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SAW CO sensors based on SnOx organic-like film with poly ethylene glycol

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1. Introduction

Carbon monoxide is a kind of dangerous gas formed by incomplete burning of carbon and carbon-containing compounds. Because of its colourless and odourless property, it is difficult to observe the leak of CO gas. Most commercial CO sensors need to be heat up for activating, and the sensor can be applied in sensing CO gas. Therefore, developing a precise sensor for detecting the CO gas at room temperature is needed and necessary in modern life.

Because of small size, low cost, simple fabrication and high performance, surface acoustic wave (SAW) devices have been used in radio-frequency (RF) and intermediate-frequency (IF) filter for several decades. Moreover, most energy of SAW is confined within 1-2 wavelength under the surface leading to high sensitivity. SAW sensors were fabricated to detect various items such as Ammonia [1], carbon dioxide [2], humidity [3], hydrogen [4], ultraviolet [5]. Because SAW sensor is sensitive to mass loading, viscoelastic change and electrical alteration. Therefore, SAW sensor is suitable for CO gas detection.

In the study, a CO sensor module was developed by two-port SAW oscillator and sensing layer. Then, SnOx organic-like film or SnOx-PEG film was selected as CO gas sensing material to form two kinds of CO sensor module. A dual-delay line configuration was constructed for sensing stability. Finally, the thermal and humidity experiments were tested. The CO gas sensing experiment was measured for investigating the sensitivity, repeatability and stability of two different CO sensor modules.

2. Results

2.1 Experimental details

Two-port 145 MHz SAW resonators were fabricated using 128° YX-$LiNbO_3$ substrate by MEMS process. The external amplifier was designed by circuit simulation software for overcoming the insertion loss of SAW resonator, and then integrating the external amplifier and two-port SAW resonator into a two-port SAW oscillator.

The experimental substrates were cleaned by 95% ethyl alcohol solvent and distilled water to get rid of the surface pollutants and organic substances. The step could improve the adhesion between deposited film and substrate. The plasma deposition system was constituted of a bell-jar reaction chamber and a radio frequency generator. The chamber pressure was pumped down to 20 mtorr before providing mixtures of TMT ($Sn(CH_3))_4$ and oxygen gases. The depositing conditions were an input power of 100W and 40:40 in mtorr of TMT and oxygen gas. After 10 minutes duration, the tin oxide organic-like film was deposited on the $LiNbO_3$ substrate. Figure 1(a) show the SEM images of SnOx organic-like film. The structure of the SnOx organic-like film was porous. Then the post treatment with Poly ethylene glycol (PEG) was presented. The new type of sensor film was fabricated by PEG with molecule weight of 1000. Figure 1(b) is the SnOx-PEG film images. The SnOx film was reunited with PEG, so the film became round structure.

In order to enhance the stability of SAW sensor, a dual-delay line system, shown in Fig. 2, was configured to reduce the environmental interferences like humidity, temperature and pressure. The dual-delay line system consists of two SAW oscillators, one is deposited with sensing film as the sensing part and the other was still bare surface as the reference part. Two oscillators were connected to a mixer for mixing the oscillating signals, then a low pass filter was set for getting the stable output signal.

In CO gas measurement, N_2 gas was used to clean and maintain the air consistency in the chamber. The flow rate of CO and N_2 gases were controlled by a flow meter. When CO gas was attached on the sensing area, a frequency shift was caused by mass loading and acoustoelectric effect. The frequency shift of sensor module was acquired by a frequency counter and recorded by a personal computer through a general purpose interface bus (GPIB) in real time.

2.2 Measurement results and discussions

The real-time responses to the various CO concentrations of the fabricated sensor module are shown in Fig. 3. Every measurement in different CO concentrations was tested with three cycles of leading CO and N_2 gases at room temperature. Both

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CO and N_2 gases were led to the chamber with constant time. The CO concentrations include 200, 600, 800 and 1000 ppm. The frequency shifts are 2.48, 2.74, 2.95 and 3.12 kHz, respectively. The other sensor module was deposited with SnOx-PEG film for enhancing the sensitivity. The frequency responses are 4.12, 4.73, 5.03 and 5.5 kHz. The frequency shifts versus CO concentrations of the SnOx and SnOx -PEG sensor modules. The results show that the sensitivities of SnOx and SnOx-PEG sensor module are 0.75 Hz/ppm and 1.68 Hz/ppm respectively. The SnOx-PEG sensor module is more sensitive to CO gas than the SnOx one.

