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Love Wave Fully Integrated Lab-on-chip Platform for Food Pathogen Detection - LOVE-FOOD

(Contract No 317742 – Starting Date: 1 September 2012)

Deliverable 2.2

"Report on Love wave SAW/resonator devices sensitivity to mass and viscous loading"

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17 September 2013	v1	Text prepared by G. Papadakis, NCSR-D & E. Gizeli, FORTH
17 September 2013	v2	Additions provided by JM Friedt, Senseor
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Executive Summary

This work package, deals initially with the design and fabrication of two types of SAW-based Love wave devices (delay lines and resonators) operating at various frequencies and covered with various waveguides. The most promising chips after careful evaluation will be selected to be used in an array format integrated with microfluidics for the development of the final LOC platform.

In the current reporting period, we continued with the evaluation of fabricated acoustic devices started during Task 2.1 and completed in Task 2.2. The evaluation was based on sensitivity of the devices to mass and viscous loading.

The results have indicated that there are more than one combinations of operating frequency/waveguides that can be selected for the final array chip. Since the geometrical features in all cases are identical the fabrication procedure will also be similar. Therefore, the design and fabrication of the biochip will proceed having alternative possibilities under consideration.

Main Text

Task 2.2: Report on LOVE wave SAW/resonator devices sensitivity to viscous and mass loading (M6-M12, D.2.2, FORTH)

SENSEOR provided the FORTH partner with resonators and an additional batch of SAW delay lines operating at 300MHz covered with photoresist waveguide of approximately 0.45μm thickness. In summary, resonators and 32 delay lines operating at 5 different frequencies (35, 105, 155, 310 and 450 MHz) were evaluated for acoustic signal quality using 2 different waveguides; PMMA and photoresist. The PMMA percentages used for the evaluation ranged from 0 up to 20%. PMMA with increased roughness was also used in an attempt to increase the surface area to facilitate immobilization procedures. 28 out of the 32 devices checked were functional providing a good acoustic signal. In this new batch of SAW delay lines the issue of easily scratched metal pads was solved.

According to this task, resonators were expected to be produced and evaluated. Resonators did perform according to the simulations, namely two narrowband modes located at the stopband input and output, with the cavity modes only propagating in a free acoustic cavity condition and a clean spectrum free of such modes in the stopband if the cavity if filled with a periodic grating following the same pattern as those found in the Bragg mirrors. However, the two acoustic modes of interest did not exhibit sufficient quality factor improvement with respect to the delay line to justify added tests in a practical environment. Most significantly, the simulations were performed assuming a loss-less guiding layer. However, the fabricated devices did exhibit acoustic losses similar to those found in delay line configurations: hence, the added difficulty of analyzer resonator data was not compensated for by either improved baseline stability or improved signal to noise ratio gained from a lower insertion loss level. Hence, resonators were excluded from the subsequent evaluation.

A summary of the work done in Tasks 2.1 and 2.2 is schematically represented in fig. 1.

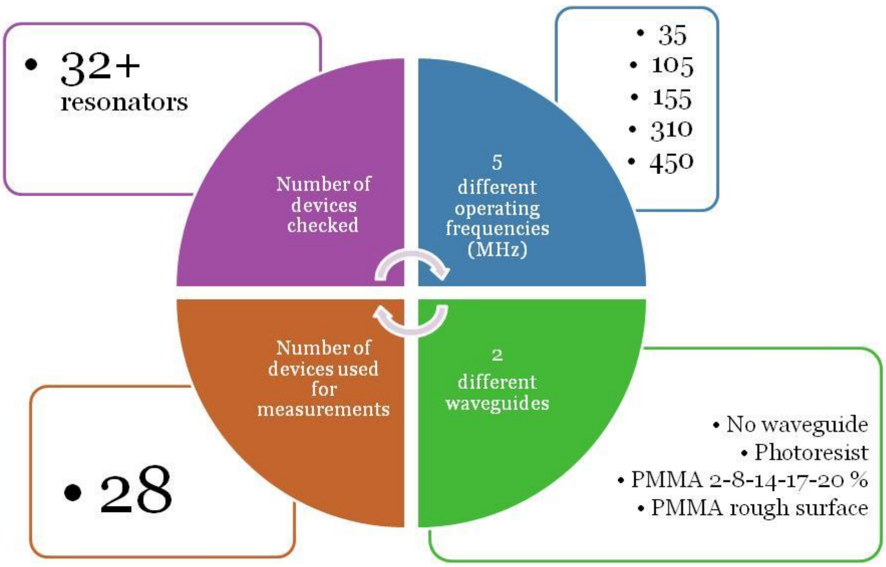

Fig. 1: Summary of the work done in Tasks 2.1-2.2

Task 2.2: Performance evaluation of SAW devices to liquid sensing (M6-M12, D.2.2, FORTH).
According to this task, SAW delay lines previously found to be functional were further evaluated in liquid environment in 4 stages (evaluation described in deliverable 2.1). Based on the previous reported evaluation, the SAW chips operating at 155MHz covered with a photoresist waveguide were the most sensitive in terms of mass detection and performed well under similar conditions that the final LOC platform will operate, giving comparable results to Qsense commercially available sensors.

