Development of Thin Film based Surface Acoustic Wave (SAW) Sensor

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ABSTRACT

The present thesis is focused on sputtered ZnO films exhibiting two different properties (i) Ultraviolet (UV) photoconductivity and (ii) Piezoelectricity, and based on these properties a surface acoustic wave (SAW) based UV photosensor, and a strain mediated magnetoelectric (ME) sensors have been fabricated and investigated. The study concentrates on two interesting effects namely acoustoelectric and magnetoelectric interaction and utilizes the semiconducting and piezoelectric properties of ZnO respectively.

ZnO is a wide band gap material which has attracted much attention because textured layers can be easily fabricated at room temperature, and exhibits multifunctional properties for a variety of applications in transparent electronics, high frequency SAW devices, piezoelectric sensors and actuators, and optoelectronics devices.

Growth of c-axis oriented ZnO films using rf magnetron sputtering technique is described and the deposition conditions have been optimized for obtaining either thin semiconducting films for UV sensors or insulating piezoelectric films for ME sensors. The photoconductivity and UV response of ZnO films in metal-semiconductor-metal (MSM) configuration have been investigated. The photodetector performance in two types of SAW devices (i) delay line template and (ii) the resonator template have been compared. A 36 MHz surface acoustic wave delay line based oscillator has been used to study the effect of acousto-electric interaction due to photo generated charge carriers in rf sputtered ZnO film under UV illumination (\(\lambda=365\) nm, 20–100 \(\mu\)W/cm\(^2\)). Design aspects for developing a delay line based SAW oscillator are specified. The observed linear downshift in frequency (2.2 to 19.0 kHz) with varying UV intensity (20–100 \(\mu\)W/cm\(^2\)) is related to the fractional velocity change due to acousto-electric interaction. UV illumination level of 100 \(\mu\)W/cm\(^2\) leads to a characteristic frequency hopping behavior arising due to a change in the oscillation criteria, and is attributed to the complex interplay between the increased attenuation and velocity shift. Design aspects for SAW based oscillators in three different topologies are discussed, and a handheld prototype for SAW sensor with measurements electronics has been fabricated.

Magnetoelectric interaction via strain mediated coupling in multilayered piezoelectric and magnetoelastic system is explained. Usefulness of thin film ME structures over bulk laminated composites is discussed. Potential thin film materials for the preparation of piezoelectric thin film layered structures and prospective magnetostrictive foil substrates are identified. Strong magnetoelectric effects are observed with piezoelectric ZnO films on Nickel and Metglas magnetostrictive foil substrates. Reproducible ME effects with ZnO/Ni have been measured in the longitudinal and transverse configuration, and it is observed that effects in the transverse configuration are much stronger than the transverse ME effects. Resonance effects due to mechanical resonance in the cantilever structure with thin magnetostrictive Metglas foil substrates are shown to generate strong magnetoelectric effects. The observed effects are correlated with the piezomagnetic behavior of the magnetostrictive foils on which sputtered ZnO films were directly integrated.