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Fabrication of ZnO Thin Film Sensor for CO_2 Monitoring

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Abstract. The flexible carbon dioxide sensor is a prospective technology for the extensive application of oSAW device. The purpose of this study is to optimize the crystallization of ZnO film for a carbon dioxide sensor by sol-gel technology and inkjet technology. The flexible CO_2 sensor composes of a ZnO layer sandwiched in between a flexible sheet, IDT electrode layer, and top sensor layer. The ZnO thin film uses the sol-gel method and spin coating. Triethanolamine adds into ZnO solution to promote the robust of ZnO film. The IDT of the top electrode layer is nano silver by inkjet printing technology. Finally, Triethanolamine film is coated as the CO_2 sensor layer. The center operating frequency of this SAW CO_2 sensor is measured by the vector network analyzer. The results prove that the significant deviation of frequency resulted from the absorption of CO_2 is observed. The characteristics of this CO_2 sensor is thin, portable and flexible. The improvement of fabricated parameters will enhance the effect of sensing of this saw CO_2 sensor in future.

Keywords: ZnO thin film, sol-gel method, CO_2 sensor, inkjet printing.

1. Introduction

Past few years, the surface acoustic wave (SAW) device has become a main issue, for the flushing of the special requirements of the sensor. In 1885, Lord Rayleigh describes the propagation properties of the surface acoustic wave in his studies. This property affects the amplitude and velocity of wave and allows SAW sensors to transfer the mass and mechanical variation [1]. After that, surface acoustic wave is widely understood and applied. White and Voltmer demonstrate the basic SAW delay line structure deposition of IDT on the piezoelectric plate in 1965 [2]. As we know, most of substrates of surface acoustic wave device are mainly rigid substrate, for the stabilization of wave propagation in device system and high temperature operating condition. In addition, for the wide application of surface acoustic wave such as sensors, touch panels and filters, the flexible substrate has been developed. Sensors can be used in various fields such as physics (temperature, pressure, strain, acceleration) [3-4], chemistry (DNA, hydronium concentration, gas concentration) [5-7], and optics (UV) nature [8]. The purpose of this study is to develop a flexible SAW ZnO CO_2 sensor by sol-gel method and inkjet printing technology. ZnO is a unique material which exhibits the properties of semiconductivity, and piezoelectricity, ZnO thin film sensors possess the advantage of operation at room temperature, fast and wide response, high sensitivity, and low cost. There are many method for preparation of ZnO thin films, such as DC or RF sputtering [9-10], metal organic chemical vapor deposition [11], spray pyrolysis [12] and sol-gel method [13]. Sol-gel method is low cost and good homogeneity and also easy to control. For these reasons illustrated as above, the sol-gel method is applied in ZnO thin film deposition processes. In addition, if flexible sensor could be fabricated by printing, it will reduce its cost. Inkjet printing technology may provide a solution. An innovative flexible surface acoustic wave sensor for the application of the non-planer is proposed in this study. Therefore, this study is to fabricate a ZnO SAW device for a flexible carbon dioxide sensor by inkjet technology and sol-gel technology [14]. The prototype successfully demonstrates its availability and expands the application of SAW device.

2. Experimental details

2.1. ZnO hybrid preparation

ZnO thin films were produced on flexible substrate by traditional sol-gel method, as shown in Fig.1. Firstly, the flexible polyimide substrate is cleaned by the atmospheric pressure plasma. The sol-gel solution includes ethanol, glycol, Triethanolamine (TEA) and zinc. The prepare acetate solution was coated on the flexible polyimide substrate using a spin coater at 800 rpm during 15sec. The coated flexible polyimide substrate was dried on heat plate at 70℃ for 30 min. These step were repeated three times and then the coated flexible polyimide substrate was annealed at 250℃ for 1 hour. Crystalline structure of the deposited ZnO thin film was studied using X-ray diffraction (XRD). Scanning electron microscope was employed to examine the surface morph of the sensor structures.

