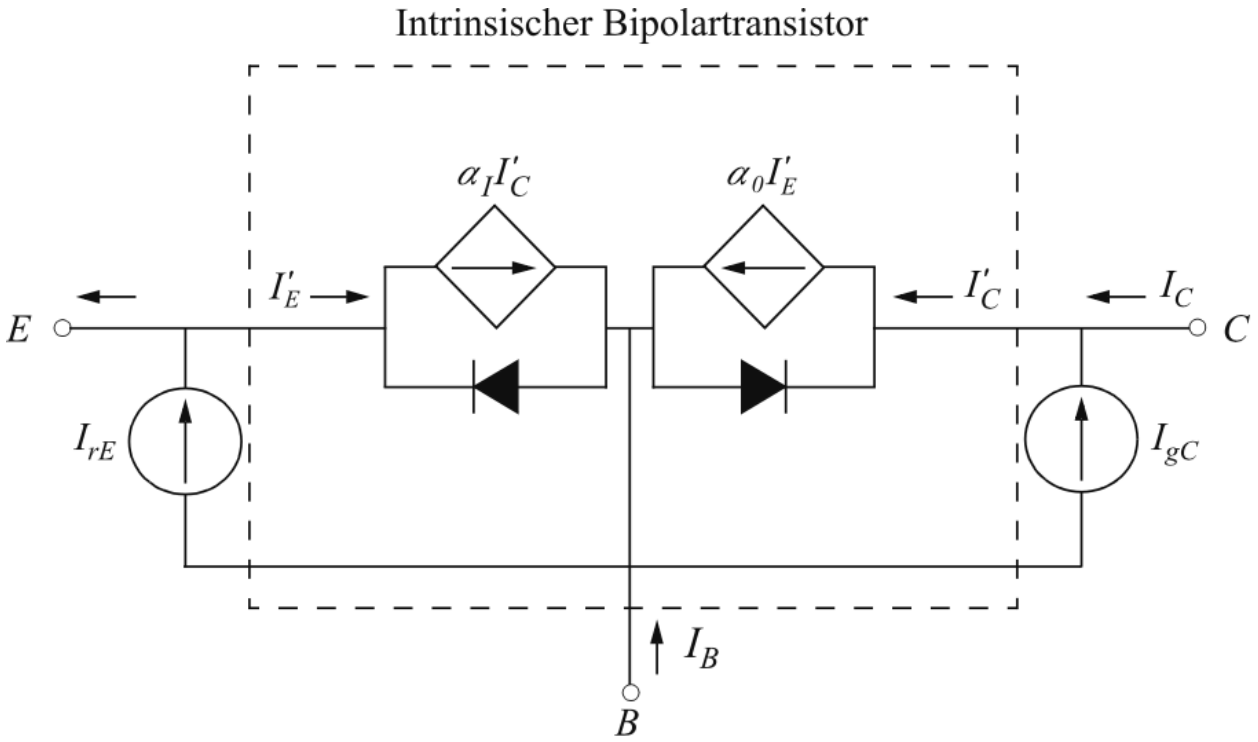


Ausgangskennlinien in Basisschaltung

