Semiconductor Technology from A to Z

Devices

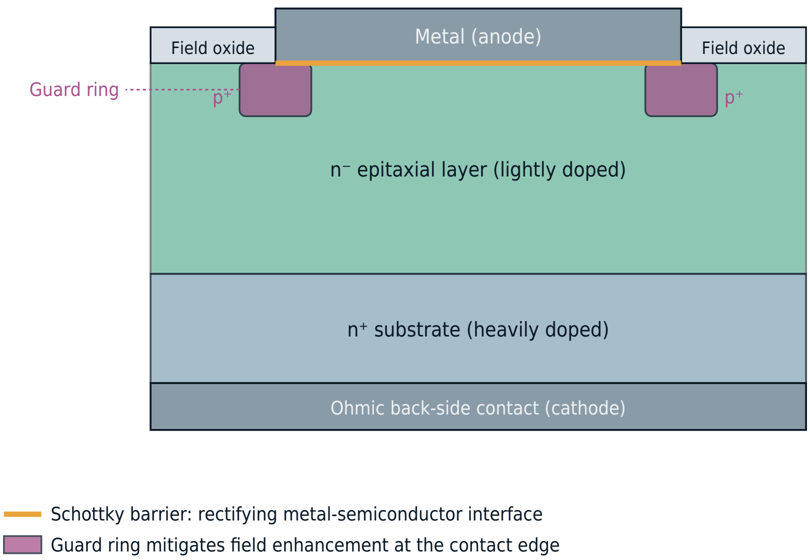
The Schottky Diode

The Metal-Semiconductor Junction as a Rectifier

The Schottky diode uses the same metal-semiconductor junction already introduced in the chapter on the metal-semiconductor FET (MESFET) as a gate contact, but here as a standalone two-terminal device for rectification rather than a controllable channel contact. A metal contact – commonly platinum silicide, chromium, molybdenum, aluminum, or titanium, depending on the desired barrier height and process compatibility – is deposited directly onto lightly doped n-type silicon or n-type GaAs. Unlike a classic p-n diode, the rectifying barrier here forms directly at the metal-semiconductor interface itself, without needing a second, oppositely doped semiconductor region to be implanted or diffused.

Cross-Section of a Schottky Diode

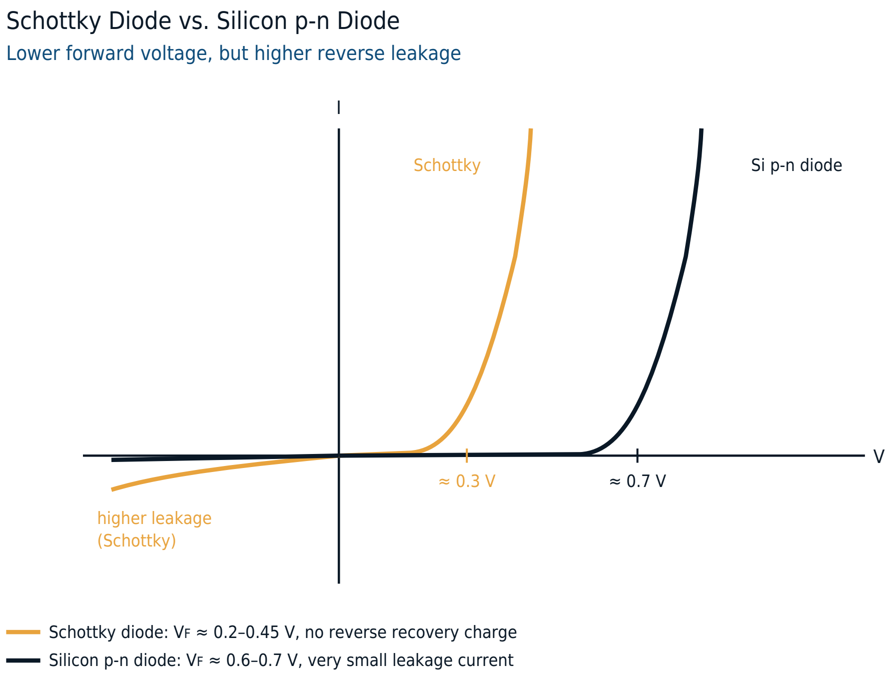
Metal contact directly on lightly doped n-type silicon



At the edge of the metal contact, the electric field is strongly enhanced compared to the flat contact area, which would otherwise undesirably increase leakage current and reduce breakdown voltage; a so-called guard ring – a shallow p-n junction implanted in a ring around the contact edge with opposite curvature – specifically mitigates this field enhancement and is standard in practically all modern Schottky diode designs.

Low Forward Voltage and Fast Switching

Because the Schottky barrier height is typically lower than the built-in diffusion voltage of a comparable p-n junction, the forward voltage of a silicon Schottky diode is usually only 0.2 to 0.45 V, compared to about 0.6 to 0.7 V for an ordinary silicon p-n diode. This several-hundred-millivolt reduction in forward voltage significantly lowers power dissipation at high currents, which brings a noticeable efficiency gain particularly in applications with low output voltage and high current, such as rectifier circuits in switching power supplies.



Of even greater practical importance, however, is the switching behavior: because the Schottky diode is a pure majority-carrier device – unlike the p-n diode, no injection and storage of minority carriers occurs in the respective other region –, the so-called reverse recovery charge is almost entirely eliminated. In an ordinary p-n diode, switching from forward to reverse conduction first requires depleting the minority carrier charge stored in the device, which can take anywhere from a few tens to several hundred nanoseconds depending on the device and causes unwanted current spikes during that time; Schottky diodes, by contrast, can switch within a few nanoseconds or even less, since essentially only the comparatively small junction capacitance needs to be recharged.

Trade-offs and Applications

These advantages come at a noticeable cost, however: the lower barrier height that enables the low forward threshold voltage also acts in the reverse direction, so Schottky diodes exhibit a markedly higher leakage current and a lower breakdown voltage rating than comparable p-n diodes – the leakage current can be several orders of magnitude higher and also increases more strongly with temperature, which can lead to thermal instability at higher operating temperatures.

In practice, Schottky diodes are therefore mainly used where switching speed and low forward losses matter more than high breakdown voltage: as rectifiers in low-voltage switching power supplies, as freewheeling diodes in buck converters in place of a much slower p-n diode – as already mentioned in the chapter on switching regulators –, and as mixer and detector diodes in RF technology, where their low junction capacitance and lack of carrier storage enable clean switching behavior up into the gigahertz range. For higher breakdown voltages in power applications, where classic silicon Schottky diodes reach their physical limits, SiC Schottky diodes have become established, as described in the chapter on compound semiconductors; they combine the low switching delay of the Schottky principle with the much higher breakdown field strength of silicon carbide, achieving breakdown voltages of several hundred to over 1000 V while retaining very fast switching behavior.