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Implementation of Surface Acoustic Wave Vapor Sensor Using CMOS Amplifiers

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1. Introduction

A potential market has grown for demanding various sensors in areas including chemistry, medicine and biology. Although surface acoustic wave (SAW) filters have seen much use in telecommunication, SAW-based sensors have recently emerged for many attractive features in medical and chemical applications [1]. The use of acoustic microsensor to detect the physical properties, such as mass loading and viscosity, provides the benefits of real-time electronic readout, compact size, robustness, and low cost. Monolithic integration of biosensors with existing microelectronics will allow biochemical detection system to be further miniaturized in mass production and enhanced with software-definable functions. Chemical sensing through the use of acoustic wave devices has long been available using ST-quartz as the piezoelectric material for generating acoustic wave. Therefore, in order to modulize and miniaturize the sensing system, it is of major interest to develop biosensor systems by taking advantages of standard IC technology [2][3].

In this work, the fabrication of SAW devices and the related oscillating circuit using 0.35 μm CMOS process are presented. The SAW sensor with CMOS technology is a potential candidate for the development of microsensor.

2. Experiments

Fig. 1 shows the schematic layout of a two-port SAW device in this work. Two single-finger interdigitated transducers were fabricated on an ST-quartz substrate with a propagation direction perpendicular to the x-axis of the quartz. The electrodes were 1/4 wavelength wide and separated by 1/4 wavelength at the target center frequency. A 157MHz device whose λ is approximately 20 μm was then designed with a delay path length of 10λ, and IDT length of 100λ, and uniform aperture width of 70λ [4]. A processed SAW device in the wire-bonded package is demonstrated in Fig. 2(a). The SAW device with a metal cap is used to isolate the gas sensor system as shown in Fig. 2(b).

Before full circuit implementation, a summary of circuit design using SAW devices is presented. For an oscillator to be used in biochemical detection, a MOS amplifier with a feedback loop through the SAW delay line is designed to construct an oscillator [2] as shown in Fig3. In order to meet Barkhausen criteria, the amplifier must provide sufficient gain at the target oscillator frequency to overcome the SAW insertion loss as well as the proper phase. Fig. 4 illustrates the schematic of CMOS amplifier circuits.

The flow to accomplish a SAW sensing circuit is shown in Fig.5. There are three major parts in the SAW sensing system including SAW delay line, CMOS amplifier and matching networks. First, the SAW device has been designed and fabricated based on the required electrical properties. After completing the SAW device, a amplifier was designed based on the center frequency and insertion loss of the SAW device. Next, the circuit of phase matching should be considered to compensate the SAW device and amplifier. Additional passive components were used to achieve the phase matching. While the chip process was completed, the SAW device was wire-bonded with the amplifier in a PCB or metal package. A picture of the fabricated chip is shown in Fig.6. The SAW delay line and amplifier were initially characterized by a network analyzer, respectively.

3. Result and discussion

The SAW oscillator was tested with a commercial spectrum analyzer with Vd = 3V. The phase noise of the oscillator was measured by Agilent E5052A signal source analyzer. The operating frequency of the oscillator is 157.2MHz as shown in Fig. 7. The phase noise of this oscillator is shown in Fig.8. The achieved phase noise of the oscillator with SAW device is –150dBc/Hz at 100KHz offset. Comparing to the traditional oscillator design with LC tank, the oscillator with SAW device in this study has well phase noise value at 100KHz due to the high-Q in SAW devices. The excellent phase noise would stabilize the peak drift of oscillator. The power consumption was 70 mW and expected to be reduced if the SAW device was properly impedance matched and the RF amplifier design is optimized. A lower insertion loss would be desirable for a low gain amplifier. In this work, the insertion loss of SAW device was about –20dB. The results of alcohol sensing with a PECH thin polymer film on a SAW device are demonstrated in Fig. 9. The oscillation frequency shift between gas on and off is approximately 10KHz.

