Miniature taste sensing system based on dual SAW sensor device

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Summary: *In this paper we report on a novel analytical sensing system, so-called electronic tongue, based upon a dual shear horizontal surface acoustic wave device, to discriminate between liquids with different basic tastes. 60 MHz IDT delay line sensors were micro-fabricated on 36° rotated Y-cut X-propagating* $LiTaO_3$ *and placed under a small PTFE housing containing the liquid under test. Synthetic samples were analyzed with the four basic tastes of sour, salt, bitter, and sweet. The electronic tongue device classified correctly all the different basic tastes. Finally, dultion tests have been performed in order to determine the detection limit of the taste sensor and hence its appliction potential.*

Keywords: *Smart tongue, SAW device, taste sensor*
Category: *6 (Biosensor)*

1 Introduction

The use of acoustic microsensors to detect the physical properties of liquids and gases, such as mass density and viscosity, offers the benefits of a real-time electronic read-out, small size, robustness, and low unit cost. By employing so-called chemical interfaces, the interaction of a chemical analyte with the sensor surface results in a change of propagating characteristics of the wave. In the food and beverage industries, environmental testing, and other areas, human sensory tests have mainly been performed, however, the results often depend on subjective judgment. Therefore the development of taste and odour sensors is very important. Surface acoustic wave (SAW) devices have the ability to directly respond to the mechanical and physical properties of materials in contact with the device surface. Here we propose a surface acoustic wave (SAW) electronic tongue sensor system that can be used to determine the different taste properties of liquid samples. The term “electronic tongue” was introduced at the Eurosensors X conference in 1996 [1] while the first concepts of taste sensors were published a few years earlier, in 1990 [2]. The reported devices were based on potentiometric principles utilising either ion selective lipid membranes or ion selective electrodes. Winquist et al. introduced a voltametric electronic tongue in 1997 [3]. Unlike electronic tongue devices reported so far, the devices described in this paper are miniature, low-cost, robust, durable, micropower devices based on physical rather than chemical principles. The main advantage of our proposed SH-SAW sensor is that it can detect various properties of an adjacent liquid <u>without</u> any coating films. The approach adopted is based on a generic fingerprint correlated to key physical parameters and so does not employ a bio-chemical selective layer. This in turn increases the lifetime and durability of the resultant devices, albeit with a loss of specificity.

2 Device design and operating principle

Two SH-SAW IDTs are designed using the software package L-Edit (Tanner Tools) and fabricated on 36° rotated Y-cut X-propagating $LiTaO_3$ (36YX.LT) substrate employed for simultaneous measurements of both mechanical (acoustic) properties, and electrical (electro-acoustic) parameters of the liquid under test. This is achieved through a dual delay line configuration, one shorted (metallized and electrically shielded) and the other left free (electrically active). This way, apart from mass loading and viscosity (shorted delay line), it is possible to monitor additionally the permittivity and conductivity (free delay line) of the liquid under test, parameters that can be related to taste properties, such as sweetness and saltiness. Figure 1 shows a picture of the fabricated SH-SAW device.

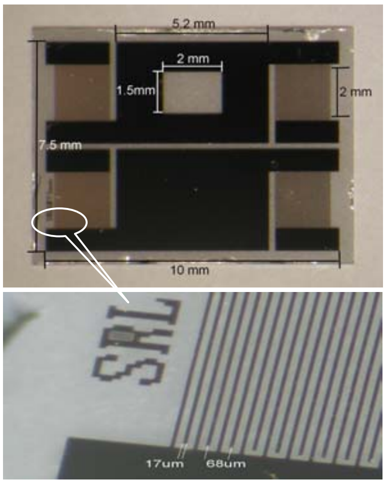

Figure 1. Photograph of fabricated SH-SAW device

The SH-SAW wave that propagates on the surface of $LiTaO_3$ substrate has an associated electric field that propagates several micrometers into a liquid. This electrical interaction (also known as the acousto-electric interaction) with the liquid affects the velocity and/or attenuation of SH-SAW propagation and it is utilised in sensing the dielectric properties of the liquids. When the surface is electrically shorted, the piezoelectric potential becomes zero and thus only horizontally polarised shear displacement waves interact with the fluid. In this case, mechanical properties including the viscosity and density will be detected. On the other hand, the piezoelectric potential at the free surface extends to the liquid and subsequently measures the complex dielectric properties such as relative permittivity and conductivity. Previous work on the analysis of different drinks [4] and fat content in milk [5] has been very encouraging.

