INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:
Interaction of Surface Acoustic Waves with Organic Semiconductor and its Applications

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SHORT ABSTRACT

With the introduction of the concept of surface acoustic wave (SAW) by Lord Rayleigh in 1885 and after the advent of the interdigital transducer (IDT) in 1965, the propagation of SAW has been widely studied in piezoelectric based devices. A SAW device provides multitude of signal processing and frequency response related attributes, depending on the geometry of the IDTs deposited and on the properties of the piezoelectric substrate. SAW based signal processing units such as filters, oscillators, convolvers, correlators, matched filters etc. find their applications in radar systems, TV receivers, digital radio, spread-spectrum communications, electronic counter-measures, air traffic control and data-handling systems. SAW devices have also been used for sensing pressure, humidity, temperature, as well as bio and chemical analytes by analyzing the respective change in the SAW propagation parameters.

The interaction of SAW and charges accessible in a semiconductor leads to an enhancement in the signal processing capability of SAW as well as in the characteristics of the semiconductor device. The SAW based convolvers and correlators have seen large increase in their device efficiency after incorporating with semiconductors in various configurations. Furthermore, when SAW interacts with a semiconductor, the energy and momentum carried by SAW gets transferred to charges at an average rate creating a dragging force on them. This phenomenon is known as the acoustoelectric (AE) effect, and has been demonstrated to increase the conductivity and current in various inorganic semiconductor based two terminal device and field effect transistor (FET). In the last two decades, the organic semiconductor based devices have been widely studied and brought to limelight owing to their compatibility for low cost and solution processable fabrication. However unlike the inorganic semiconductors, the organic materials form polycrystalline layer, and their charge transport mechanism is limited by the energy barriers at the different grain boundaries which act as trap sites and degrade device performance. As a matter, factors effecting the stability of organic semiconductors have been investigated in the last few years, and the interaction of an acoustic wave with these materials has not been reported yet. In this thesis, the main focus has been on the study of how SAW interacts with an organic semiconductor, regioregular poly(3-hexylthiophene) (rrP3HT) layer and demonstrate the various signal processing characteristics that this interaction establishes. The introduction of this thesis covers

the basic concept of SAW, literature survey on the performance of various devices interfacing SAW with inorganic semiconductors, and the scope of organic semiconductor based electronic devices.

The first major contribution of this thesis is the novel demonstration and analysis of acoustoelectric charge transport in rrP3HT thin films deposited on Rayleigh and Shear horizontal (SH) SAW devices. An enhancement in current was observed in the two terminal hole-only device in presence of SAW, attributed to reduction in the effective energy difference between hopping states due to AE effect leading to lesser traps. The AE effect was validated to have a directional dependency with respect to SAW, and devices remained stable over time with exposure to SAW. The results showed that SAW could be used as an effective means to modulate the energy states and transport of charges in organic semiconductor based electronic devices.

The second major contribution in this research work is the fabrication of rrP3HT based OFET interfaced with Rayleigh SAW. The OFET showed a significant reduction in the gate voltage in presence of SAW, especially in devices with smaller channel width, owing to the decrease in the number of trap states due to the AE effect which evenly distributes the charge transport paths in the direction of wave propagation.

The third major contribution of this thesis is demonstration of organic semiconductor based excitonic transistor for the first time. The SAW piezoelectric field enables the ionization of exciton into electron and hole, then the SAW modulated field in the rrP3HT layer stores and carries the charges forward. To achieve the electrical control of the exciton flux for the transistor, a dual metal insulator semiconductor (MIS) configuration has been proposed and analyzed.

The fourth major contribution of this thesis is demonstration of an efficient rrP3HT based monolithic SAW convolver. A simple monolithic structure, ease of fabrication and repeatability of low cost solution processing technology considerably eliminated the problems encountered with the previously reported SAW convolvers, while providing record high efficiency.