4. Conclusion

The monolithic integration including a SAW sensor and a 0.35 μm CMOS chip has been demonstrated in this study. This compact integrated microsensor will be promising for future chemical and biological sensing applications.

Acknowledgements

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5. References

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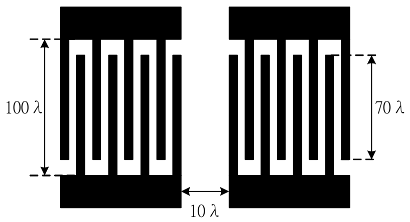

Fig. 1. A diagram of the sensor device

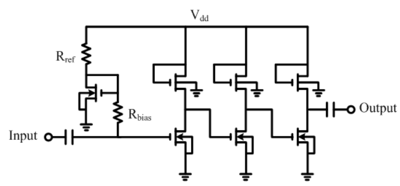

Fig. 4. The schematic of amplifier circuit

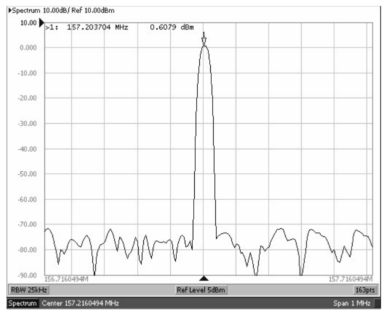

Fig.7. The power measurement of oscillator

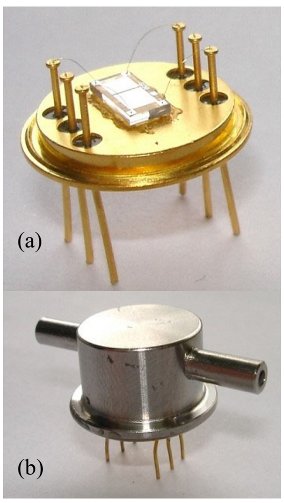

Fig. 2. The photo of SAW device (a) w/o cap (b) w/i cap

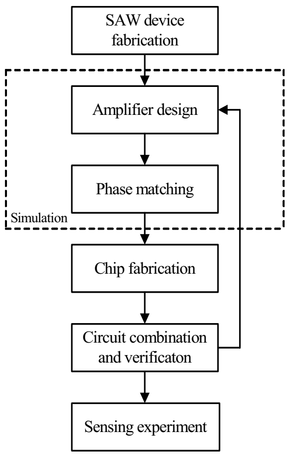

Fig. 5. The design flow of sensor circuit

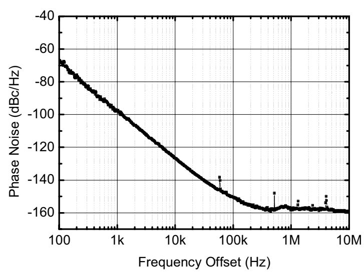

Fig. 8. The phase noise measurement of oscillator

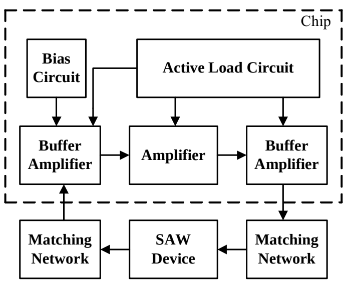

Fig. 3. The schematic of sensor system

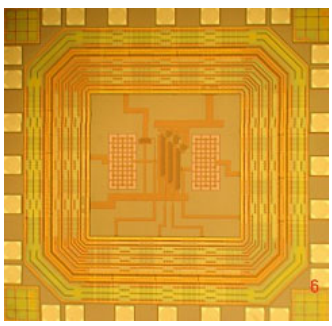

Fig. 6. The photo of the circuit

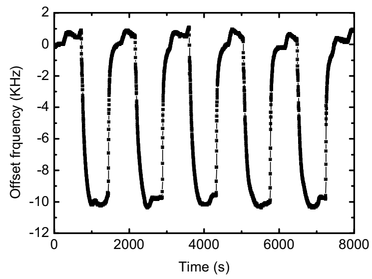

Fig. 9. Sensing results