

**Influence of Semiconductor Metal Oxide Properties on High-Temperature Gas Sensing Characteristics**

**Bilge Saruhan<sup>1\*</sup>, Roussin Lontio Fomekong<sup>1,2</sup>, Svitlana Nahirniak<sup>1</sup>**

<sup>1</sup> German Aerospace Center, Institute of Materials Research, Department of High-Temperature and Functional Coatings, Linder Hoehe, 51147 Cologne, Germany

<sup>2</sup> currently in: Higher Teacher Training College, University of Yaounde I, P.O.BOX 47 Yaounde, Cameroon

Semiconductor metal oxides (SMOx) are widely used in gas sensors due to their excellent sensing properties, abundance and ease of manufacture. The best examples of these sensing materials are SnO<sub>2</sub> and TiO<sub>2</sub> that have wide bandgap and offer unique set of functional properties, the most important of which are electrical conductivity and high surface reactivity. The main material specific aspects that strongly affect the gas sensing properties and can be controlled by synthesis method are morphology/nano-structuring and dopants to vary crystallographic structure of metal oxide sensing material.

High temperature gas sensors are mainly designed to solve gas detection and monitoring problems with high operating temperature environment such as gas turbines, combustion system of power plants and for control of engine emission, exhaust gas monitoring and environmental protection. Such sensors have to operate with reasonable sensitivity under harsh conditions such as high temperatures in coexistence of multiple gases and high humidity. Good sensing properties are difficult to achieve under high temperatures gas environment by using simple semiconducting metal oxides. Therefore the development of innovative sensor materials is required for achievement of excellent high temperature sensing performance towards NO<sub>x</sub>. Literature focuses on cost effective metal oxide based gas sensors operate mostly at temperatures <400 °C with only a few exceptions above 400 °C. High-temperature NO<sub>x</sub>-sensing is an increasing requirement for process. TiO<sub>2</sub> is one of the semiconducting oxides that are capable of operating at and above 600 °C. However, TiO<sub>2</sub> is a high resistive n-type semiconductor with relatively poor conductivity for sensing oxidative gases such as NO<sub>2</sub>. This disadvantage can be prevailed through addition of low valence dopants to alter its electronic structure. Another strategy is to use catalytically doped perovskite based titanium compounds such as BaTiO<sub>3</sub>. Additionally, the sensor designs can be optimized, for instance memristor sensors with TiO<sub>2</sub> layers are reported to yield promising results.

This context reports the sensor material developments achieved as resistive sensors using doped TiO<sub>2</sub> and Ti-compounds such as Rh-doped BaTiO<sub>3</sub>. For the synthesis of doped TiO<sub>2</sub> layers, PVD-Sputtering process was utilized, while Rh-doped BaTiO<sub>3</sub> was synthesized by co-precipitation method. Doping of TiO<sub>2</sub> through trivalent cations promotes p-type behavior exhibiting good sensing properties to NO<sub>2</sub> at temperatures above 500 °C while Ni-doping

displays the maintenance of n-type behavior and better H<sub>2</sub>-sensing properties at 600 °C. Sensor design plays also role in sensors properties by using the same sensor material. Thus, the application of memristor sensor design with undoped and Cr-doped TiO<sub>2</sub> reveals that the sensor operation temperature can be decreased significantly, as the sensitivity increases a factor of 10-25. Thus, NO<sub>2</sub> sensing can be achieved already at 120°C with a very high sensor signal (almost 25 times higher than that of the one obtained with interdigital gas sensor design). On the other hand, nanoparticles of Rh-doped BaTiO<sub>3</sub> prepared as sensing layers of interdigital gas sensors show excellent NO sensing properties even at 900 °C.