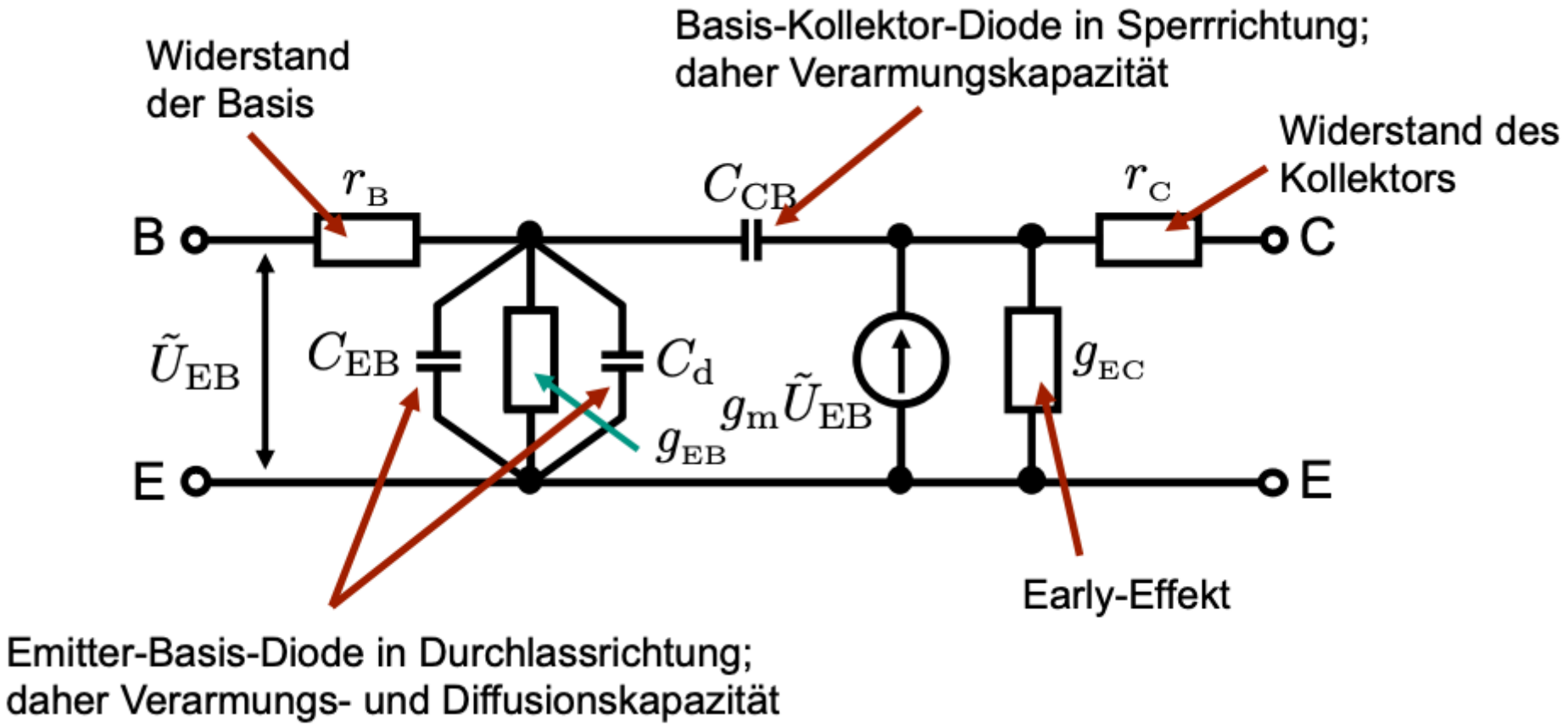


Ebers-Moll-Modell

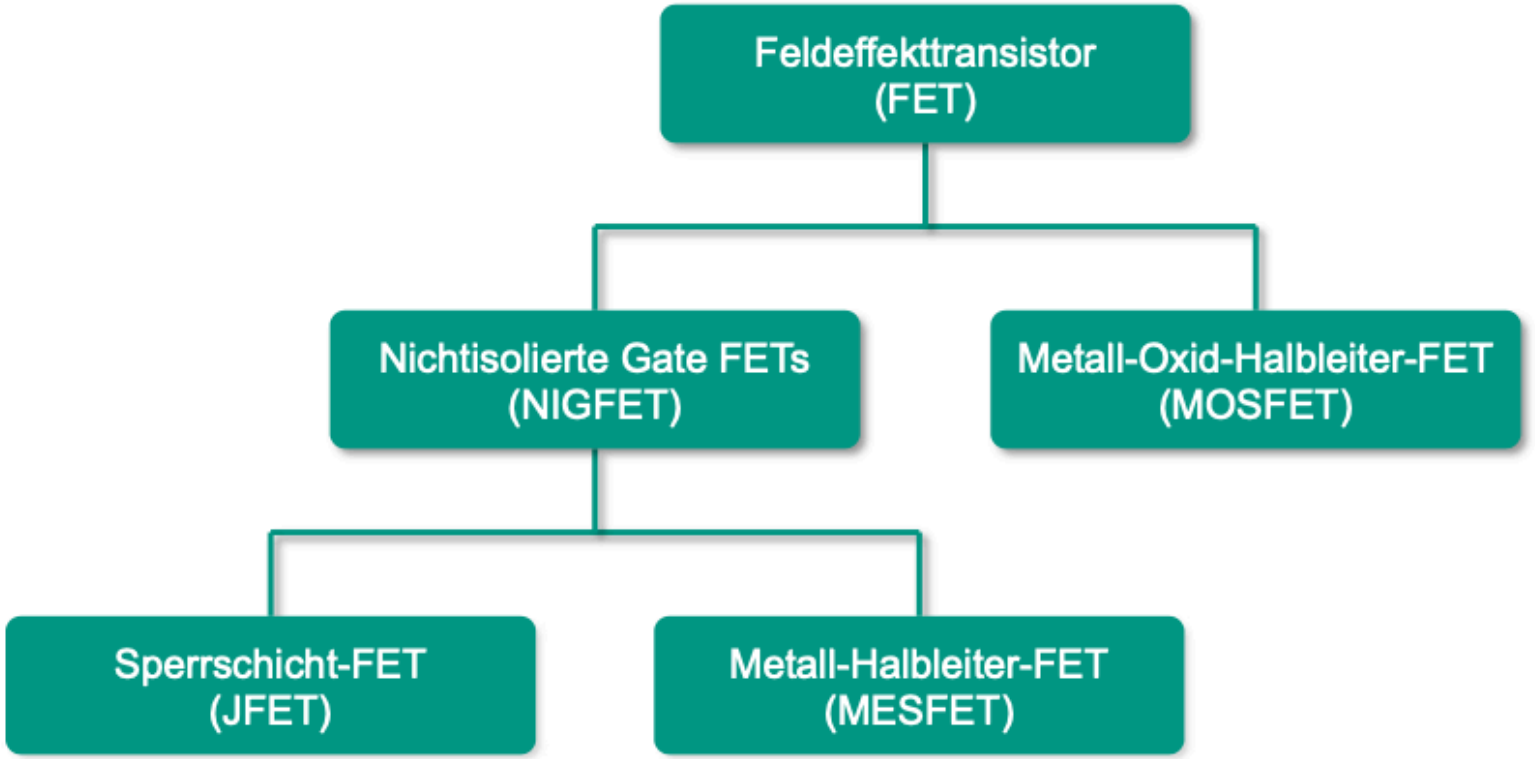




