Baliga's FOM

Baliga, B J, "Advanced Power MOSFET Concepts"

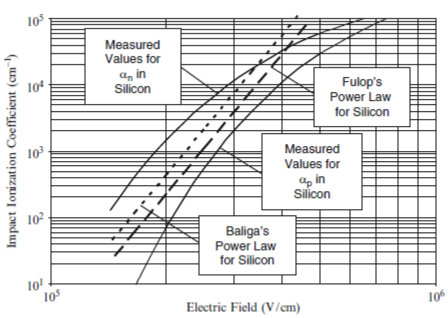
$qN_D = \frac{\epsilon E_{crit}^2}{2V_{BV}}$ (max doping density to have $E_{max} \le E_{crit}$)

$$R_{on,sp} = \sqrt{\frac{2\epsilon V_{BV}}{\mu_n^2}}\sqrt{\frac{1}{\left(\frac{\epsilon E_{crit}^2}{2V_{BV}}\right)^3}} = \sqrt{\frac{2^4 V_{BV}^4}{\mu_n^2 \epsilon^2 E_{crit}^6}} = \frac{4V_{BV}^2}{\mu_n \epsilon E_{crit}^3}$$

Baliga's Figure of Merit ($\mu_n \epsilon E_{crit}^3$)

"Ideal" specific on-resistance

Note: Impact Ionization



α = Impact ionization coefficient $\left(\frac{\#}{cm}\right)$

Empirically modeled as

$\alpha = k_1 E^7$

Definition of Breakdown:

$$\int_0^{W_D} \alpha \, dx = 1$$

from our analysis: $E = -\frac{qN_D}{\epsilon}x + \frac{qN_D}{\epsilon}W_D$

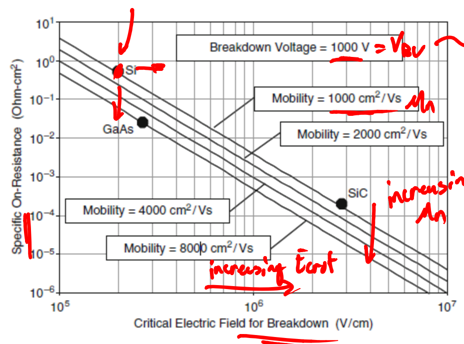
$$1 = \int_0^{W_D} k_1 \left(-\frac{qN_D}{\epsilon}x + \frac{qN_D}{\epsilon}W_D\right)^7 dx$$

Plug in $E_{max} = \frac{qN_D}{\epsilon}W_D$

$$W_{PP,B}(Si) = 2.404 \times 10^{10} N_D^{-7/8}$$

$$E_{C,1D,B}(Si) = 3,700\ N_D^{1/8}$$

Ideal Specific On-Resistance



↑V_{BV} ⇒ ↑$R_{on,sp}$ (square)

(Very high voltage Majority → Minority carrier devices)

Tradeoffs: Area

↑A ⇒ ↓R, ↑C

Baliga, B J, "Advanced Power MOSFET Concepts"

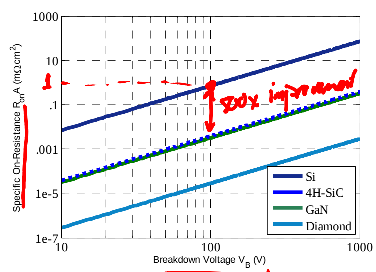
WBG Materials

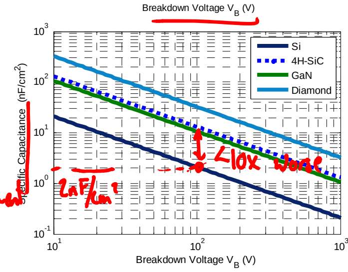
Table 2.1. Physical characteristics of Si and the major WBG semiconductors

Property	Si	GaAs	6H-SiC	4H-SiC	GaN	Diamond
Bandgap, E_g (eV)	1.12	1.43	3.03	3.26	3.45	5.45
Dielectric constant, ε_r[a]	11.9	13.1	9.66	10.1	9	5.5
Electric breakdown field, E_c (kV/cm)	300	400	2,500	2,200	2,000	10,000
Electron mobility, μ_n (cm²/V·s)	1,500	8,500	500 80	1,000	1,250	2,200
Hole mobility, μ_p (cm²/V·s)	600	400	101	115	850	850
Thermal conductivity, λ (W/cm·K)	1.5	0.46	4.9	4.9	1.3	22
Saturated electron drift velocity, v_{sat} ($\times 10^7$ cm/s)	1	1	2	2	2.2	2.7

[a] $\varepsilon = \varepsilon_r \cdot \varepsilon_o$ where $\varepsilon_o = 8.85\times10^{-14}$ F/cm.

