Semiconductor Technology from A to Z

Compound Semiconductors

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Fundamentals & Material System

Why Compound Semiconductors for Power Electronics?

Silicon has dominated power electronics for decades, but it runs into physical limits: at high blocking voltages, a Si device needs a thick, lightly doped drift region to safely support the electric field – which costs on-resistance and therefore losses. Compound semiconductors such as silicon carbide (SiC) and gallium nitride (GaN) have a significantly higher breakdown field strength than silicon. This allows thinner, more highly doped drift regions at the same blocking voltage – and thus noticeably lower conduction losses combined with a smaller chip area.

Material Comparison: SiC, GaN and Silicon

A direct comparison shows clear differences: silicon has a bandgap of 1.12 eV, 4H silicon carbide reaches 3.26 eV, and gallium nitride 3.4 eV – both compound semiconductors are clearly wider-gap materials. The critical breakdown field strength rises from about 0.3 MV/cm for silicon to roughly 2.8 MV/cm for SiC and 3.3 MV/cm for GaN. SiC additionally stands out with high thermal conductivity (about 4.9 W/cmK versus 1.5 W/cmK for silicon), which makes heat dissipation at high power levels easier. GaN, in turn, reaches a very high electron saturation velocity, enabling especially high switching frequencies.

Property	Silicon	4H-SiC	GaN
Bandgap (eV)	1.12	3.26	3.4
Crit. field strength (MV/cm)	0.3	2.8	3.3
Thermal conductivity (W/cmK)	1.5	4.9	1.3
Saturation velocity (10^7 cm/s)	1.0	2.0	2.5
Electron mobility (cm^2/Vs)	1400	900	1200

Values for 4H-SiC and silicon at room temperature, intrinsic bulk material. GaN electron mobility in the 2DEG (AlGaN/GaN heterostructure) can be significantly higher.

The Baliga Figure of Merit

To objectively compare semiconductor materials for power switches, B. Jayant Baliga defined a figure of merit: $BFOM = \varepsilon_r \cdot \mu \cdot E_c^3$, formed from permittivity, carrier mobility and the critical field strength raised to the third power. It indicates how small the specific on-resistance can theoretically become at a given blocking voltage. Because the critical field strength enters to the third power, the material advantage of SiC and GaN has an especially strong effect: both exceed silicon by more than two orders of magnitude in the Baliga figure of merit.

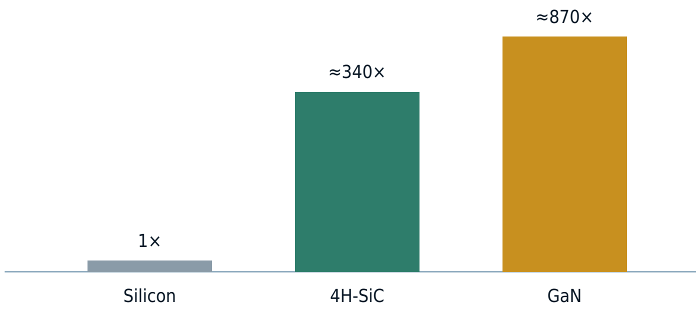
Baliga Figure of Merit (BFOM)

Material figure of merit for the minimum achievable on-resistance

$$\mathrm{BFOM} = \varepsilon r \cdot \mu \cdot Ec^3$$

εr: permittivity · μ: carrier mobility · Ec: critical breakdown field strength

BFOM relative to Si



Positioning: Where Is Each Material Used?

SiC plays to its strengths mainly at high voltages and power levels – for example in traction inverters for e-mobility or in industrial applications. GaN, on the other hand, excels at high switching frequencies and medium voltages, for example in chargers and fast-charging infrastructure, where compact form factor and low switching losses matter most. The following chapters first cover crystal growth and substrates, then the devices of both material systems in detail.