Silicon Carbide (SiC) Sensors for Automotive Applications

Gheorghe Brezeanu,
University "Politehnica" of Bucharest, Romania

gheorghe.brezeanu@dce.pub.ro

Summary: Silicon carbide sensor devices, capable of operating at high temperatures specific to automotive applications are investigated. Temperature sensors based on SiC-Schottky diodes and SiC-MOS capacitor gas detectors are designed, fabricated and measured. The performances of both sensors are tested in harsh environments. Temperatures of over 300°C were accurately monitored and maximum responsivities to CH_4 of 8.16% were determined by investigations up to 200°C.

Keywords: Automotive, Silicon carbide, sensors, Schottky diode, MOS capacitor.

SiC temperature and gas sensors

The considerable industrial interest in Silicon Carbide following its promising applications in power electronics, hostile-environment electronics and sensors has led to substantial international research effort over the last fifteen years.

SiC is seen as a key material for Hybrid and electric vehicles applications, such as DC/AC and DC/DC converters, inverters and high temperature, harsh environment-capable sensors. This wide gap semiconductor is suitable for sensors and power systems due to its higher breakdown electric field, high thermal conductivity and current capability. In addition, it is a very hard material, with a Young's modulus of more than 400GPa. It is chemically inert and highly resistant to radio-active environments.

The essential types of detection required in auto-motive electronics include temperature and gas sensing as the top contenders (Fig. 1). The working temperature, of around 300°C, far exceeds the capabilities of conventional Si-based detectors. Accurate temperature sensors can be obtained using SiC-Schottky barrier diodes (SBDs). When biased at constant current, these devices exhibit linear voltage-temperature dependence provided their electrical parameters, particularly Schottky barrier height and ideality factor, are reproducible and temperature independent. Gas sensors are typically based on a capacitor (Metal-insulator-SiC structure) with a catalytic contact. Incoming hydrocarbon gases are decomposed by the catalytic metal, generating hydrogen and other gas fragments (the process occurs at temperatures above 150°C). The hydrogen atoms diffuse through the metal, bond to the structure of the dielectric and create a charged layer close to the semiconductor surface. This entire process modifies the devices' electrical properties, allowing detection. Both types of SiC-based sensors can be manufactured on SiC epitaxial layers (lowering cost) and are capable of producing accurate and stable results when the technological processes can ensure uniform and well adherent contacts between SiC and metal/insulator.

The suitability of temperature and gas sensors on silicon carbide for operation at elevated temperatures in harsh environments is presented in this paper. Similar technologies, methods for extracting parameters and high temperature measurement techniques were developed for both detectors.

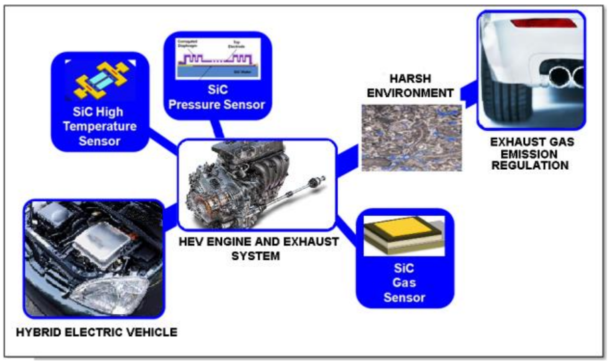

Fig. 1: SiC in hybrid automotive applications.

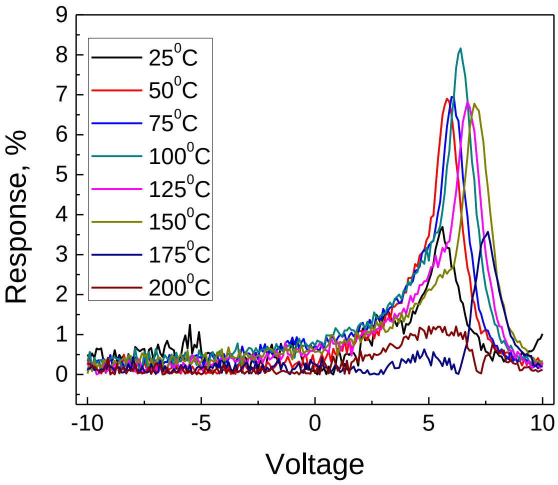

Fig. 2: CH_4 detection responsivity at various temperatures for SiC-MOS capacitor gas sensor.