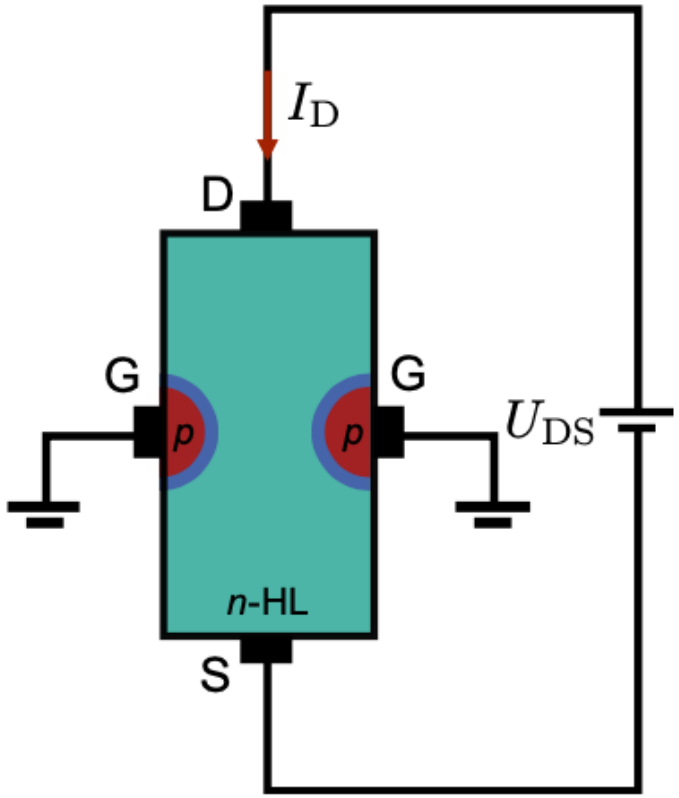
Wechselstromverhalten eines Bipolartransistors