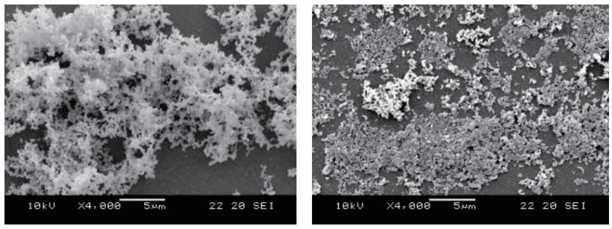
3. Conclusions

Two-port SAW sensors based on two kinds of SnOx organic-like filmd have been developed for detecting carbon monoxide. A dual-delay line configuration was constructed for reducing environmental fluctuations. The thermal and humidity experiments were implemented to test its stability. The results show that the dual-delay line configuration can indeed reduce the affection from thermal and humidity fluctuations. In CO gas measurement, two sensor modules (SnOx and SnOx-PEG) were exposed to CO gas with different concentrations. The results show that SnOx-PEG film is more sensitive to CO gas than SnOx film. In addition, the two-port SAW CO sensor shows good repeatability and fast response in the CO gas measurement. Therefore, the developed SAW sensor is potential to be a good candidate for CO detection.

Acknowledgment
The authors gratefully acknowledge the financial support from Ministry of Science and Technology of Taiwan under the grant MOST 108-2221-E-036-013.

References

1. O.K. Varghese, D. Gong, W.R. Dreschel, K.G. Ong, C.A. Grimes, Sensors and Actuators B 94 (2003) 27.
2. S. Sivaramakrishnan, R. Rajamani, C.S. Smith, K.A. McGee, K.R. Mann, N. Yamashita, Sensors and Actuators B 132 (2008) 296.
3. T.T. Wu, Y.Y. Chen, and T.H. Chou, J. Phys. D: Appl.Phys 41 (2008) 085101.
4. F.C. Huang, Y.Y. Chen, T.T. Wu, Nanotechnology 20 (2009) 065501.
5. W.S. Wang, T.T. Wu, T.H. Chou, Y.Y. Chen, Nanotechnology 20 (2009) 135503.



(a) (b)

Fig. 1 SEM images of (a) SnOx organic-like film; (b) SnOx organic-like film coated PEG.

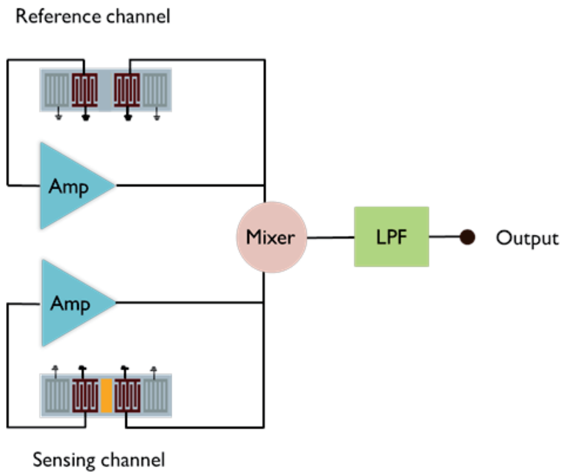
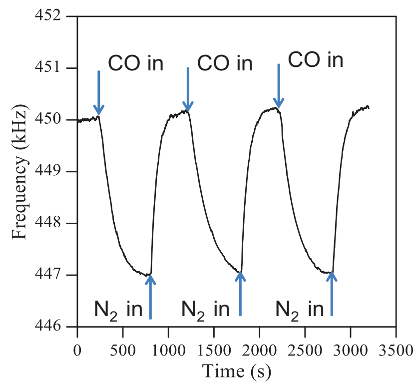
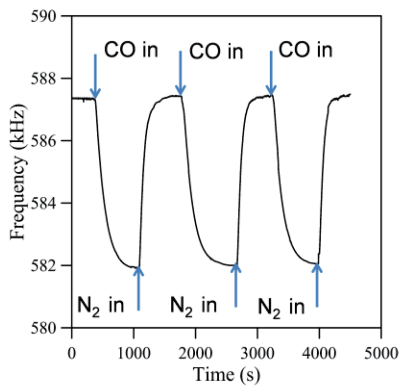


Fig. 2 Schematic diagram of dual delay line configuration.



(a)



(b)

Fig. 3 Frequency shifts of (a) SnOx module and (b) SnOx-PEG module to the 1000 ppm CO gas.