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Sensors and Actuators B 122 (2007) 457–460
SENSORS AND ACTUATORS B CHEMICAL
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# The interference of humidity on a shear horizontal surface acoustic wave ammonia sensor

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Received 14 August 2005; received in revised form 13 June 2006; accepted 13 June 2006
Available online 28 July 2006

**Abstract**

The interference of humidity on an ammonia sensor was studied in this work. The shear horizontal surface acoustic wave (SH-SAW) device coated with L-glutamic acid hydrochloride was fabricated and used as an ammonia sensor. The sensitivity of the SH-SAW ammonia sensor was 4.6 ppm/ppm and the mass loading dominated the perturbation in dry air at 50 °C. As the humidity rose in the environment, the perturbation was primarily from the elastic effect. This work estimated the cross-sensitivity of the interference of humidity. Finally, the neural network technique was used to identify ammonia in the environment.


*Keywords:* Shear horizontal surface acoustic wave; L-Glutamic acid hydrochloride; Ammonia; Humidity; Cross-sensitivity

## 1. Introduction

Ammonia exists in ambient polluting aerosols and may cause diseases to humans; therefore, the detection of ammonia gas is an important task. The chemical interfaces for ammonia detection have been widely developed. Penza et al. [1–3] employed the polypyrrole film prepared by the Langmuir–Blodgett (LB) technique to selectively and sensitively detect ammonia gas of 46–10,000 ppm. Hohkawa et al. [4,5] studied the characteristics of surface acoustic wave (SAW) sensors based on porous alumina with a Pt or Co catalyst for ammonia detection. Palladium metal-oxide-semiconductor (Pd-MOS) structures were also proved to be useful for ammonia detection [6]. D'Amico et al. [7] employed a SAW delay line coated with a selectively absorbable platinum (Pt) film to sensitively detect ammonia. $SnO_2$ and group-III-element-doped zinc oxide were successfully used to detect ammonia at 350 °C [8,9]. In the past, we continuously studied the detection properties of SAW sensors to ammonia based on L-glutamic acid hydrochloride to ammonia [10–16]. It was proved that the SAW delay lines based on L-glutamic acid hydrochloride had high sensitivity, selectivity, reversibility, and repeatability to ammonia in dry air. The detection limit of the L-glutamic acid hydrochloride sensor for ammonia was less than 0.90 ppm ammonia in dry air.

The interference of humidity is often a serious problem of ammonia sensors. All previous studies, which investigated the interference of humidity so far, made discussions when the concentration of ammonia was more than 1 ppm. In fact, it is necessary to realize the interference of humidity on the detection of ppb level ammonia for application of biosensors. A shear horizontal surface acoustic wave (SH-SAW) device fabricated on a $LiTaO_3$ substrate is a well-known liquid sensor, because it does not present severely attenuation when the surface is loaded with a liquid. In addition, the advantages of the SH-SAW device, such as a high electromechanical coupling coefficient, relative small size, fabrication reproducibility, and fast output, are attractive to gas and liquid sensors. So, this work investigated the SH-SAW sensor coated with L-glutamic acid hydrochloride to demonstrate the interference of humidity on the detection of ppb level ammonia. Finally, this work applied the neural network technique to identify ammonia in humidity to prove the possibility of the application of the sensor.

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doi:10.1016/j.snb.2006.06.017

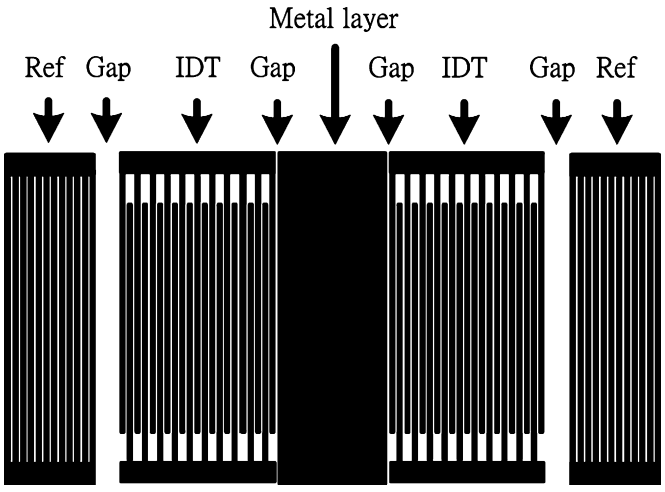


Fig. 1. The two-port SH-SAW resonator used in this study.

