INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Programme of Study	:	**Ph.D.**

Thesis Title:
Surface acoustic wave devices using coupled resonance with nano- and microstructures for biosensing applications.

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SHORT ABSTRACT

Surface acoustic wave (SAW) is an elastic wave that propagates on the surface of a material with its energy mainly confined to a depth of about one wavelength at the surface. Usually, SAW devices are realized on polished piezoelectric substrates with metallic interdigital transducer (IDT) made on the surface for the transduction of electrical energy to acoustic energy and vice versa. In the last few years, the demand for low cost, compact and sensitive biosensors for the detection of disease-causing pathogens has increased. SAW biosensor is an analytical device that comprises IDT on a piezoelectric substrate as transducer and a chemically functionalized active area that electivity detects a specific biological analyte. SAW biosensors are helpful because they offer real-time, label-free detection with high sensitivity and selectivity. They are a promising low-cost alternative to the conventional fluoroimmunoassay, radioimmunoassay and surface plasmon based optical biosensing techniques. Of all the SAW-based biosensing systems, Love wave (LW) devices are the most promising choice for biosensor design. Guiding layer of the LW devices keeps the energy of the wave at the surface providing high mass sensitivity and also shields the IDT from liquids. Finite element (FE) simulation of LW device considering different guiding layer materials to calculate mass sensitivity, insertion loss and the coupling coefficient of the device are presented in the thesis.

The thesis mainly focuses on the investigation of coupled resonance effect in LW and shear horizontal (SH) SAW device with micro or nanostructures made on the top surface of the device for high mass sensitivity biosensing applications. The first major contribution of the thesis is analysis of coupled resonance in an LW device with ZnO nanorods and an SH-SAW device with SiO_2 micro-ridges designed on the surface via 3D FE simulation for both resonator and delay line geometries. At a particular size of the nanorods, both the substrate and nanorods vibrate in unison causing a sharp swing in the resonance frequency of the device, leading to a transition between inertial and elastic loading regimes. Simulation results show that at coupled resonance the device offers high mass sensitivity because of increase in the stiffness of the contact between nanorods and the device surface. However, coupled resonance leads to a decrease in the electromechanical coupling coefficient of the device and an increase in the insertion loss of the device.

The second major contribution in this research work is the fabrication of LW resonator and delay line devices by a standard UV-photolithography. The devices are characterized by connecting them to a network analyzer via an appropriate matching circuit. ZnO nanorods were grown on the surface of the devices by low temperature hydrothermal solution method and an attempt was made to control the height and orientation of the nanorods by using the direct growth, polyethylenimine (PEI) assisted growth, and template growth aided by e-beam lithography. As the nanorods tend to merge, it is difficult to control the orientation and uniformity of rods on the device surface required to achieve coupled resonance.

The third major contribution of the thesis is FE simulation of SH-SAW resonator with S1813 micro-ridges followed by fabrication of the devices, verification of coupled resonance, and biosensing experiment. Polymer ridges of fixed width and various heights are designed along the wave propagation direction on the surface of the resonator. The coupled resonance effect showing a sharp decrease and an increase in the resonance frequency of the device is attained at a critical ridge height and the same configuration is used for specific detection of biotin. The S1813 ridges are silanized by aminopropyltriethoxysilane (APTES) and the subsequent protein attachment is confirmed by confocal microscopy. Different concentrations of biotin solution are applied on the sensing and reference devices immobilized with avidin and bovine serum albumin (BSA), respectively. The device gives high mass sensitivity, three times greater than the mass sensitivity offered by a conventional layered SH-SAW device.
