

Type of Presentation:

Oral

Topic:

Gas Sensors

## Development of a sensitive and selective mixed-potential ammonia sensor for automotive exhausts

G. Nematbakhsh Abkenar<sup>1</sup>, J. P. Viricelle<sup>1</sup>, M. Rieu and P. Breuil<sup>1</sup>

<sup>1</sup>Mines Saint-Etienne, Univ Lyon, CNRS, UMR 5307 LGF, Centre SPIN, F - 42023 Saint-Etienne France  
Tel.: +33477426659

E-mail: gita.nematbakhsh@emse.fr

**Abstract:** Selective catalyst reduction (SCR) system using ammonia gas as a reductant, is one of the most reliable ways to control NO<sub>x</sub> emissions from diesel engine vehicles and trucks. In order to optimize the conversion rates of NO<sub>x</sub> and to prevent inducing excessive NH<sub>3</sub> to the air, an NH<sub>3</sub> sensor is required to control the SCR system for maintaining NH<sub>3</sub> slip at an acceptable level. In this study, a highly selective ammonia sensor was developed to detect ammonia emissions from automotive exhaust. The effects of operating temperature and electrode composition on NH<sub>3</sub> response were investigated. The results indicate that the selectivity and stability of sensors are extremely dependent on previous parameters. These sensors also show remarkable sensing properties even for low concentrations of ammonia with logarithmic dependence on the gas concentration.

**Keywords:** Ammonia, Mixed-potential sensors, Selectivity, Vanadium oxide, Gas sensor.

### 1. Introduction

One of the most effective technologies in decreasing large-scale NO<sub>x</sub> emission produced by diesel engine vehicles is Urea-SCR (selective catalytic reduction) system. However, an excess of urea injection can cause NH<sub>3</sub> emissions to the environment [1, 2].

So, many studies have been carried out in order to develop an effective ammonia sensor for harsh environments of automobiles exhausts. Nevertheless, most of existing sensors suffers from cross-sensitivity to other toxic gases, low sensitivity and stability [3].

V<sub>2</sub>O<sub>5</sub> has been proved to be one of the interesting metal-oxides suitable for gas-sensing applications due to its catalytic properties [4].

In the present study, low-cost highly selective YSZ-based mixed potential sensors with Au-V<sub>2</sub>O<sub>5</sub> working electrode and platinum reference electrode were fabricated.

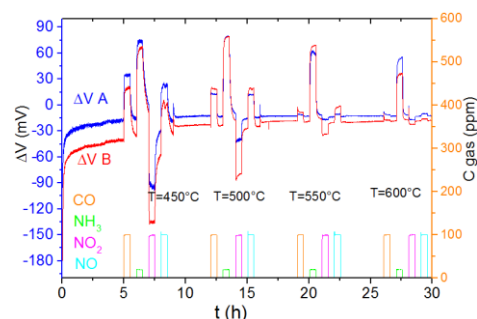
### 2. Experimental

Sensors were fabricated using Al<sub>2</sub>O<sub>3</sub> (2 cm×5cm) substrates. An electrolyte layer of YSZ (8mol% Y<sub>2</sub>O<sub>3</sub>-doped) was screen-printed followed by 2 hours sintering at 1380 °C. Afterwards, the reference electrode (platinum) and working electrode (Au-V<sub>2</sub>O<sub>5</sub>, 3 different mass ratio 85-15, 70-30 and 50-50) were printed on YSZ layer using commercial inks of platinum and gold, and home-made ink V<sub>2</sub>O<sub>5</sub>. A platinum resistor was also printed at the backside of the alumina support to control the sensor temperature.

The sintering temperature of reference and working electrodes were 850 °C and 600 °C respectively. The measured sensors' responses ( $\Delta V$ ) are the potential difference between reference and working electrode.

### 3. Results and discussion

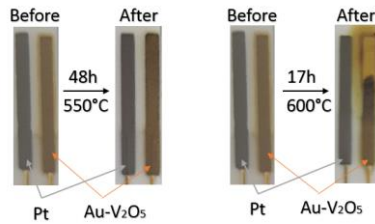
Fig. 1 shows the responses of sensors with Au - 15% V<sub>2</sub>O<sub>5</sub> working electrode, to 100 ppm CO, NO<sub>2</sub>, NO and 20 ppm of NH<sub>3</sub> at four different temperatures of 450, 500, 550 and 600 °C. It can be seen that the sensors respond to all gases at lower temperatures while by increasing temperature to 600 °C the selectivity toward NH<sub>3</sub> is greatly improved.



**Fig. 1.** Responses of Au-15%V<sub>2</sub>O<sub>5</sub> sensors to 100 ppm CO, NO<sub>2</sub>, NO and 20 ppm of NH<sub>3</sub> at temperatures of 450, 500, 550 and 600 °C.