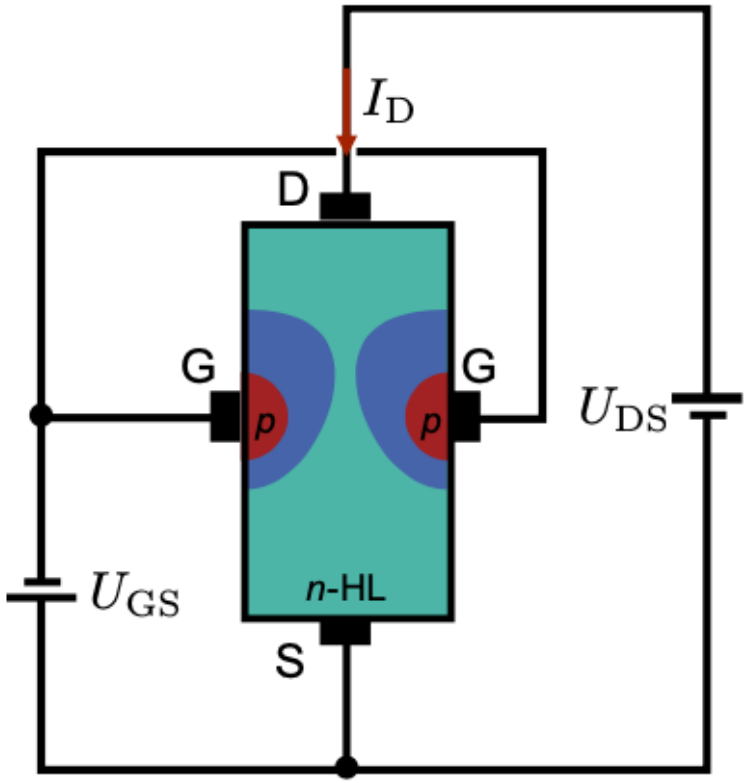


Arten von Feldeffekttransistoren



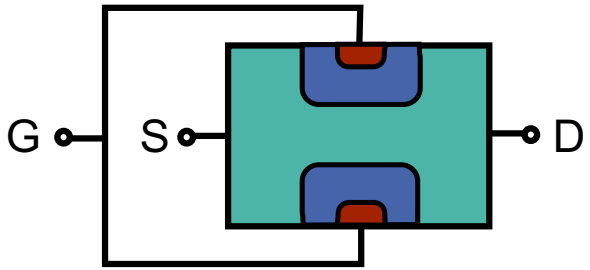
Funktionsweise von Feldeffekttransistoren



