Nanoscale Surface Acoustic Wave Sensors for Early Cancer Detection

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Abstract:

The variety of research areas involving applications of surface acoustic wave (SAW) devices has recently been extended to include the field of biosensing technology. The velocity of the surface acoustic waves, and thus the operating frequency, is dependent upon the mass density of a biolayer on the surface of the device. This biolayer contains antibodies directed against cancer cell proteins; if the target proteins are present in the environment, they will bind to the antibody layer. This causes a change in the mass of the biolayer, which in turn results in a change in the operating frequency of the device. This change can then be detected by interrogating the device with a radio frequency (RF) signal, which is reflected back via an input/output interdigital transducer (IDT) so that the signal can then be analyzed for perturbations caused by binding effects within the biolayer. Presently, the SAW device understructure has been fabricated using electron beam lithography and tested for response to electrical probing. Ultimate goals include addition and testing of the biolayer and antenna for RF interrogation.

Introduction:

In the field of biosensing technology, SAW sensors can be used to determine the presence of specific molecules in the surrounding environment. SAWs are generated by interrogating piezoelectric substrates with an electrical signal; the extreme sensitivity of SAW devices to small surface mass changes makes them ideal for detecting nanoscale particles. Our specific SAW sensor is comprised of a single input/output IDT with an array of reflector strips on either side. An electrical signal is sent to the I/O IDT, causing SAWs to propagate outward towards both reflector arrays, one of which was coated with a biolayer composed of a protein cross-linker and antibodies specific to the target protein. If the target proteins are present in the environment, they adhere to the antibodies, causing a change in the mass of the device. By the principle of mass loading, a frequency shift occurs in the SAW propagating back towards the I/O IDT from the reflector array coated with the biolayer [1]. This shift can then be detected using radio frequency identification (RFID) technology by adding an I/O antenna to the IDT.

The novelty of our project arises from the application of SAW biosensors to cancer detection and the addition of RFID technology (see Figure 1). To this end, modifications to the general SAW device blueprint include use of antibodies whose target proteins are specific to cancer cells, addition of an RFID antenna, and the fabrication of nanoscale IDTs to produce an operating frequency in the GHz range.

Since SAW devices operate on a principle very similar to that of thickness shear wave devices, in which, by the Sauerbrey equation, the central operating frequency is inversely proportional to the amount of observable mass change, such a high operating frequency allows mass changes posed by minute targets such as cancer cell proteins to be detected [2].

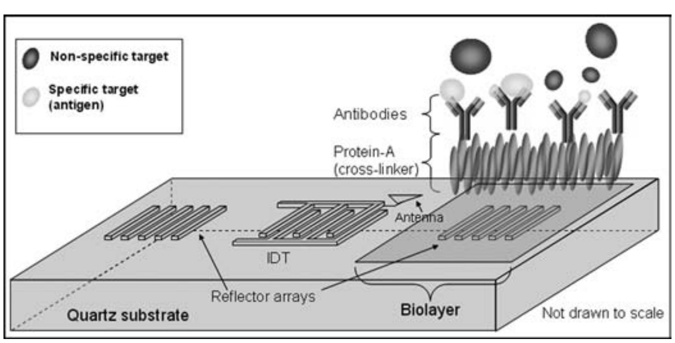

Figure 1: Schematic layout of a completed RFID SAW device.

Fabrication:

The complexity of the RFID SAW device design made it necessary for us to focus solely on fabrication of the metal understructure of the device and achieving a response to electrical signal probing. The metallization design was created using graphic design software, and electron-beam lithography was used for exposure of the resist. An ST-quartz wafer was coated with ZEP520A photoresist and a thin layer of gold to dissipate charge buildup during electron-beam

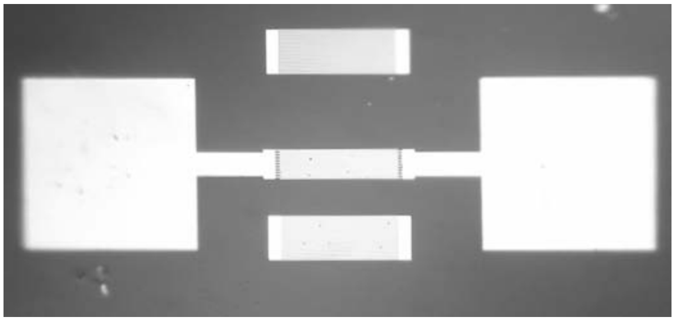

Figure 2: Metallization (Au) of a SAW device.

lithography. The wafer was then exposed, developed, and metallized with chromium (for adhesion) and gold (see Figure 2).