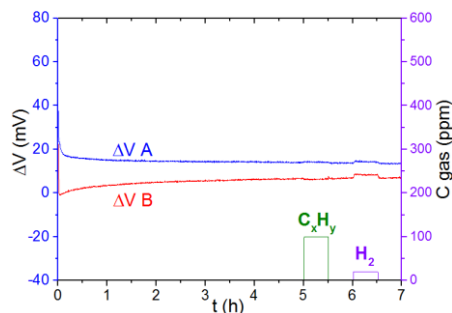
The stability of sensors was tested by exposing them at 550 °C and 600 °C for long duration. Fig. 2

clearly shows that working electrode is completely destroyed after 17h working at 600 °C while it is stable after 48h working at 550 °C. Hence, investigate were made to decrease the selective working temperature of sensors.



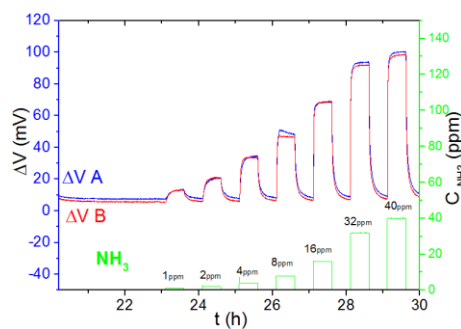
**Fig. 2.** Electrodes' appearances for new-fabricated Au - 15% V<sub>2</sub>O<sub>5</sub> sensors sintered 1h at 600 °C before and after tests for 48h at 550 °C and 17h at 600 °C.

After testing different mass percentages of V<sub>2</sub>O<sub>5</sub> in working electrode, we concluded that by increasing this value to 50%, the selective temperature of ammonia sensors could be decreased to 550 °C. The selectivity of sensors were also confirmed by testing other possible gases such as hydrocarbons and hydrogen. Fig. 3 reveals that these sensors shows almost no response to 20ppm of H<sub>2</sub> and 100ppm of C<sub>x</sub>H<sub>y</sub>.



**Fig. 3.** Responses of Au-50% V<sub>2</sub>O<sub>5</sub> sensors to 20ppm of H<sub>2</sub> and 100ppm of C<sub>x</sub>H<sub>y</sub> (a mixture of 56ppm propene (C<sub>3</sub>H<sub>6</sub>), 28 ppm n-butane (C<sub>4</sub>H<sub>10</sub>) and 16ppm methane (CH<sub>4</sub>)) at 550°C.

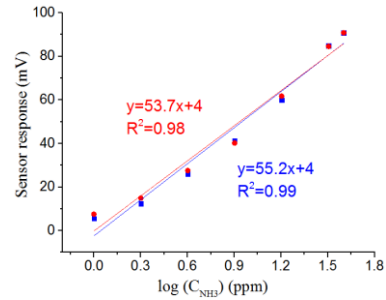
The sensing performance of resulting ammonia sensors at 550 °C was investigated by stepwise change in the NH<sub>3</sub> concentration from 1 to 40ppm (Fig. 4). These results indicate that the sensors have high sensitivity to NH<sub>3</sub>, even at low concentrations.



**Fig. 4.** Responses of Au-50% V<sub>2</sub>O<sub>5</sub> sensors to different concentration of NH<sub>3</sub> at 550°C.

As illustrated in Fig. 5, the measured sensors' responses have logarithmic characteristic as a function of NH<sub>3</sub> concentration with sensitivity of around 55 mV/decade.

Further investigations are going on to gain deeper insight in sensing mechanism of V<sub>2</sub>O<sub>5</sub> based working electrode which governs the sensor's performance.



**Fig. 5.** Logarithmic dependence of sensors' response to NH<sub>3</sub> concentration at 550°C.

## 4. Conclusions

Selective ammonia sensors were developed using V<sub>2</sub>O<sub>5</sub>-Au as working electrode, and platinum reference electrode. Selectivity of sensors were found to be so temperature dependent. The durability of these sensors were increased by increasing the mass of percentage of V<sub>2</sub>O<sub>5</sub> to 50% in working electrode with optimum operating temperature of 550 °C. A logarithmic trend of sensor responses as a function of NH<sub>3</sub> concentration were observed with sensitivity of around 24 mV/decade.

## References

- [1]. K. Shimizu, I. Chinzei, et al. Doped-vanadium oxides as sensing materials for high temperature operative selective ammonia gas sensors, *Sensors and Actuators B*, Vol 141, 2009, pp. 410-416.
- [2]. M. van Nieuwstadt, I. Dpadhyay, et al. Control of Urea SCR Systems for US Diesel Applications in *IFP Energies nouvelles International Conference*, Dearborn, USA, 2011, pp. 655-665.
- [3]. A. Muzamil, F. Qazi, et al. "Recent Trends in Electrochemical Detection of NH<sub>3</sub>, H<sub>2</sub>S and NO<sub>x</sub> Gases", *International Journal of Electrochemical Science*, Vol 12, 2017, pp. 1711-1733.
- [4]. V. Modafferi, S. Trocino, et al. Electrospun V<sub>2</sub>O<sub>5</sub> composite fibers: Synthesis, characterization and ammonia sensing properties, *Thin Solid Films*, Vol 548, 2013, pp. 689-694.