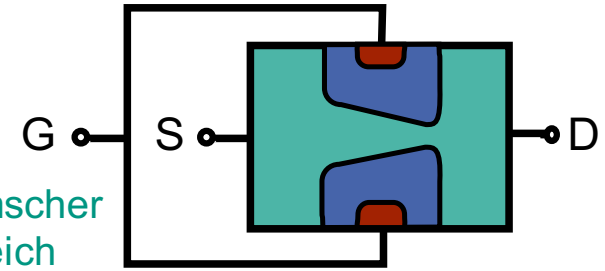


Funktionsprinzip eines JFET

$U_{GS} = 0, I_D = 0$

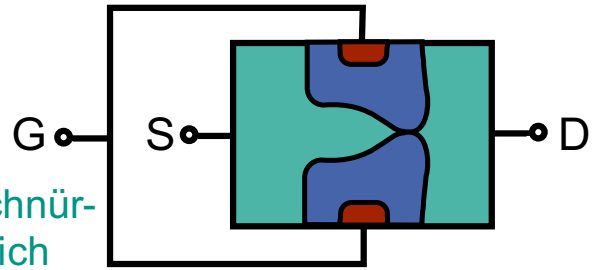


$U_{DS} + |U_{GS}| < U_P$



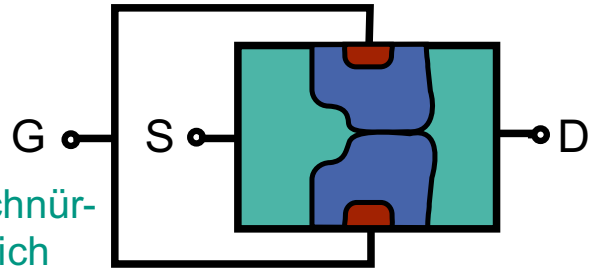
Ohmscher Bereich

$U_{DS} + |U_{GS}| > U_P$



Abschnür-Bereich