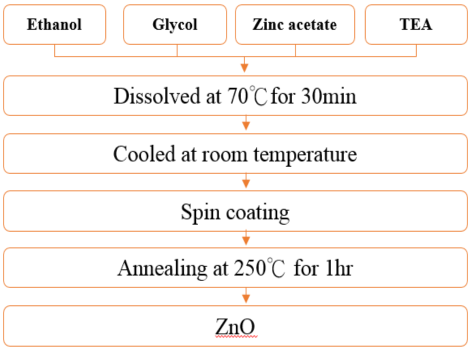

Fig. 1: The preparation process of ZnO thin film

2.2. Device fabrication

The flexible CO_2 sensor device is composed of a ZnO layer sandwiched between a Polyimide (PI) sheet, interdigital transducer (IDT), and active layer, as shown in Fig.2. The flexible Polyimide (PI) sheet serves as the bottom substrate, the thickness of Polyimide (PI) sheet is 0.125mm. The interdigital transducer (IDT) is made of nano silver. The wave change of the ZnO layer will induce an electric potential between the interdigital transducer (IDT) sheet and flexible Polyimide (PI) sheet due to the internal polarization of ZnO. The responsibility of the active layer could be enhanced by Triethanolamine, this is an effective way to support the sensor at the receiver.

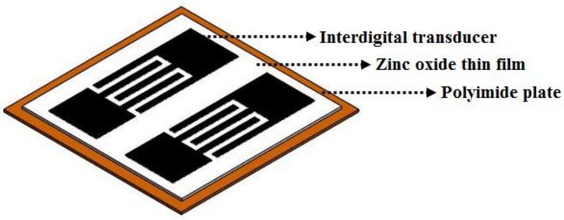

Fig. 2: The flexible carbon dioxide sensor

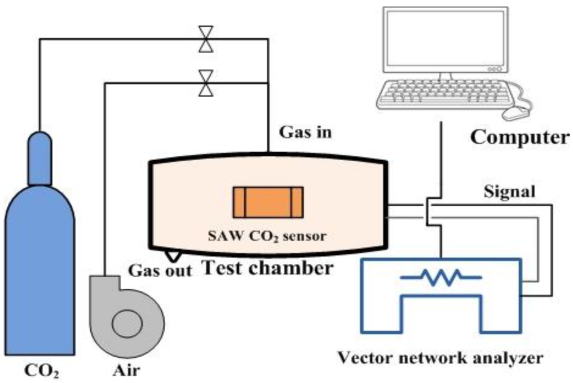

Fig. 3: Schematic diagram of CO_2 sensor measured system

2.3. CO_2 Sensor Measurement

The system to measure the change of frequency of the sensor on CO_2 monitoring is shown in Fig.3. The CO_2 sensor is installed in a test chamber and purged until the pressure reaches the preset value by dry mixture air, then high purity CO_2 gas is injected. The variation of CO_2 response is measured by the vector network analyzer (VNA). Also, the curves of frequency in various concentrations of CO_2 are systematically characterized.

3. Results and discussions

Fig.4 (a). Shows the XRD pattern of post deposition annealed ZnO thin film grown in 250℃, The phase and crystal structure of the sample has been identified. The diffraction peak can be well indexed to the wurtzite ZnO with hexagonal structure. The SEM image of the atomic grains of ZnO film is shown in Fig.4 (b), it observed that the ZnO film creates the better crystalline growth under this conditions.

