PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

**Advanced Research**

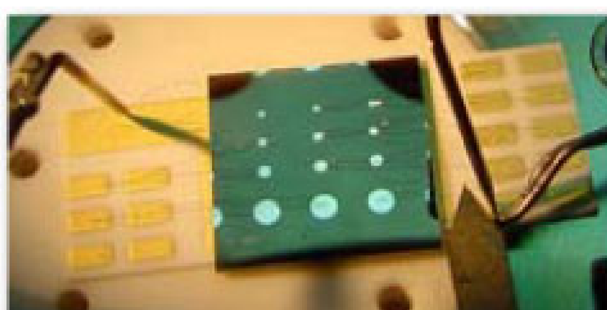
09/2004

# Silicon Carbide Micro-Devices for Combustion Gas Sensing Under Harsh Conditions

## Description

Reducing pollution and improving energy efficiency require sensitive, rugged sensors that can quantitatively detect gases that are produced in advanced combustion systems. Most materials cannot withstand the high temperature, chemically reactive environments encountered in power plants. This project is focused on developing solid state sensors based on the wide bandgap semiconductor silicon carbide (SiC), which can tolerate high temperatures and pressures as well as corrosive gases. Drawing upon the tools of semiconductor physics, surface science and chemistry, at the level of individual atoms and molecules, an understanding of the underlying physical mechanisms leading to sensing will be developed.

To date, prototype SiC gas sensors have been fabricated in the microfabrication clean room at Michigan State University (see figure). From in-situ electrical measurements performed under simulated exhaust conditions, we have discovered that the sensor response to hydrogen-containing species is due to two independent phenomena. Based on these results, conditions for stable and fast sensor operation at high temperature have been identified.



*Array of SiC sensors mounted on a header for high-temperature gas testing. Chip is 1 $cm^2$.*

## CONTACTS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## PROJECT COST

| | |
|---|---|
| **Total** | $941,570 |
| DOE | $753,256 |
| MSU | $188,314 |

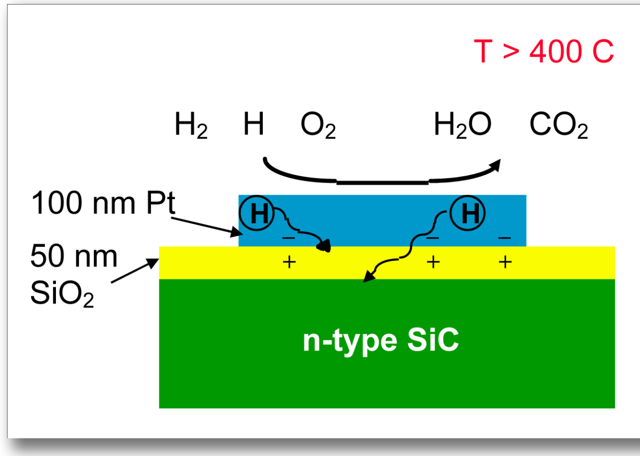
## PROJECT DURATION

10/01/2003 – 09/30/2006

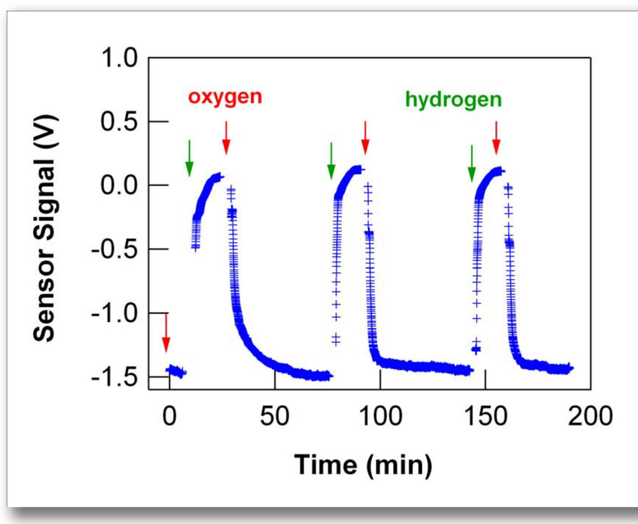
## WEBSITES

www.netl.doe.gov/coal

Phase 1 will focus on the fundamental materials properties and sensing mechanisms of the metal - oxide - SiC devices, culminating in the testing of sensors in realistic energy plant environments. Ultrahigh vacuum techniques will be used to study the metal electrode surface chemistry and sulfur contamination. The gas-induced changes in the metal - SiC barrier height will be probed via internal photoemission. Model sensors will be tested at a variety of temperatures and environments, to identify potential applications for SiC sensors in fossil energy power systems.




*Cross-sectional view of a Pt/$SiO_2$/SiC catalytic gate field-effect gas sensor*




*SiC gas sensor operating at 530 °C in a simulated energy plant environment. The sensor switches reversibly between alternating pulses of reducing (1% $H_2$ in $N_2$) and oxidizing (10 % $O_2$ in $N_2$) gases.*

**Further reading:** P. Tobias, S. Ejakov, B. Golding and R. N. Ghosh, "Interface states in high temperature gas sensors based on silicon carbide", invited issue IEEE Sensors Journal, 2, p. 543 (2003).