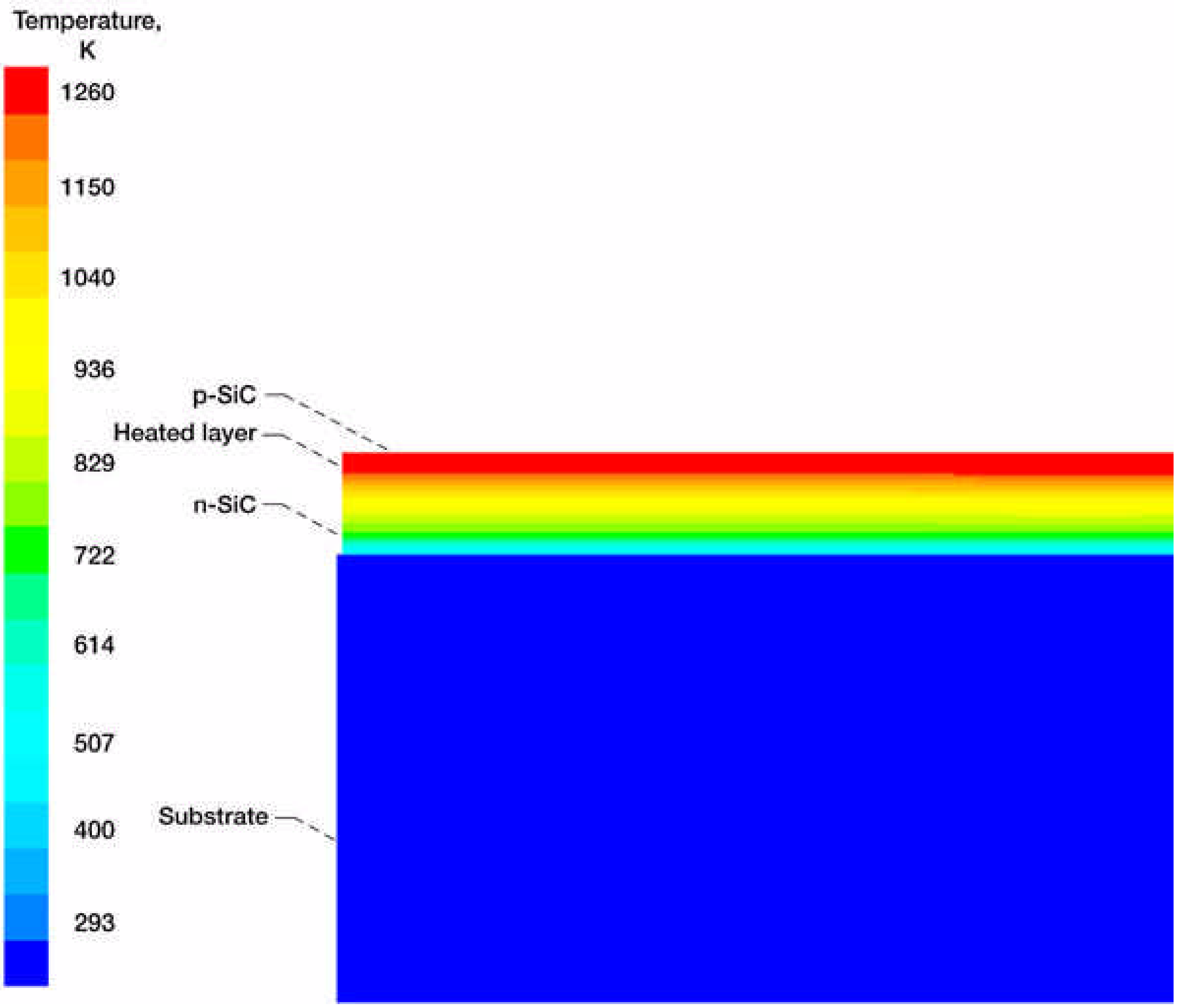
Temperature Distribution Within a Defect-Free Silicon Carbide Diode Predicted by a Computational Model

Most solid-state electronic devices—diodes, transistors, and integrated circuits—are based on silicon. Although this material works well for many applications, its properties limit its ability to function under extreme high-temperature or high-power operating conditions. Silicon carbide (SiC), with its desirable physical properties, could someday replace silicon for these types of applications. A major roadblock to realizing this potential is the quality of SiC material that can currently be produced. Semiconductors require very uniform, high-quality material, and commercially available SiC tends to suffer from defects in the crystalline structure that have largely been eliminated in silicon. In some power circuits, these defects can focus energy into an extremely small area, leading to overheating that can damage the device.

In an effort to better understand the way that these defects affect the electrical performance and reliability of an SiC device in a power circuit, the NASA Glenn Research Center at Lewis Field began an in-house three-dimensional computational modeling effort. The goal is to predict the temperature distributions within a SiC diode structure subjected to the various transient overvoltage breakdown stresses that occur in power management circuits. A commercial computational fluid dynamics computer program (FLUENT—Fluent, Inc., Lebanon, New Hampshire) was used to build a model of a defect-free SiC diode and generate a computational mesh. A typical breakdown power density was applied over 0.5 µsec in a heated layer at the junction between the p-type SiC and n-type SiC, and the temperature distribution throughout the diode was then calculated. The peak temperature extracted from the computational model agreed well (within 6 percent) with previous first-order calculations of the maximum expected temperature at the end of the breakdown pulse. This level of agreement is excellent for a model of this type and indicates that three-dimensional computational modeling can provide useful predictions for this class of problem.

The model is now being extended to include the effects of crystal defects. The model will provide unique insights into how high the temperature rises in the vicinity of the defects in a diode at various power densities and pulse durations. This information also will help researchers in understanding and designing SiC devices for safe and reliable operation in high-power circuits.



Temperature contours in a silicon carbide diode predicted by FLUENT 5.0.

For more information, visit us http://www.grc.nasa.gov/WWW/SiC/SiC.html.

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