Experimental Procedure:

For our preliminary runs, several variations of the basic device design were fabricated in parallel to test the effect of individual geometrical parameters on the strength of the return signal. Some variables tested included the number of IDT finger pairs and reflector strips, shorted versus unshorted reflector strips, and resonating versus nonresonating devices. In subsequent runs, it became necessary to increase the size of the device pads to facilitate probing with our equipment. Metallization thickness was also varied in order to determine an ideal resist-to-metallization thickness ratio.

Results and Discussion:

After fine-tuning the fabrication procedure and achieving a satisfactory yield, a network analyzer was used to test the devices for resonance. A distinct return loss was detected in several of the devices (see Figure 3). It was found that the distinctness of the response (Q) varied approximately directly with the number of reflector strips in each array. Though the Q of the S11 return loss was high, the magnitude was only about -0.18 dB. It was also found in nearly all of the devices tested, resonance occurred at a significantly lower frequency than the expected 2.440 GHz (as in Figure 3). This anomaly was found to be part of an unexpected trend wherein the resonant frequency of the device decreased as the metallization mass increased (see Figure 4).

Future work on the RFID SAW devices should involve the addition of the biolayer and RF antenna. Experiments should be undertaken with specific and non-specific antigens to verify that the target proteins are binding properly to the antibodies and a detectable mass change results from immobilization. The inverse relationship of the metallization mass of the device to its resonant frequency should also be more fully investigated.

Acknowledgements:

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References:

[1] Handbook of Biosensors and Electronic Noses. Kress-Rogers, Erica, ed. Boca Raton: CRC Press, 1997.

[2] Dr. Peter J. Edmonson, private communication.

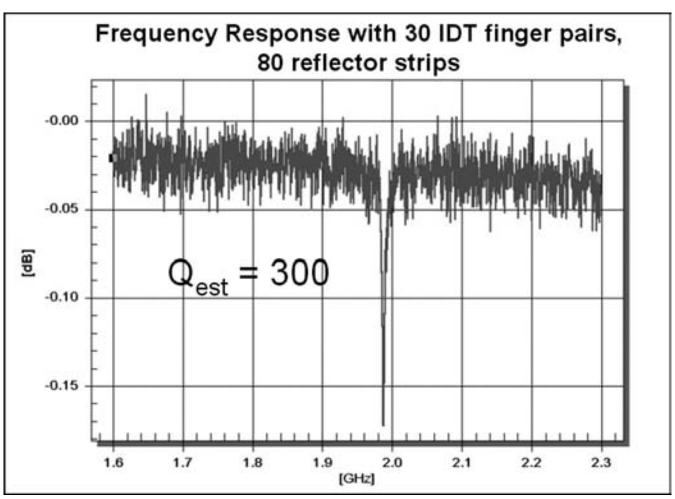

Figure 3: Frequency response of a fabricated SAW device.

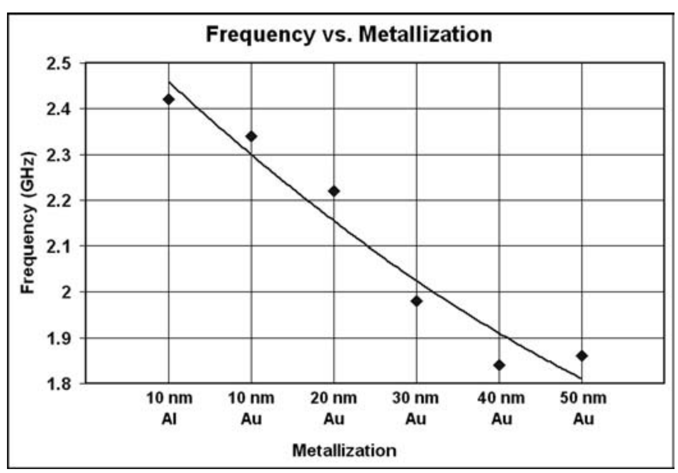

Figure 4: Frequency vs. metallization curve.