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Resonant conditions for Love wave guiding layer thickness

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Abstract

In this work we report a systematic investigation of polymer overlayer thickness in a Love wave device working at a fundamental frequency of 110MHz and at the 330MHz harmonic. At both frequencies we observe the initial reduction in insertion loss associated with a Love wave device. Significantly, we also observe a series of resonant conditions as the layer thickness is further increased. The separation of these resonances is attributed to an increase in thickness of half of the acoustic wavelength in the polymer.

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A Love wave is a type of shear horizontally polarized surface acoustic wave that can be produced in a surface skimming bulk wave (SSBW) device when an overlayer with an acoustic shear velocity less than that in the bulk is deposited over the propagation path [1]. The overlayer acts as a guiding layer producing a reduction in the insertion loss compared to that of an uncoated SSBW device. The use of Love wave devices for biosensing applications was first reported in 1992 [2] and has since attracted much attention [3-7]. It has been reported that an optimum thickness for the Love wave guiding overlayer exists [7,8]. However these studies have not investigated extending the thickness of the overlayer much beyond the initially observed maximum in the signal. In this work we report a systematic investigation of the effect of overlayer thickness on the insertion loss and shift in resonant frequency for a Love wave device operated at a 110 MHz fundamental frequency and at the 330 MHz harmonic.

The SSBW devices used in our experiments consisted of a split-finger (double-double) interdigital transducer (IDT) design. 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. With an appropriate IDT metalisation thickness, this split finger design also produces a SSBW when operated at the third harmonic. Coating the SSBW device with a suitable overlayer allows a Love wave to be excited at either the fundamental or third harmonic frequency [9]. Each IDT was of length 40λ and aperture 65λ where the wavelength λ was 45 μm, the finger widths were 6.75 μm and spacings were 4.5 μm. The path length was 7 mm and the guiding layer consisted of spincoated Shipley S1813 photoresist with film thickness varied by diluting the photoresist with 1 methoxy-2-propanol acetate (Aldrich Chemicals) and varying the speed of spin-coating. After deposition the resist films were soft baked at 110°C for 90 seconds; film thickness for the layers were confirmed by measurements using a Veeco Dektak 3 Surface Analysis System. The insertion loss and resonant frequency of the devices were measured using an Agilent 8712ET network analyzer.

In figure 1 we show the insertion loss (squares) and resonant frequency (triangles) as a function of overlayer thickness for operation at the fundamental frequency of 110 MHz; the solid curves are included to show the trends in the data. The Love wave guiding effect can clearly be seen with an initially improving insertion loss and a reducing frequency of operation with increasing overlayer thickness. The lowest insertion loss, due to the guiding effect, occurs at around 1.5 μm. Beyond this overlayer thickness, the insertion loss increases as previously reported in the literature [7]. However, the frequency also continues to decrease with increasing overlayer thickness until at 2.7±0.1 μm a clear resonance is observed corresponding to both a large frequency decrease and a substantial increase in insertion loss. This pattern is further repeated in a periodic manner and we were able to observe four clear minima in the insertion loss and frequency before the noise level became too large. The average overlayer thickness between two successive minima was 5.2±0.1 μm.

In figure 2 we show the insertion loss (squares) and frequency (triangles) as a function of overlayer thickness for the harmonic of the same device operated at 330 MHz. As the device is operating at three times the fundamental frequency, the SSBW wavelength is one third that of the fundamental. Thus, assuming the acoustic speed in the overlayer is independent of frequency, the acoustic wavelength in the overlayer will also be one third that occurring when the device is operated at the fundamental frequency. This is reflected in figure 2 in the positions of the resonances and the initial Love peak, which now occurs for an overlayer thickness of 0.5±0.1 μm. The periodic pattern in the frequency shift is clearly observable with a period in the overlayer thickness of 1.7±0.1 μm compared to that of 5.2±0.1 μm at the fundamental frequency. A series of related maxima and minima can also be observed in the insertion loss although the exact shape is different to that observed at the fundamental. Equating the period in the overlayer thickness to one half of an acoustic wavelength gives an estimated acoustic speed in the overlayer of (1120±60) m/s.

In conclusion, we have systematically studied the effect of increasing the overlayer thickness on a SSBW device. A series of resonance patterns have been observed in the insertion loss separated by a thickness consistent with a change of half an acoustic wavelength in the overlayer. This was observed for operation at both the fundamental frequency and harmonic for the same device.

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Figure Captions

Fig.1 Insertion loss (squares) and resonant frequency (triangle) for a device operated at the fundamental frequency as a function of overlayer thickness.

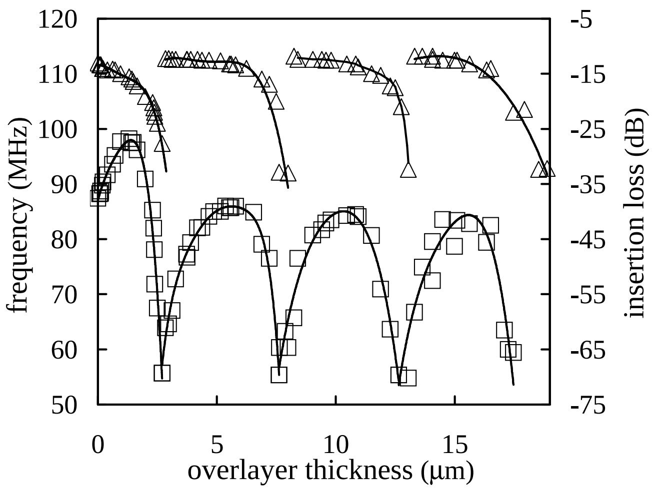

Fig. 2 Insertion loss (squares) and resonant frequency (triangle) for a device operated at the third harmonic as a function of overlayer thickness.