HIGH FREQUENCY DUAL SH-SAW DEVICES FOR LIQUID SENSING

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Summary: *Novel high-frequency dual delay lines and resonator SAW sensor configurations have been designed for liquid analysis. The SAW devices operate at a wireless ISM frequency of between 400 MHz and 500 MHZ and they are built on a 36° YX $LiTaO_3$ piezoelectric substrate. A low cost liquid analysis cell has been developed and integrated into an automated measurement system. Measurements have been performed on water based solutions with different basic tastes (e.g. salty, sweet, sour and bitter). The device was able to discriminate between basic tastes, except bitter (quinine sulphate).*

Keywords: *high frequency SH-SAW, delay line, resonator*

1. Introduction

It is a well-known fact that surface acoustic wave (SAW) sensors operating in liquid phase require a horizontal-polarized mode to reduce acoustic loss. Various devices using different piezoelectric crystals and different wave modes (Love waves, shear horizontal acoustic plate mode, flexural plate waves (FPW) or shear horizontal surface acoustic waves (SH-SAW)) have been reported in literature [1-3].

The focus of this paper is on the design of two types of high-frequency SH-SAW sensors and the development of an automated measurement system for the rapid analysis of liquid samples.

2. Design of SH-SAW sensors

The sensing principle of the proposed dual SH-SAW sensors is based on the acoustic wave-liquid interaction that results in perturbations of the propagation characteristics of the wave. These perturbations are translated to the electrical domain to signal attenuation/phase or frequency shift measurements. To make the sensor sensitive to both mechanical (e.g. density, viscosity) and electrical (e.g. conductivity, permittivity) properties of the liquid under test, two sensing areas with different boundary conditions are used: one metalized and one free. The wave propagating on the metalized surface is confined closer to the solid-liquid interface and has its piezoelectric potential zeroed, thus being sensitive mostly to mechanical parameters. The mechanical wave on the free surface has an electrical field associated that makes it suitable for sensing electrical properties of the liquid; this wave also has a stronger tendency to dissipate its energy into the bulk of the crystal, and consequently is more lossy.

A 36º YX $LiTaO_3$ piezoelectric crystal has been chosen as the substrate for our sensors due to its high coupling coefficient and the SH mode supported. Interdigital transducers (IDTs) and reflectors are patterned on this substrate using standard photolithographic process at Georgia Institute of Technology.

Previous results obtained by the research group at Warwick for SH-SAW devices operating at lower frequencies (61.2 MHz) were encouraging [4] and new sensors have been fabricated for higher frequencies (400 MHz to 500 MHz). This results in smaller, lower cost devices operating at free wireless ISM frequencies.

Two sensor configurations have been analyzed, designed and fabricated: a dual delay line and a dual resonator. The delay line IDTs (Fig.1) are made of 25 solid finger pairs, have an acoustic aperture of 800 μm and each finger has a width of 2.4 μm. The opening on the free sensing area has a width of 480 μm and overall die dimensions are 5100 μm x 2700 μm.

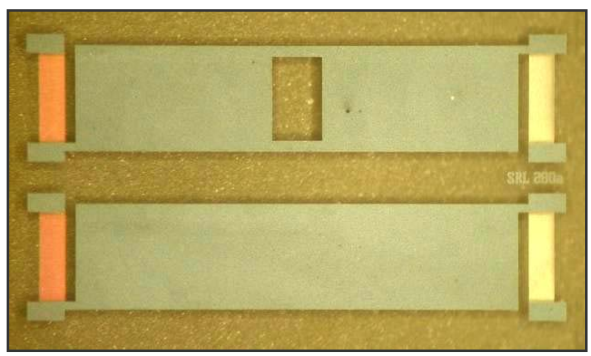

Fig.1. Dual delay line configuration: free line at top showing window for sensing liquid above.

The dual two-port resonator sensor is shown in Fig. 2. Resonators behave like narrow-band filters and have the advantage of a high Q value, linear phase response and lower insertion loss when compared to the delay line [5]. Resonator IDTs have a common ground and are made of 5 solid fingers of 2.4 μm pitch and 384 μm acoustic aperture. The resonating cavity is 168 μm wide and the reflectors on each side of the cavity consist of 300 strips of 2.4 μm pitch. Overall die dimensions are 3660 μm x 1270 μm.