## 2. Experimental

The SH-SAW sensor designed as a two-port resonator was fabricated on a 36°YX-$LiTaO_3$ substrate by a lift-off method, using aluminum 120 nm metallization. A metal layer was deposited on the cavity for good adhesion of the chemical interface. The structure of the SH-SAW sensor is illustrated in Fig. 1. The design parameters of the SH-SAW resonators were as follows: the wavelength was 28 μm, the number of fingers of a pair of interdigital transducers (IDTs) was 29, the aperture was 750 μm, the length of the reflector was 1400 μm, the metallization ratio was 0.5, and the length of the cavity was 1148 μm. The operating frequency of the resonator was 148 MHz. The characteristics of the SH-SAW resonator were measured by a network analyzer (E5071A, Agilent, USA). L-Glutamic acid hydrochloride was the chemical interface. A known quantity of L-glutamic acid hydrochloride (Aldrich, USA) was weighed and dissolved in a known volume of deionized water at 75 °C, to a concentration of 0.1 mg/ml. Prior to the coating layer being applied, the surface of the SH-SAW resonator was cleaned in acetone and dried in an oven (Rendah, Taiwan) at 80 °C. Then, a coating of L-glutamic acid hydrochloride was deposited on the surface of the SH-SAW resonator by air brushing. The thickness of the L-glutamic acid hydrochloride coating was approximately 290 nm measured by ellipsometry.

Two SH-SAW resonators were introduced into a SH-SAW sensing system (Nenogram balance, ftech, Taiwan), to which a dual-device configuration was applied. The RF electronic oscillator circuit generated RF signals in the SH-SAW sensing system. A precise temperature-controller ensured the temperature stability of ±0.01 °C. Dry air used to dilute the ammonia gas and also as a carrier gas. The gaseous ambience was controlled by a mass flow controller (Sierra, USA) at a flow rate of 110 ml/min. All detections were performed at 50 °C. Before testing the gas response, the sensors were exposed to dry air for 30 min to stabilize the initial SH-SAW signal. Lastly, a frequency counter monitored the frequency shifts of the SH-SAW sensing system, which was connected to a computer system via a RS-232 interface board.

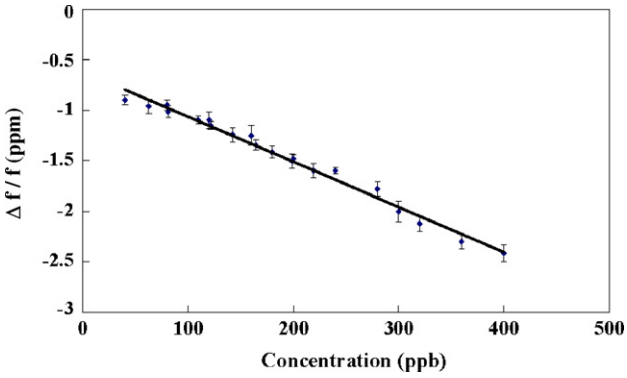


Fig. 2. Responses of the SH-SAW sensor to ammonia of different concentrations in dry air at 50 °C.

## 3. Results and discussion

The responses of the SH-SAW sensor to ammonia diluted with dry air were measured at 50 °C and the results are shown in Fig. 2. It shows that the negative frequency shift linearly increased as the ammonia concentration increased from 40 to 400 ppb. The sensitivity, which was defined as the slope of the correlation line, was 4.6 ppm/ppm in dry air at 50 °C. Fig. 3(a) indicates the frequency shift due to the absorption of humidity. The positive frequency shift rapidly increased as the humidity increased up to 60%RH and then saturated. Fig. 3(b) shows the responses to humidity in 40 ppb ammonia-containing air. It illustrates similar results to Fig. 3(a).

The L-glutamic acid hydrochloride deposited on the surface of the SH-SAW sensor acts as a selective sink. The responses of the sensor depend on the changes in properties of the L-glutamic acid hydrochloride to absorb the target. L-Glutamic acid hydrochloride is a stiff and non-conductive material, so that the perturbation after absorption can be described as follows [17]:

$$\Delta f = (k_1 + k_2) f_0^2 h \rho_f - k_2 f_0^2 h \left\{ \frac{4\mu(\lambda + \mu)}{v_0^2(\lambda + 2\mu)} \right\}, \quad (1)$$

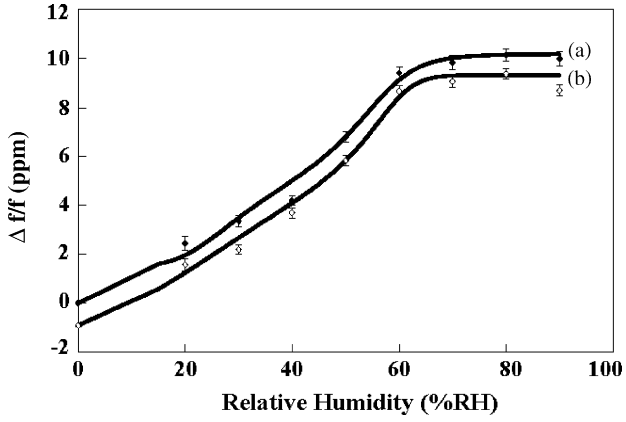


Fig. 3. Responses of the SH-SAW sensor to relative humidity in (a) pure air and (b) 40 ppb ammonia-containing air at 50 °C.