B Ozpineci, L M Tolbert, "Comparison of Wide-Bandgap Semiconductors for Power Electronics Applications"



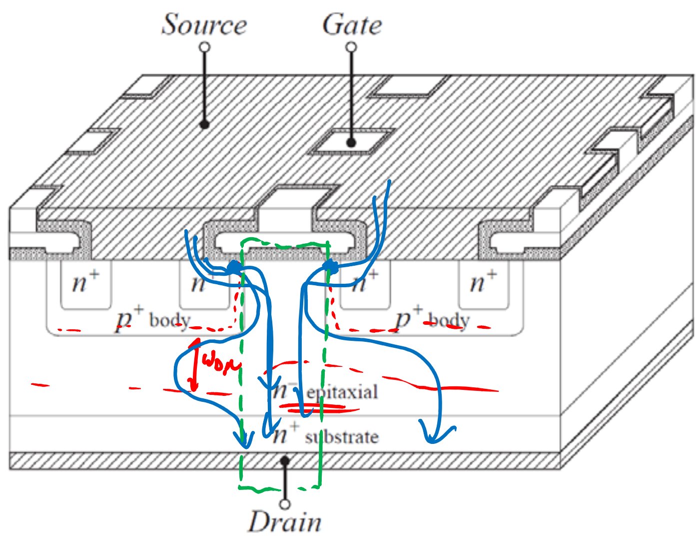


example FoM: $R_{on,sp} C_{sp}$ (mΩcm² nF/cm²)

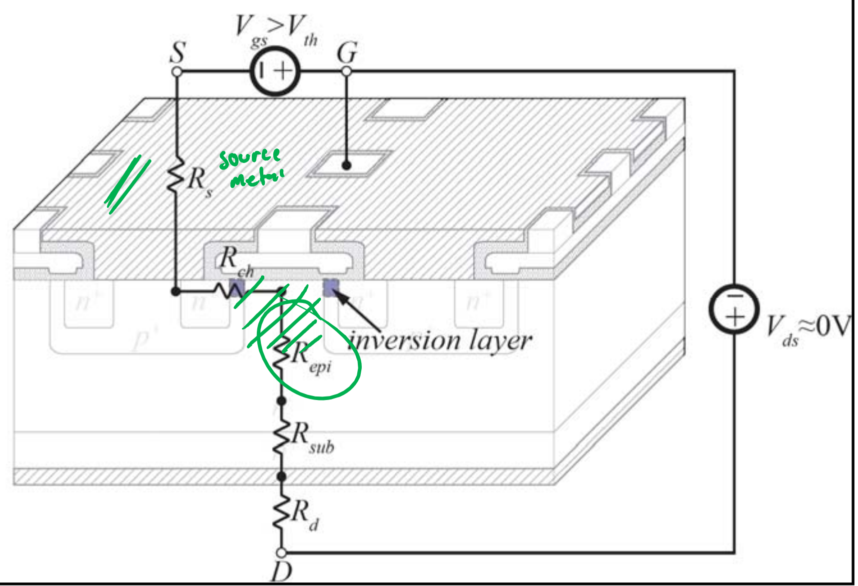
from Si → GaN

$R_{on,sp} C_{sp}$ → 50x improvement

MOSFET Cross Section



MOSFET On-Resistance



Resistance Contributions Vs. Voltage

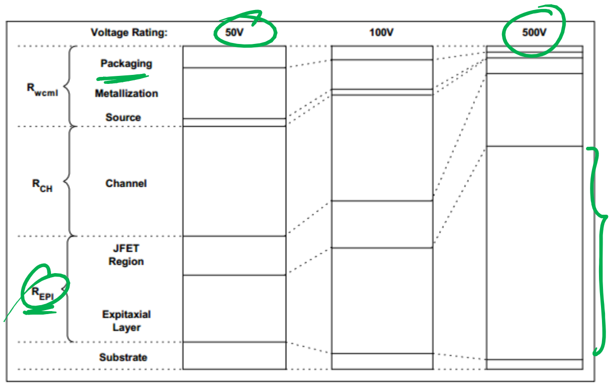
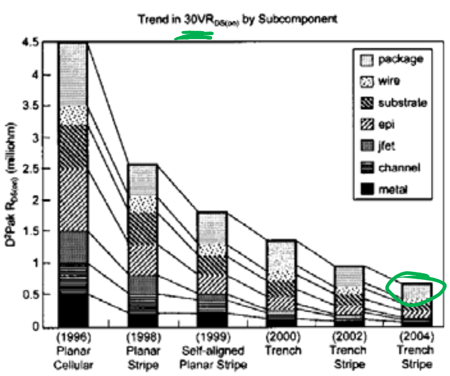


Figure 9. Relative Contributions to $R_{DS(on)}$ With Different Voltage Ratings.

V. Barkhordarian et al. "Power MOSFET Basics"

Resistance Contributions



A. Lidow er al. "The Semiconductor Roadmap for Power Management in the New Millennium