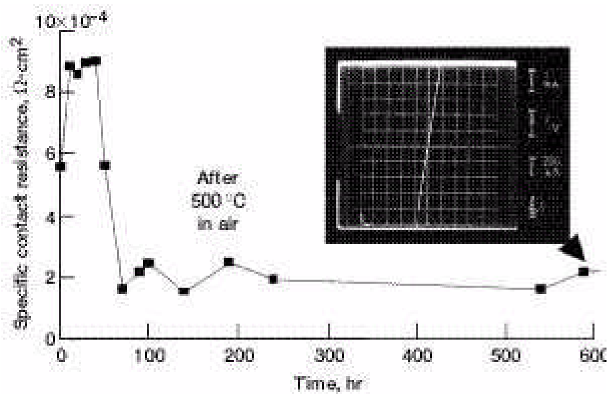
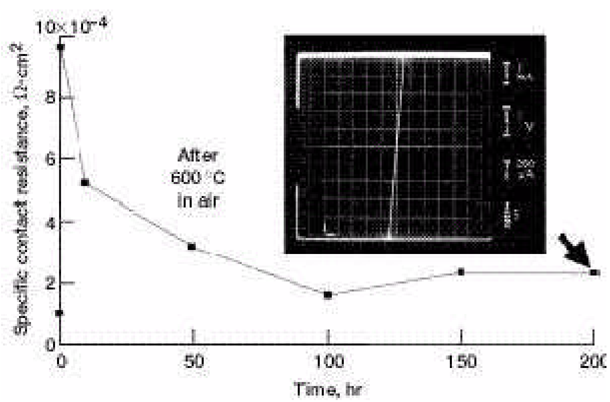
Thermally Stable Ohmic Contacts on Silicon Carbide Developed for High-Temperature Sensors and Electronics

The NASA aerospace program, in particular, requires breakthrough instrumentation inside the combustion chambers of engines for the purpose of, among other things, improving computational fluid dynamics code validation and active engine behavioral control (combustion, flow, stall, and noise). This environment can be as high as 600 °C, which is beyond the capability of silicon and gallium arsenide devices. Silicon-carbide- (SiC-) based devices appear to be the most technologically mature among wide-bandgap semiconductors with the proven capability to function at temperatures above 500 °C. However, the contact metalization of SiC degrades severely beyond this temperature because of factors such as the interdiffusion between layers, oxidation of the contact, and compositional and microstructural changes at the metal/semiconductor interface. These mechanisms have been proven to be device killers. Very costly and weight-adding packaging schemes that include vacuum sealing are sometimes adopted as a solution.



Specific contact resistance of $Ti/TaSi_2/Pt$ on an n-type SiC epilayer measured after a 500 °C treatment in air. The inset shows the corresponding I-V characteristics after 640 hr, showing excellent linear behavior.



Specific contact resistance of $Ti/TaSi_2/Pt$ on an n-type SiC measured after a 600 °C *treatment in air. The inset shows the corresponding I-V characteristics after 200 hr, showing excellent linear behavior.*

Research work at the Sensors and Electronics Branch of NASA Glenn Research Center's Instrumentation and Controls Division has demonstrated thermally stable I-V characteristics and contact resistance of Ti(100nm)/$TaSi_2$(200nm)/Pt(300nm) ohmic contact metalization on n-type 6H-SiC after 500 °C and 600 °C treatment in air for over 600 hr (top figure) and over 200 hr (bottom figure), respectively. Auger electron spectroscopy and high-resolution trans-mission electron microscopy were used to analyze the metal and semiconductor interfaces to understand the prevailing reactions. The thermal stability of the ohmic contact in air is believed to be due to the formation of silicides and carbides of titanium after being initially annealed at 600 °C in N_2 for 30 min. Most importantly, the oxidation of silicon species is proposed to be the critical diffusion barrier mechanism that prevents further oxygen penetration into the metalization.

These results had an immediate impact on ongoing research in SiC sensors and electronics projects. Real operating environment testing of SiC devices with this metalization scheme is planned. This contact scheme is expected to have the following attributes:

1. Ohmic contact with reasonably low contact resistance relative to the bulk epilayer
2. Long-term contact stability in the harsh environment
3. Compatibility with SiC large-scale integrated fabrication technology
4. Good wirebond strength
5. Compatibility with high-temperature interconnect and packaging technology

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