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SENSORS ON SILICON CARBIDE (SiC)

A CHALLENGE FOR ELEVATED TEMPERATURES IN HOSTILE ECOSYSTEMS

Abstract

The development of advanced sensors and actuators capable to operate in harsh environmental conditions, which include, but are not limited to, high temperatures, high radiation, high shock and chemically corrosive environments have experienced significant expansion in recent years. Temperature has an essential role in many industrial processes and other various applications because several physical characteristics of materials and devices change when exposed to thermal stress. This aspect works in tandem with the fact that most technological processes require careful monitoring of temperature levels in order to ensure optimal quality and yield. Therefore, precise, robust, and reliable temperature sensors are among the primary requirements in the industrial sector, especially for the cement, drilling, aviation, automotive or geothermal industries.

Wide band-gap semiconductor-based temperature sensors have become a promising alternative for harsh industrial applications. Silicon carbide (SiC) is a particularly suitable material due to its mechanical robustness, radiation and chemical inertness and wide bandgap which allows fabricated devices to operate at temperatures over 400°C. Among all devices fabricated on SiC, Schottky barrier diodes (SBD) are excellent candidates for high-temperature sensing in hostile settings due to simple, cost-effective structure, very compact size and quasi-linear voltage-temperature dependence.

This paper is focused on SiC-SBD-based sensing elements, included in a high temperature probe and tested in industrial applications. Diodes with annealed Ni/4H-SiC contacts are designed, fabricated and measured up to 400°C. For sensing applications, these devices are forward biased at a constant current.

In order to offer an application-oriented solution for characterizing such high-temperature-capable Schottky contacts, a model adequate for replicating inhomogeneous Schottky diodes' forward characteristics over wide temperature and bias ranges is discussed. According to this *p*-diode model, the Schottky contact current is considered to flow through a few parallel-connected internal diodes, each with a stable and constant barrier height, near-unitary ideality factor and specific series resistance. A distinctive model parameter defines the inhomogeneity degree and is directly connected to the number of parallel diodes necessary to fully reproduce the electrical behavior of a non-uniform Schottky contact. Accurate fitting of experimental curves, even those with visible irregularities (due to the series resistances' influences), was achieved.

The temperature probe also comprises a dedicated read-out circuit, used to convert sensor output voltage to current in the industrial standard (4 mA – 20 mA). Following calibration, the sensor system was assembled and incorporated into an industrial casing. Several such temperature probes were tested in the raw meal mill of a cement factory alongside standard thermocouple-based counterparts for several months.