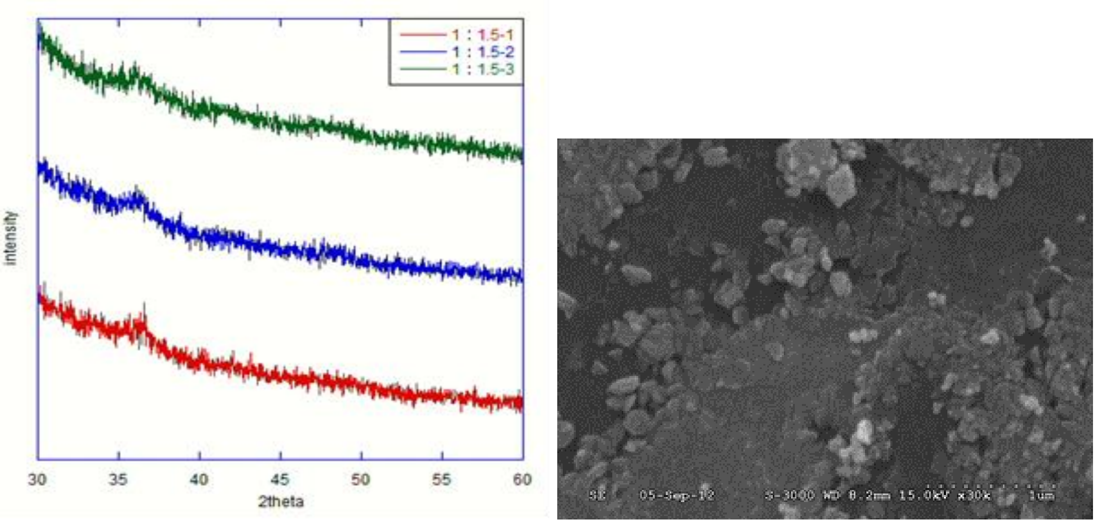

Fig. 4: (a) X-ray diffractogram of the ZnO thin film and (b) SEM image of the ZnO thin film

The CO_2 response measurements are performed for the ZnO sensor, the ZnO sensor exhibits the good gas sensing characteristics. The frequency decreases from 83.046 MHZ to 82.120 MHZ as CO_2 is filled gradually. The frequency of CO_2 sensor by VNA is shown in Fig.5. The results proof that the flexible CO_2 sensor is available as the concentration of CO_2 is changed.