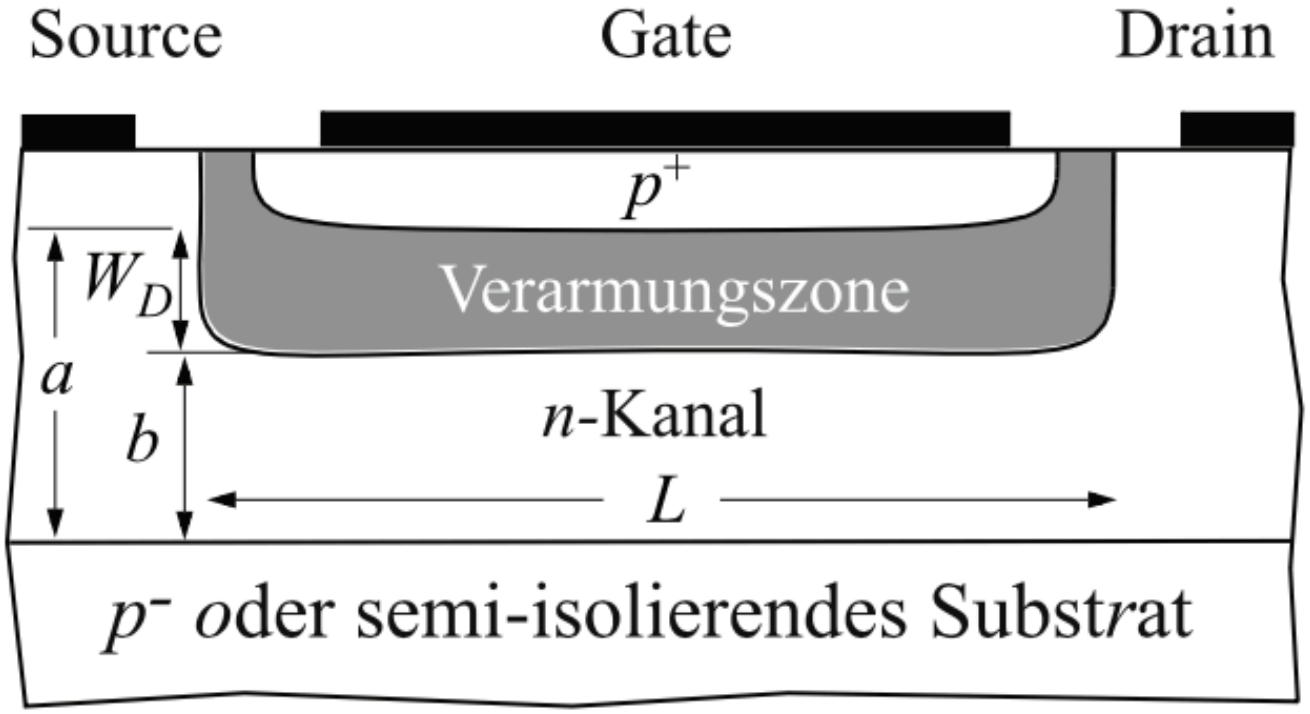
$U_{DS} + |U_{GS}| > U_P$



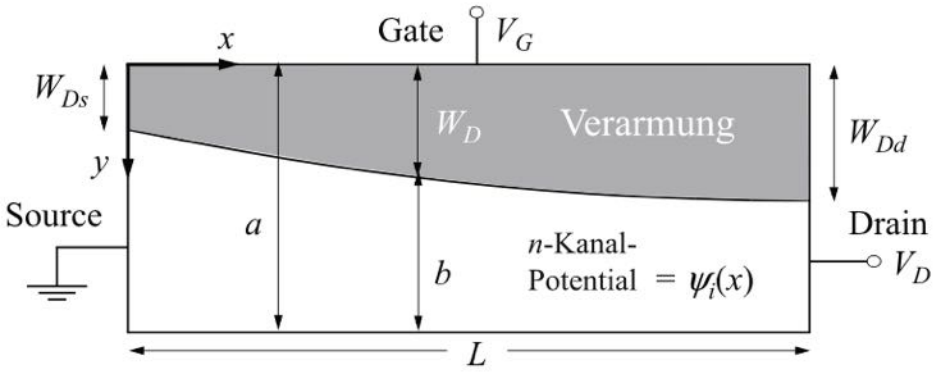
Abschnür-Bereich

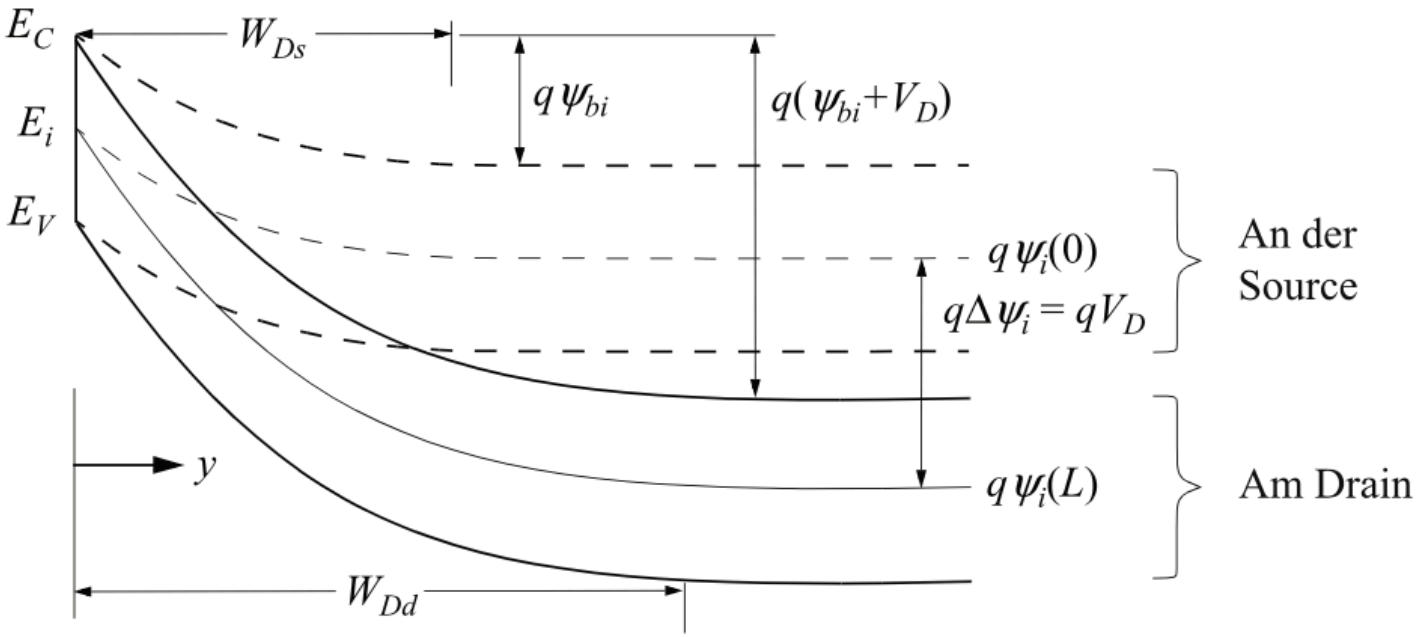
Wichtig: Im Folgenden soll Source auf Masse liegen; alle anderen Spannungen sind auf Source bezogen.