As a next step, we compared the performance of the 155MHz devices in respect to a new batch of fabricated 300MHz delay lines. Evaluation was done in relation to protein mass sensitivity and to viscous loading. The new batch consisted of 10 devices covered with photoresist (approximately 0.4μm in thickness). These were firstly examined for their signal quality in air which was found to be between -20 and -22 dB.

Regarding the protein mass sensitivity comparison, a 200μg/ml neutravidin solution in PBS buffer was adsorbed on the surface of the two types of delay lines covered with either photoresist or with PMMA waveguides. The biggest phase change (up to 45 deg) was observed with the 300 MHz device covered with photoresist followed by the 155 MHz device, which was also covered with photoresist (up to 35 deg phase change). The 300 MHz device with a PMMA waveguide (8%) gave nearly 30 deg change which was found to be higher than the respective 155 with 17% PMMA (up to 25 deg). The results are summarized in Table 1.

Device freq.	Waveguide	dB	deg
300 MHz	photoresist 0.4um	1.5-3	35-45
300 MHz	photoresist removed	<1	<5
300 MHz	PMMA 8%	2-3	29
155 MHz	Photoresist ~1um	1.5	30-35
155 MHz	PMMA 17%	1-1.5	15-25
155 MHz	PMMA 8%	1-2	5-10
155 MHz	no PMMA	<1	10

Table 1: Performance of the 155 and 300 MHz delay lines covered with different waveguides in terms of protein mass sensitivity.

The experimental results indicate a higher mass sensitivity for the higher operating frequency device and especially when photoresist is used as a waveguide. This does not necessarily exclude the use of lower frequency (155 MHz) devices for our purposes since these devices were also quite sensitive. In fact, we have the option to use either of the two frequencies with the appropriate photoresist or PMMA waveguide. However, it should be noted that the most sensitive devices led also to greater distortion of the acoustic signal. This issue was solved by the construction of a new device holder and flowcell by Jobs-Tech partner. Although this new setup was not a finalized version it performed extremely well in comparison to the old setup (Fig. 2), therefore allowing for the exploitation of the mass sensitive photoresist coated devices.