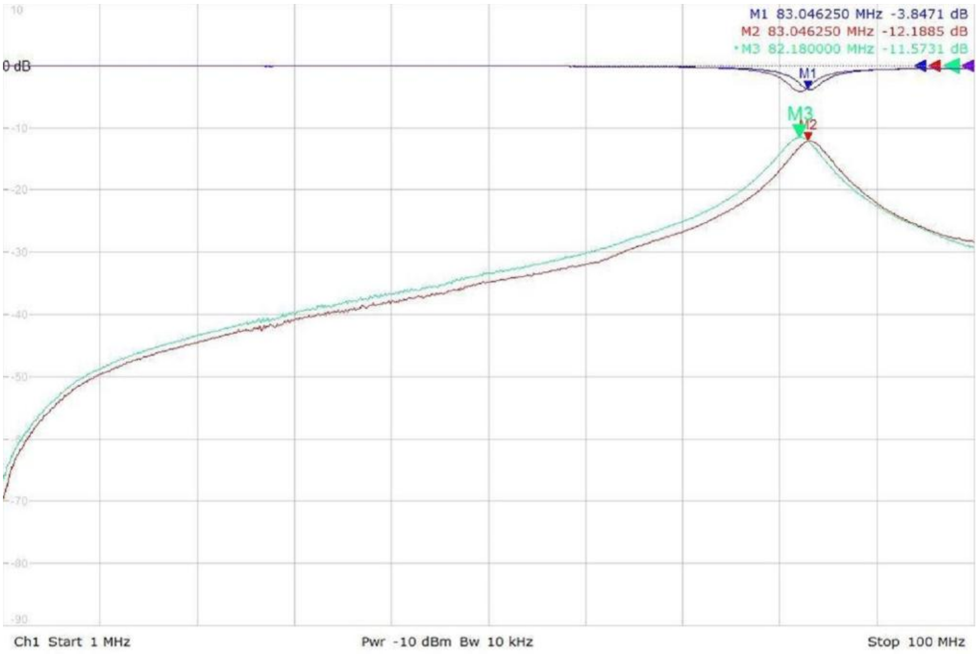

Fig. 5: Sensor response of ZnO thin film to CO_2 by vector analyzer network

4. Conclusions

CO_2 sensor based on ZnO film is fabricated by the full inkjet printing technology and sol-gel method. The cheaper cost and flexible characteristics will apply on more field. In this study, ZnO thin film was adopted to produce a sensor for CO_2, the variation of CO_2 concentrations can be monitored in this study, this result shows the response is changed obviously. Therefore, the flexible SAW device based on the ZnO film is available on the realistic product. In addition, the advantage of this product is low cost, easy fabrication. More application is developed in future.

5. Acknowledgements

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6. References

[1] R. Lord, “On Waves Propagated along the Plane Surface of an Elastic Solid”, Proc, London Math, Soc, Vol.17 (1885), p. 4-11.

[2] R.M. White and F.W. Voltmer, “Direct piezoelectric coupling to surface elastic waves”, Appl. Phys.Lett, Vol.7 (1965), Issue 12, p. 314-316.

[3] H. Wohltjen and R. Ressy, “Surface acoustic wave probe for chemical analysis”, Parts I–III, Analytical Chemistry Vol.51 (1979), p. 1458–1475.

[4] R. Lucklum and P. Hauptmann, “Transduction mechanism of acoustic-wave based chemical and biochemical sensors”, Measurement Science and Technology 14, (2003), pp. 1854.

[5] H. Wohltjen, “Acoustic Wave Sensor—Theory, Design, and Physico- Chemical Applications”, Academic Press, San Diego. (1997).

[6] P. Sharma and K. Sreenivas, “Highly sensitive ultraviolet detector based on ZnO/LiNbO3 hybrid surface acoustic wave filter”, Applied Physics Letters 83, (2003), pp. 3617.

[7] Hong, H.S., Chung, G.S., “Surface acoustic wave humidity sensor based on polycrystalline AlN thin film coated with sol–gel derived nanocrystalline zinc oxide film”, Sensors and Actuators B: Chemical, Vol.148, Issue 2, (2010), pp. 347-352.

[8] Lu, Y., Han, L., Brinker, C.J., Niemczyk, T.M., Lopez, G.P., “Chemical sensors based on hydrophobic porous sol-gel films and ATR-FTIR spectroscopy”, Sensors and Actuators B: Chemical, Vol. 36, Issues 1–3, (1996), pp. 517-521.

[9] Spangenberg, B., Popova, K., Orlinov, V., Spasova, E., Danev, G., “Reactive ion etching of crystalline quartz for SAW devices”, Vacuum, Vol. 39, Issue 5, (1989), pp. 453-461.

[10] Shih, W.C., and Huang, R.C., “Fabrication of high frequency ZnO thin film SAW devices on silicon substrate with a diamond-like carbon buffer layer using RF magnetron sputtering”, Vol. 83, Issue 3, (2008), pp. 675-678.

[11] Zhifeng Shi and Shikai Zhang, “Oxygen-induced physical property variation of deposited ZnO films by metal–organic chemical vapor deposition”, Applied Surface Science 258, (2012), pp. 8673– 8677.

[12] S.A. Studenkin, Nickolay Golego and Michael Cocivera, “Fabrication of green and orange photoluminescent undoped ZnO films using spray pyrolysis”, Applied Physics (1998).

[13] Lu, Y., Han, L., Brinker, C.J., Niemczyk, T.M., Lopez, G.P., “Chemical sensors based on hydrophobic porous sol-gel films and ATR-FTIR spectroscopy”, Sensors and Actuators B: Chemical, Vol. 36, Issues 1–3, (1996), pp. 517-521.

[14] C-T, Wang., K-Y, Huang., D. W. Lin., W-C, Liao., H-W, Lin., Y-C, Hu., “A Flexible Proximity Sensor Fully Fabricated by Inkjet Printing”, Sensors, Vol.10,(2010), pp. 5054-5062.