Quantitative Beschreibung JFET

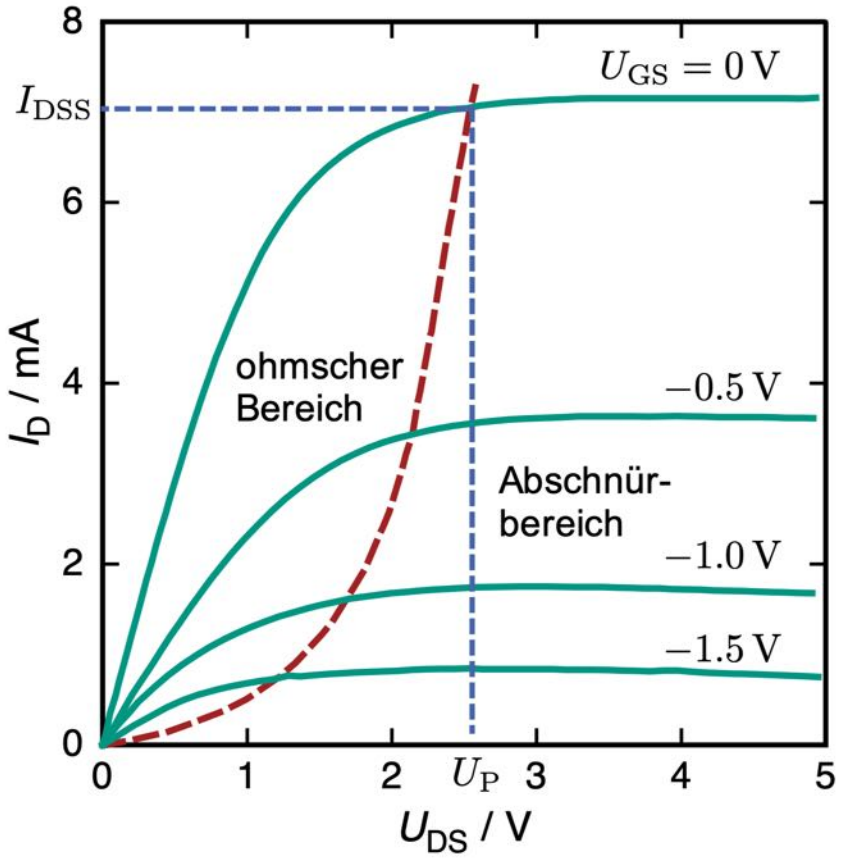


Verarmungszone und Bandstruktur JFET

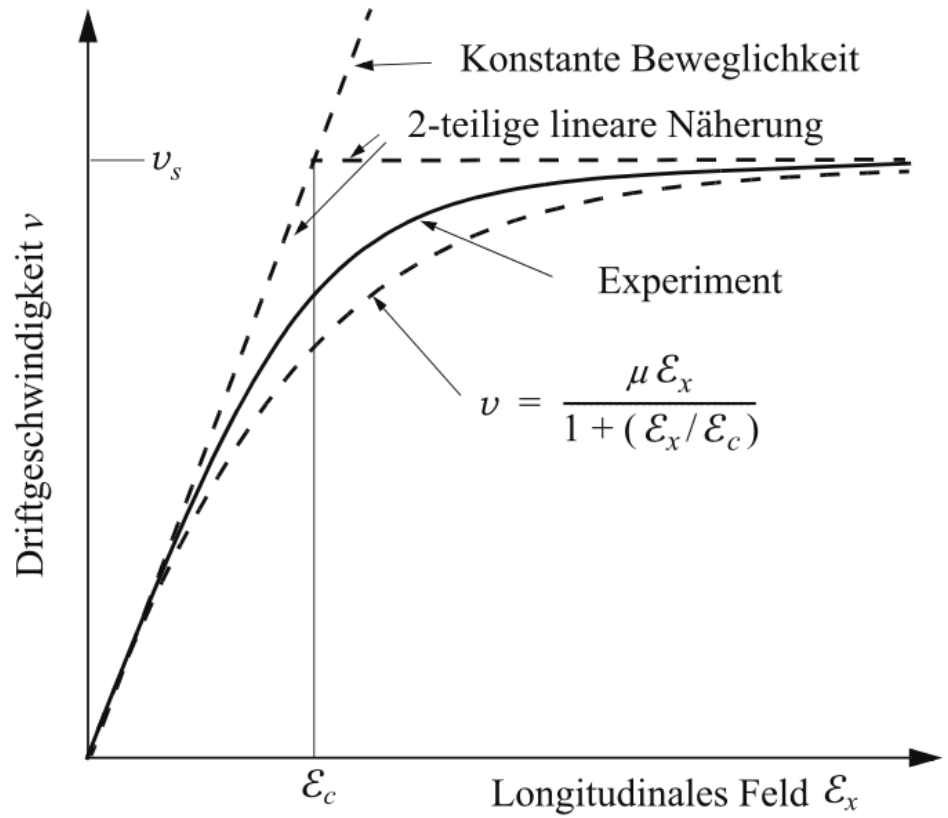