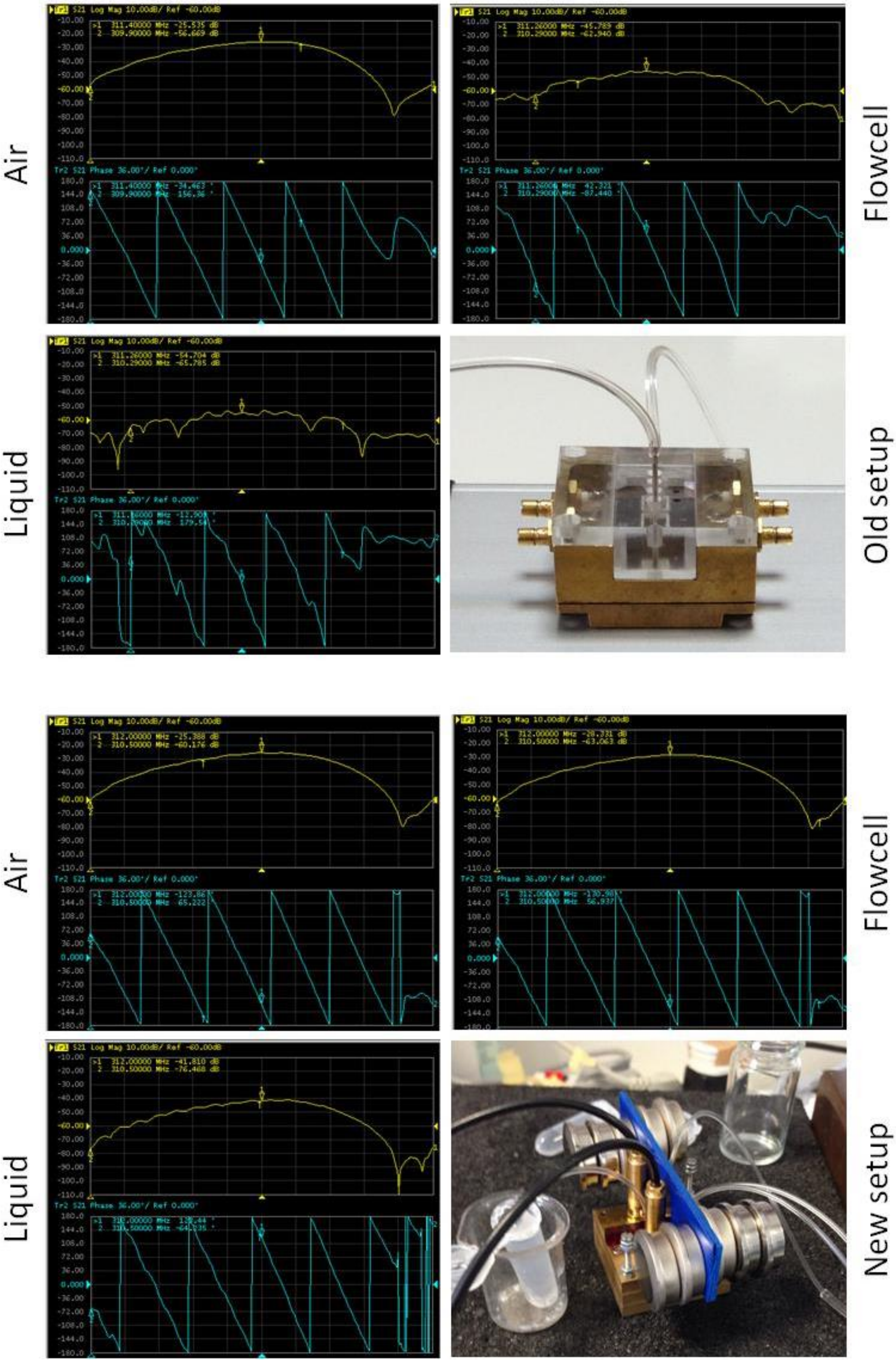

Fig. 2: Evolution of the acoustic signal distortion from air to liquid with the old and the new holder setup.

Regarding the viscous loading comparison, the experimental results upon sequential loading of various glycerol solutions verified the previous mass sensitivity findings (see Table 1). We have loaded on the 155 and the 300 MHz devices with photoresist a series of glycerol solutions in milliQ water (25%-12.5%-17%-8% v/v) and monitored in real time the amplitude and phase response. Based on the results, the 300 MHz device was found to be more sensitive compared to the 155 MHz one. Both amplitude and phase changes were greater for the 300 MHz delay line. This can be visualized when the net amplitude and phase changes are plotted as a function of the glycerol percentage in solution (Fig. 3). Both the amplitude changes and the phased changes were approximately more than two times greater for the 300 compared to the 155 MHz device. Furthermore, we have included in our comparison for viscous loading a 450 MHz device (without waveguide) and the respective 300 MHz without the photoresist. In Fig. 3 we observe that sensitivity can be increased either by increasing the operating frequency or by using the photoresist waveguide.

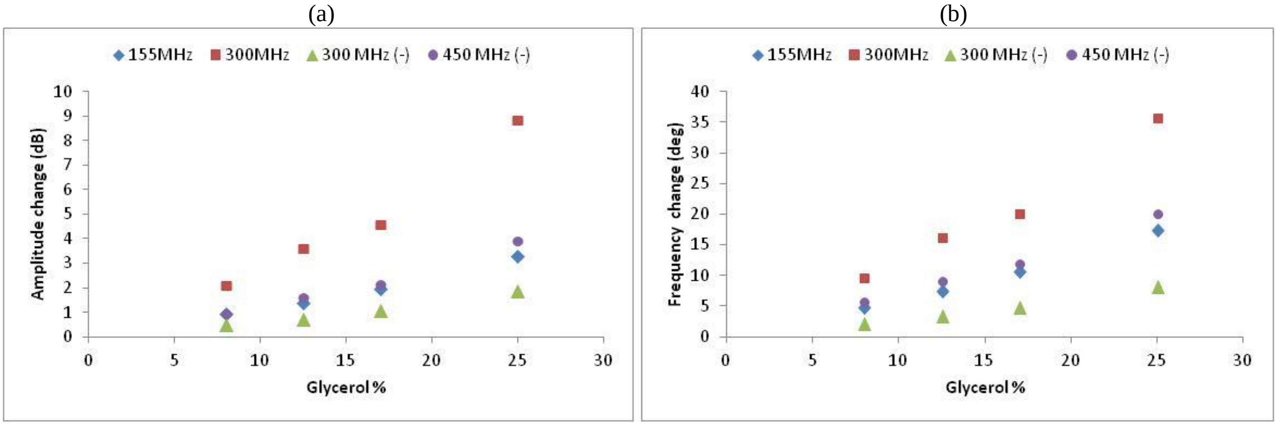

Fig. 3: Measured amplitude (a) and phase (b) changes as a function of viscous loading.

Conclusions

We have completed the evaluation of the performance of the fabricated acoustic SAW devices. We followed a 4-stage procedure in order to conclude which will be the best option to incorporate into the final platform in terms of sensitivity, reproducibility and overall performance in comparison to an established commercial chip (as for example Q-Sense).

Our results indicate that the SAW chips operating at the 300 MHz covered with a photoresist waveguide are the most sensitive in terms of mass detection and viscous loading. On the contrary, the 155 MHz were shown to perform well under similar conditions that the final LOC platform will operate, giving comparable results to Q-Sense commercially available sensors. We have concluded that both operating frequencies are sensitive enough to be adapted in the LOC platform. Since the geometrical features in both cases are identical the fabrication cost will also be similar. Therefore, we will proceed with the design and fabrication of the biochip having both possibilities under consideration.