Results

Fig. 2 shows the performances of a SiC-MOS capacitor regarding CH_4 detection responsivity with temperature. A maximum response of 8.16% was identified in measurements at 100°C.

The SiC-Schottky diode sensors were tested at automotive-specific temperatures (around 300°C), in harsh working environments. Thus, Fig. 3 illustrates a comparison between the SiC-sensor and a conventional thermocouple-based solution for temperature monitoring over a 9-hour time span. The same temperature variation trend was monitored by both detectors. Slight differences between measured values can be explained by the spatial distance of sensors' placement.

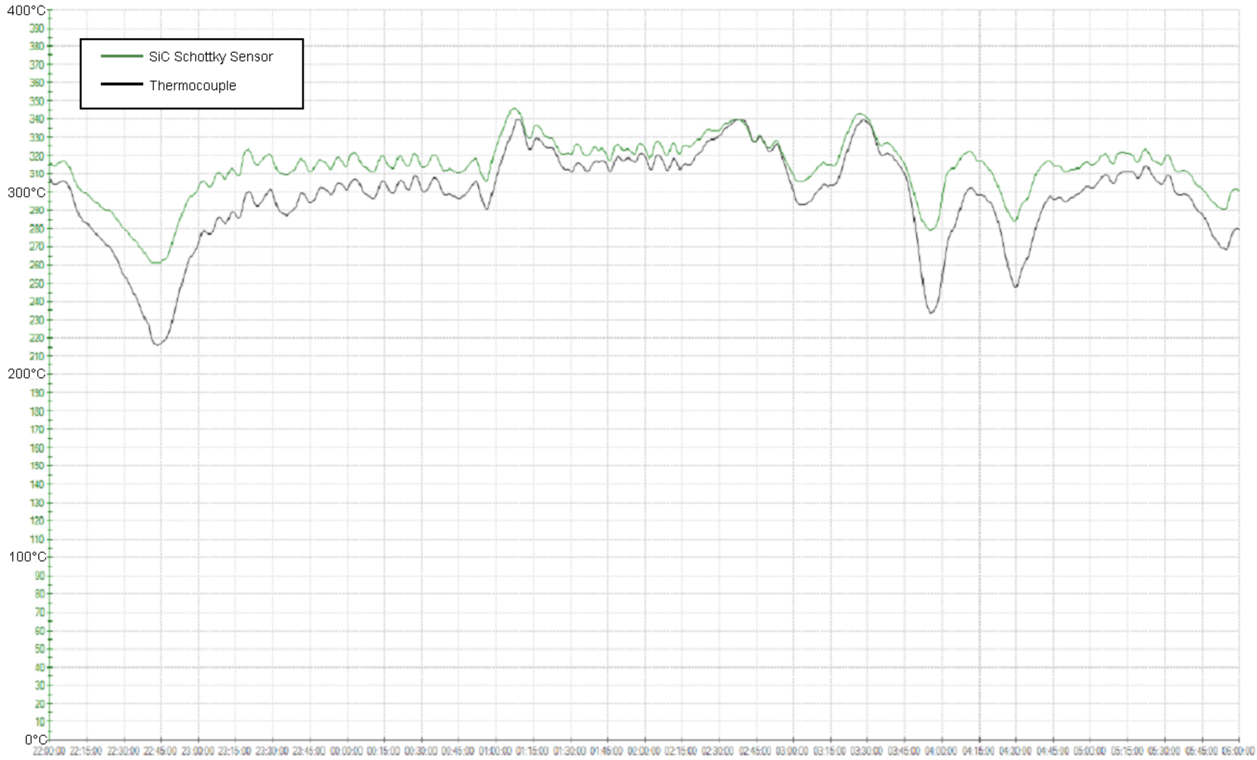

Fig. 3: SiC-Schottky versus thermocouple high temperature sensors in harsh industrial environments.