Detection of gases using an array of Love-wave sensors prepared through a combination of nanoparticles of oxides and different metals

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Abstract
A novel *array* comprised of eight *Love-wave sensors* based on *ZnO* and *TiO_2 nanoparticles* with different metals as *active centers* has been developed to detect, classify, and discriminate gases. These films work as guide and sensitive layer of every Love-wave sensor. The interaction with gases changes the electrical properties and the density of the different layers of nanoparticles, and consequently each sensor suffers a different frequency shift. So far, the array has been tested with different concentrations of toluene and ammonia. Very low concentrations of these gases have been detected and discriminated by principal component analysis.

Introduction
The efficiency of the devices based on surface acoustic waves (SAW) as gravimetric sensors for gases has been proved in the last decades. In literature, many reports proposed the use of polymers as sensitive layers [1]. However, recent reports showed that the oxide thin films used as sensitive layers of SAW devices have advantages such as their long term reliability and stability [2]. A novel idea is to use layers of nanoparticles of oxides due to their high surface area, and to dope them with different metals as active centers to change the selectivity to the gases. In this way, devices sensitive to mass-loading and electrical changes are obtained. These array of sensors combined with pattern recognition techniques are able to discriminate and classify different gases.

Materials and Methods
The Love-wave sensors developed in this work are based on a shear horizontal surface acoustic wave (SH-SAW) propagated onto ST-cut quartz. This wave, with a wavelength of λ=28 μm, is generated and detected by interdigital transducers (IDTs). To obtain a Love-wave sensor, a film of metal oxide nanoparticles has been deposited by spinning, thereby obtaining a composite film of nanoparticles capable of guiding the SH-SAW and also performs the functions of sensing layer. In order to obtain different responses of each sensor, two different layers of nanoparticles have been used (ZnO and TiO_2), and three different metals (Co, Cu and Pt) have been added to generate different active centers in the oxides. Therefore, an array of eight sensors has been obtained (Table 1).

Results
The sensor array has been tested with different concentrations of ammonia and toluene, obtaining a fast detecting and recovery response (Fig. 1a and 1b). In addition, each concentration was measured four times, being the repetitive responses for each array sensor. Each sensor showed a different frequency shift, sometimes with a response in opposite sense, due to the change in the different properties (electrical and gravimetric ones) of the layer of nanoparticles doped with the metals. Figure 2a shows the maximum frequency shift for the exposure of each sensor of the array to 100 ppm of ammonia and toluene. The different response of each array sensor did possible to use the principal component analysis (PCA) to discriminate different concentrations of each compounds (Fig. 2b).

Conclusions
Sensitive layers of nanoparticles have certain advantages over continuous films, such as th**e e**ase of preparation (deposition by spinning) and their increased sensitivity due to their high surface area. The results show that the Love wave sensor array is highly effective in detecting gases due to the change in electrical properties and density in the layers of the nanoparticles of the oxides. In addition, the response of each oxide changes dramatically when different metallic center actives are incorporated. It has been proved that the Love wave sensor array and the choice of materials for this present study have been effective in obtaining high sensitivity, selectivity, and reproducibility. Fast detection and

recovery responses have been achieved as well, detecting concentrations as low as 5 ppm of toluene and 10 of ammonia.

References

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Table 1: Sensor array composition.

Sensor	S1	S2	S3	S4	S5	S6	S7	S8
Metal Oxide	ZnO	TiO_2	ZnO	TiO_2	ZnO	TiO_2	ZnO	TiO_2
Active Centers	--	--	Co	Co	Cu	Cu	Pt	Pt

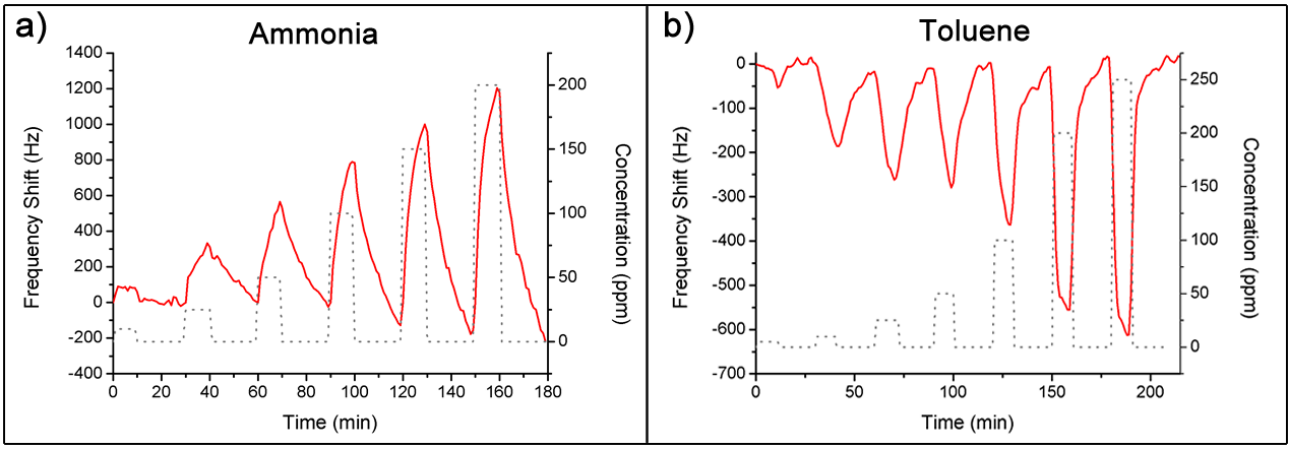

Fig. 1: Real time response of a) sensor S8 to different concentrations of ammonia and b) sensor S2 to different concentrations of toluene.

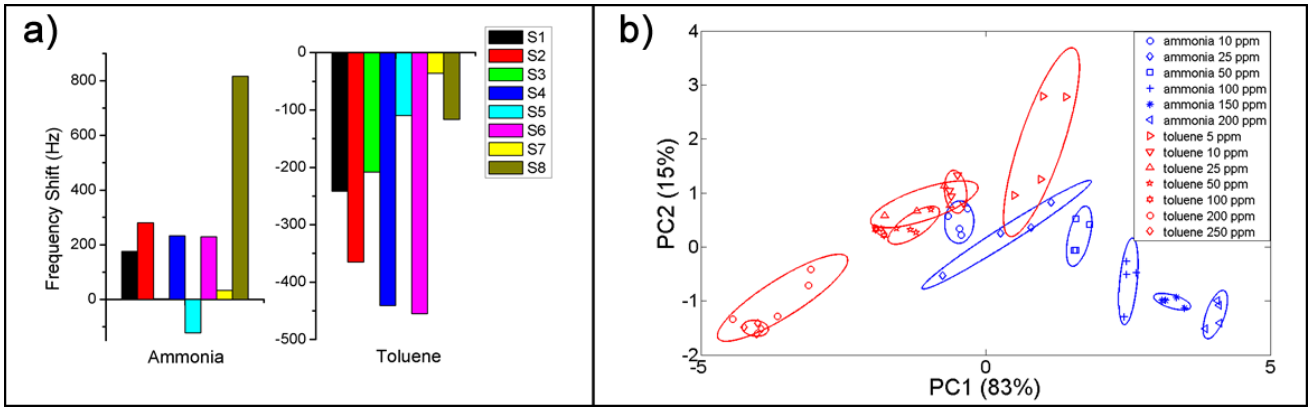

Fig. 2: a) Sensor response to 100 ppm of ammonia and toluene. b) Representation of the first two principal component of the PCA to discriminate different compounds and different concentrations.