Harmonic Love wave devices for biosensing applications

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Abstract

We have investigated simultaneous operation of a Love wave biosensor at the fundamental frequency and third harmonic, including the optimization of IDT metalization thickness. Data is presented showing a sequence of deposition and removal of a model mass layer of palmitoyl-oleoyl-sn-glycerophosphocholine (POPC) vesicles whilst frequency hopping between 110MHz and 330MHz.

Introduction: A Love wave is produced in a surface skimming bulk wave (SSBW) device when an insulating overlayer with an acoustic shear velocity less than that in the bulk is deposited over the propagation path [1]. The overlayer has the effect of confining energy to the surface and hence acting as a guiding layer. The use of Love wave devices for biosensing applications was first reported in 1992 [2] and has since attracted much attention [3-7]. The surface mass sensitivity of acoustic wave devices is known to increase with frequency [3]. However, for liquid sensing applications only a thin layer of fluid, called the penetration depth, above the sensor is probed [4]. This penetration depth, δ, reduces as the frequency increases according to $\delta = (2\eta/\rho\omega)^{0.5}$ where ω is the angular frequency, η is the viscosity and ρ the density of the fluid. When biological materials such as a vesicle layer are deposited, they may initially be attached to the mass sensitive surface as a series of spheres, in our case of diameter 50nm, which then can be opened out to form a monolayer or bilayer. The biological mass layer within the penetration depth thus changes and an

acoustic signal response is observed [9]. Here we present data showing a Love wave device operated in a frequency hopping mode utilizing both the fundamental and third harmonic during a biosensing experiment.

Experimental: In this work we have used a split-finger (double-double) interdigital transducer (IDT) design which, for Rayleigh wave devices, is known to resonate with equal strength at both the fundamental frequency and third harmonic. Devices were fabricated on ST-cut quartz with propagation orthogonal to the crystalline X direction, which is known to support a SSBW, and designed for operation at a fundamental frequency of 110MHz. Each IDT was of length 40λ and aperture 65λ where the wavelength $\lambda=45\mu m$; finger widths were $6.75\mu m$ and spacings were $4.5\mu m$. The path length was 7mm and the guiding layer consisted of Novolac photoresist dissolved between 5% and 20% (w/v) in 2-ethyoxyethylacetate (2-EEA) and spin coated at 4000 rpm for 40 seconds; after deposition the films were cross linked by baking in an oven at 200°C for 2 hours. Prior to the biosensing experiment these layers were made hydrophilic by treatment with a sol-gel derived silica coating. Hydrochloric acid was used to accelerate and polymerize a silica solution. The gel was then placed on the Novolac surface for 1 minute and washed off with deionised water. A flow cell configuration was used for the biosensing experiments. A silicone gasket was used to isolate the SAW path from the IDTs and liquid was passed through the flow cell at a rate of 0.083ml/min. The insertion loss of the device was continually monitored using a Hewlett-Packard 4195A network analyzer with markers set at the fundamental frequency and third harmonic, effectively

hopping between each frequency during the experiment. The experimental sequence consisted of initially a buffer solution, phosphate buffered saline (PBS), which was then followed by deposition of 0.2 mg/ml of vesicles of palmitoyl-oleoyl-sn-glycerophosphocholine (POPC) in PBS. The vesicle layer was then removed by a detergent, t-octyl-phenoxypolyethoxyethanol (Triton) at 0.1 (w/v) % in PBS followed by another sequence of POPC deposition and removal.

Results and Discussion: To operate a Love wave device at harmonic frequencies, both the IDT metallization thickness and guiding layer thickness must be optimized. In Figure 1 we show the effect of IDT metalisation thickness on the insertion loss at both the fundamental and third harmonic. Previous work [8] has shown that the metallization thickness of the grating is a critical parameter for surface transverse wave (STW) filter operation on this substrate with the third harmonic diminishing with increasing thickness. Our data confirms that is also the case for the IDT thickness for our uncoated SSBW device. All devices used a gold capping layer of 12nm with a Ti underlayer varied between 20nm to 80nm; from the data in Fig 1., an IDT metallization thickness of 52nm was chosen for all subsequent experiments. The effect of the Love wave guiding layer thickness was also investigated and the optimum value for observing the third harmonic whilst still retaining a significant fundamental was found to be obtained with 10% Novolac in 2-EEA. Fig. 2 shows the change in insertion loss as a function of time for a typical biosensing experiment. The mass sensitivity is known to increase with operating frequency and this is shown in a factor of five greater

change in insertion loss for the harmonic (332.325MHz) than the fundamental (110.925MHz). The rise to the initial insertion loss after the detergent treatment suggests that the POPC is fully removed by the Triton. The greater attenuation obtained during the first POPC deposition is consistent with previously published data [9].

Conclusion: In this work we have demonstrated the possibility of frequency hopping between the fundamental frequency and third harmonic of a Love wave device during the deposition and removal of a biological mass layer. The optimum interdigital transducer metalization and guiding layer thickness for simultaneous operation at these frequencies has been investigated.

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Figure Captions

Fig.1 Insertion loss for the fundamental frequency (diamonds) and 3rd harmonic (squares) as a function of IDT metalisation thickness.

Fig. 2. Change in insertion loss as a function of time for two POPC depositions and removal using a fundamental frequency of 110.925 MHz (upper line) and third harmonic of 332.325 MHz (lower line).