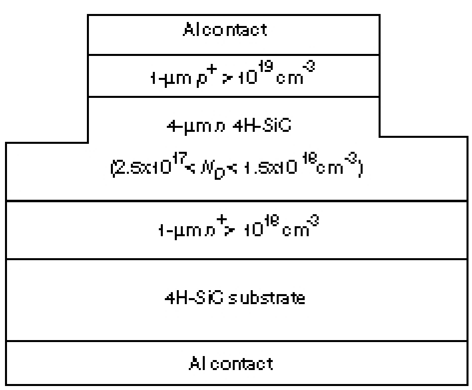
Reliable Breakdown Obtained in Silicon Carbide Rectifiers

The High Temperature Integrated Electronics and Sensor (HTIES) Program at the NASA Lewis Research Center is currently developing silicon carbide (SiC) for use in harsh conditions where silicon, the semiconductor used in nearly all of today's electronics, cannot function. Silicon carbide's demonstrated ability to function under extreme high-temperature, high-power, and/or high-radiation conditions will enable significant improvements to a far-ranging variety of applications and systems. These range from improved high-voltage switching for energy savings in public electric power distribution and electric vehicles, to more powerful microwave electronics for radar and cellular communications, to sensor and controls for cleaner-burning, more fuel-efficient jet aircraft and automobile engines.

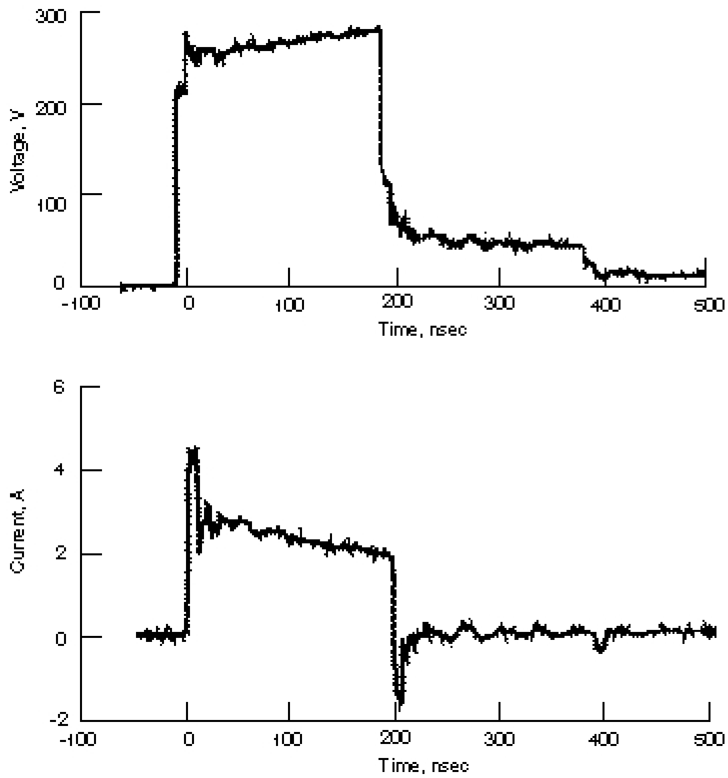
For power distribution, SiC semiconductor switches offer the promise of 10-fold to 100-fold performance improvements over present-day silicon-based devices. Before these improvements can be realized, however, present-day prototype SiC devices must be improved and made reliable. One reliability requirement of modern power rectifiers is that they must be able to withstand transient overvoltage glitches that commonly occur in power system circuits. Silicon power rectifiers in use today operate with high reliability in part because they exhibit a stabilizing property known as a positive temperature coefficient of breakdown voltage. This property permits them to withstand and recover from overvoltage glitches without sustaining permanent damage.

Prior to this work, prototype SiC rectifiers exhibited a negative temperature coefficient of breakdown voltage; those rectifiers could not reliably withstand overvoltage glitches. Such rectifiers, no matter how well they outperformed silicon rectifiers in voltage, current, and switching speed ratings, could not be incorporated into aerospace power systems where reliable operation is critical.



Prototype NASA Lewis SiC rectifier. (N_D is the donor dopant concentration.)

The figure above shows a schematic cross section of the first SiC rectifiers to exhibit a positive temperature coefficient of breakdown voltage, enabling these Lewis-fabricated rectifiers to repeatedly withstand large overvoltage glitches. The next figure shows the current and voltage waveforms recorded when one of these devices was subjected to a 200-nsec overvoltage glitch pulse. The device clearly exhibits a positive temperature coefficient of breakdown voltage: as the rectifier self-heats over the pulse duration, the voltage across the device increases (top waveform) while the current through the device decreases (bottom waveform). If one ignores the unimportant displacement current spikes at the rising and falling edges of the pulse, the peak conduction current of ~2.5 A at 20 nsec corresponds to a current density in excess of 50,000 A/cm^2.



Voltage and current response of the NASA Lewis SiC rectifier subjected to a 200-nsec overvoltage glitch.

This work demonstrates for the first time that robust SiC power devices with excellent reliability and immunity from glitches will be achievable as SiC technology matures.

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