Abstract

In the present work, the piezoelectric films of pure and A, B site substitutionally doped (K,Na)NbO_3 (KNN) and $LiTaO_3$ (LTO) were synthesized as cantilevers, uni-morphs, bi-morphs, and patches. These lead-free piezoelectric materials were deposited on various substrates and fabricated into piezoelectric energy harvesting devices. The structural, ferroelectric, pyroelectric, piezoelectric, dielectric properties, and device performances of piezoelements and devices were systematically investigated for their application as energy harvesters to self-power sensors in the automotive.

The piezoelectric devices described in this thesis were predominantly synthesized using sol-gel synthesis and spin coating technique. Successful deposition of thick films of piezoceramics up to 7.41 μm demonstrated possible using an optimized recipe and by adding ethylcellulose as a viscosity-increasing agent. The thick-film engineering enabled smooth, uniform, and laminated conformal film growth required for fabricating various devices with precise control over synthesis and highly reproducible structural, dielectric and piezoelectric properties.

Homogenous piezoelectric films are required to achieve high electromechanical energy with a sufficiently large piezoelectric constant. For this purpose, the effect of film thickness on piezoelectric and dielectric performance was investigated. Furthermore, the effect of poling on piezoceramics was studied to optimize the piezoelectric response and power output. The phase-voltage and butterfly curves using the piezo force microscopy proved the great ferroelectric and piezoelectric response of the lead-free devices. Moreover, the permittivity, leakage current, and FOM of the devices were examined to determine the best conditions for energy harvesting applications. It was observed that the piezoelectric figure of merit of tantalum doped KNN was higher (62.86 %) than lithium doped KNN (80.85 %) in comparison to pure KNN devices and 89.84 % higher in contrast to $LiTaO_3$ devices. However, the larger devices have their challenges as it was confirmed that with the increase in the area of the device, the power increases, with a tradeoff of decreasing the figure of merit. Furthermore, different piezoelectric materials and devices have applications in various fields for different frequency ranges. For instance, LTO energy harvesters are better suited to harvest energy at higher temperature ranges, whereas, the tantalum doped KNN cantilevers were more suitable at higher frequency ranges as compared to the large patches which were ideal for low frequency-high amplitude applications. Given the need for lead-free piezoelectric devices, KNN and LTO-based

piezoceramics are promising alternatives due to their repeatable properties, cost-effectiveness, and power output in a variable frequency range, which makes them suitable for MEMS energy harvesters for various applications.