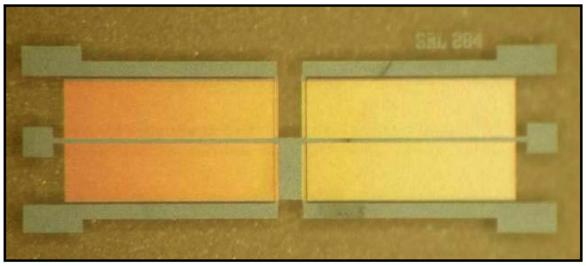

Fig. 2. Dual two-port resonator configuration (adapted from [5])

3. Experimental set-up

The SAW sensors were mounted and ultrasonically wire bonded onto a testing board. A miniature liquid cell machined from stainless steel with inlet and outlet pipes was attached to the board so that the liquid reservoir sits on top of the sensing area between the IDTs. The pipes are connected to the liquid flow system controlled by a computer via a LabWiew interface. For the delay line measurements a signal generator (HP 8648C) and a vector voltmeter (HP 8508A) were used respectively to excite and record the SAW parameters (attenuation and phase change). A block diagram of the liquid flow system is shown in Fig. 3 and a photograph of its prototype is given in Fig.4.

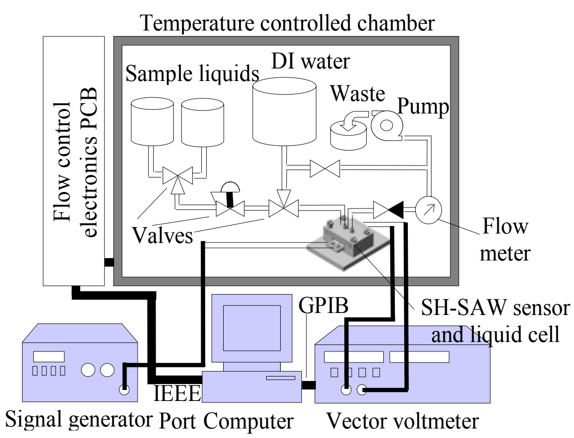

Fig.3. Diagram of liquid flow system and the automated measurement set-up

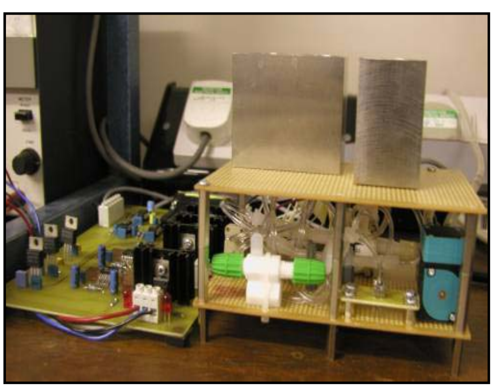

Fig.4. Prototype of liquid flow system with liquid cell, SAW on PCB, associated valves and liquid reservoirs (top).

4. Results

Four liquid samples representing the basic tastes have been chosen for initial tests: 0.1 molar saline, sucrose and HCl solutions and 0.00013 molar quinine solution. Preliminary test results from a principal components analysis of the attenuation and phase delay signals are shown in Fig. 5. The dual delay line device was able to discriminate 100% between salty, sour and sugary solutions (not shown here) but not bitter. We attribute this to the very low concentration of quinine sulphate. The resonator configuration may provide greater sensitivity and aid in the discrimination process.

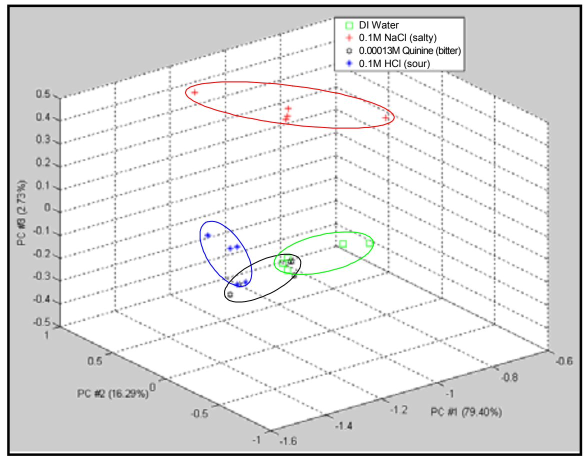

Fig.5. PCA plot of the delay-line sensor results

5. Conclusion

This paper presents novel high frequency dual delay line and resonator sensor configurations for liquid testing. An automated low cost liquid flow system has also been developed. Initial results are encouraging and applications are envisaged for the rapid, low-cost screening of liquid samples in the food and beverage industries, as well as in biomedical and environmental monitoring. It is thus a complementary tool to expensive laboratory based liquid analysis, such as GC, MS, GC-MS.

References

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