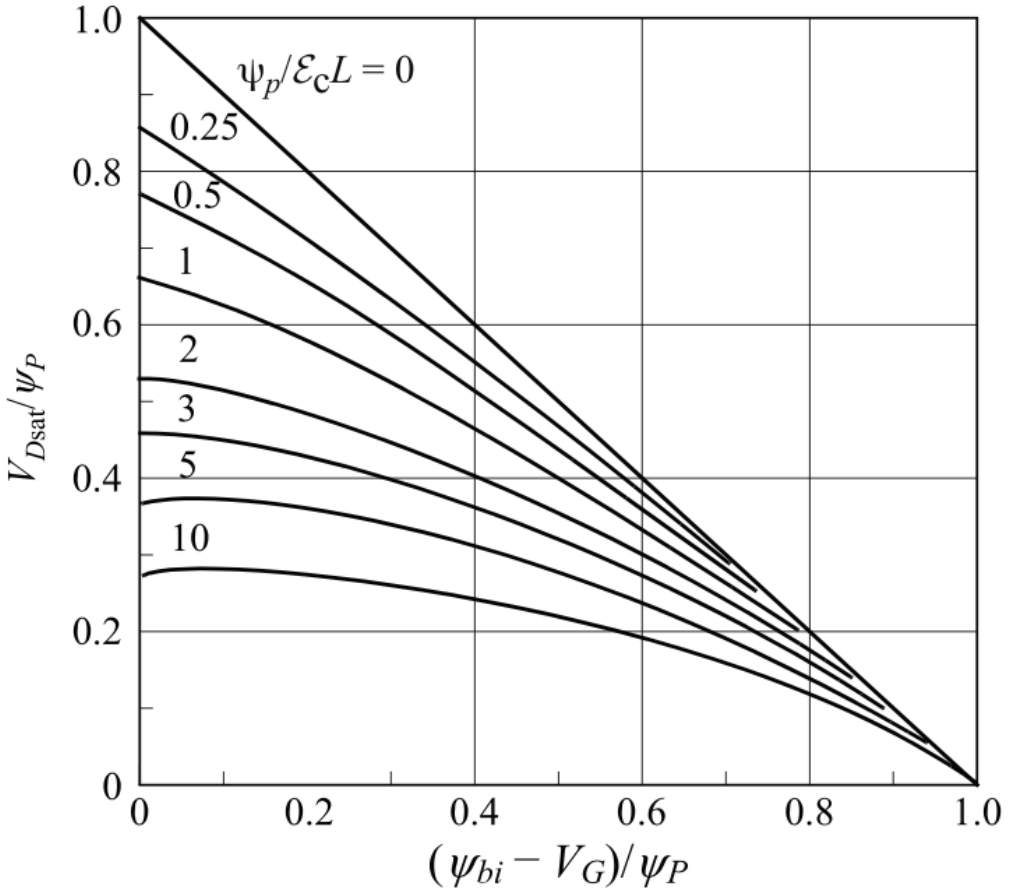


Kennlinienfeld



Lang- und Kurzkanalverhalten





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Wintersemester 2021/22