3 Experimental method and results

In order to test the sample liquids the devices were mounted on a custom designed PCB below a PTFE cell that contains the liquid under test, see Figure 2. The experimental procedure for SH-SAW devices involves the measurement of both the phase velocity and attenuation of the SH-SAW signals propagating on the two delay lines of the sensor. The set-up includes a signal generator, the SH-SAW sensor and a vector voltmeter (HP 8505A). In this, an electrical signal is fed from the signal generator to the input IDTs; the amplitude ratio ΔV and phase difference $\Delta\phi$ between the input and output signals of each delay line were monitored by the vector voltmeter.

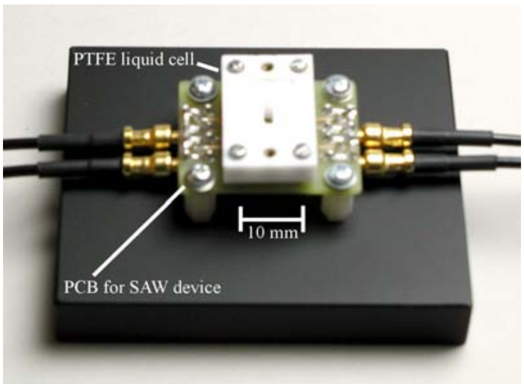

Figure 2. Total analysis taste system

The experiments were performed under controlled temperature conditions of 23 ± 0.1 °C using a commercial Dri-Bloc™ heater. Solutions used for the typical basic tastes were HCl (sour), NaCl (salt), quinine (bitter) and sucrose (sweet). Equal volumes of the mixtures (60 µl) where dispensed into the liquid cell using a micro-litre syringe and the device and cell cleaned and dried after each sample was tested using DI-water. The measurements were repeated randomly and 5 replicate measurements were conducted on each sample.

Figure 3 shows 3-D principal components analysis (PCA) of the attenuation and phase parameters for the different taste sample solutions. The concentrations used were 0.1 M for HCl, NaCl and sucrose and 1.3×10^{-4} M for quinine. The amplitude ratio and phase difference on each of the delay lines (electrical shorted and active) were used as the four parameters for the PCA.

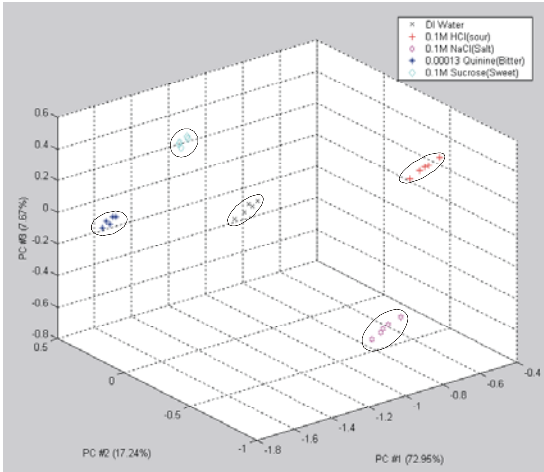

Figure 3. 3-D PCA plot for the different taste solutions showing 100 % separation

Further experiments were conducted to see the effect of diluting the different taste solutions using water and repeating the tests. The 0.1 M solutions were diluted in stages by a factor of 2^n where n varied from 1 to 5. Each time the volume of DI water was increased by a factor of 2^n and added to a fixed volume of the solutions. These results shown that the limit of detection is typically 0.1%.

4 Conclusion

A taste sensing system has been developed and is based upon a dual SAW sensor configuration. Preliminary results show that it is capable of discriminating between different basic tastes. A microsystem version is under design that will work at higher frequencies (433 and 869 MHz) and should improve sensitivity. It is believed that this system could be used as a simple, robust low-cost taste sensor.

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