Thesis title: Flexible Nanocomposite Films: Fabrication and Application in Piezoelectric and Triboelectric Nanogenerators

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ABSTRACT

Recently with the limited amount of fossil fuels remaining and increase concerns of environmental effects, there have been tremendous efforts put on the research to harvest ambient, renewable energies. Energy harvesting is the process of converting one form of energy into another form of energy, mostly to electrical power. Nanogenerators can harvest mechanical energy, which is otherwise will get wasted in the form of heat, sound, or other mechanical motions. The recent advancement in the nanotechnology intensifies the advancement in this field of harvesting energy using the nanogenerators. The present thesis focusses on to synthesize PVDF based nanocomposite material and exploring its uses for energy harvesting devices mainly by using piezoelectric and triboelectric effects.

In order to carry out work in this direction, flexible PVDF nanocomposite films have been prepared. The different loadings of ZnO nanorods are introduced into the PVDF matrix, and it is found that the β-phase content of PVDF, can be enhanced from 48.2% to 76.1% by incorporating ZnO nanorods into PVDF without any requirement of further processes. The fabricated piezoelectric nanogenerator (PENG) showed enhanced output power from the nanocomposite film with higher β-phase content. Further, different nanocomposite films have been prepared- PVDF/RGO, PVDF/$NaNbO_3$, and PVDF/$NaNbO_3$/RGO nanocomposite films to understand the contribution of the intrinsic piezoelectric properties of $NaNbO_3$ in the overall performance of PENG. It is found that $NaNbO_3$ nanorods help in the enhancement of β-phase

in PVDF, and also due to the inherent piezoelectric property, it contributes to the overall piezoelectric property of the film.

In order to study the effectiveness of using ZnO-PVDF as an active material for triboelectric nanogenerator, ZnO-PVDF nanocomposite film based triboelectric nanogenerator (TENG) have been fabricated by coupling with polytetrafluoroethylene (PTFE). The increase in surface roughness, hydrophobicity, and polarizability of PVDF with the introduction of ZnO into it plays a major contribution in getting more enhanced output power from ZnO-PVDF/PTFE based TENG as compared to PVDF/PTFE based TENG. As ZnO-PVDF nanocomposite film is also a piezoelectric material, a piezoelectric-triboelectric hybrid nanogenerator has also been fabricated. The hybrid device shows much-enhanced output power as compared to individual units.

Further to harvest energy from raindrops or ocean waves, a liquid-solid interface triboelectric nanogenerator (LSTENG) has also been fabricated. The advantage of having a double electrode instead of a single electrode has also been studied. Extensive KPFM measurements have been done to understand how the electricity is generated from LSTENG. Based on the KPFM measurements, a mechanism on how the electricity is generated using LSTENG has been proposed and experimentally verified the mechanism.

In the last part of the work, a hybrid device has been fabricated based on the trio effects-piezoelectric, triboelectric and electromagnetic effects to harvest mechanical vibrations. The hybrid device gives an open circuit voltage of ~192 V and a short circuit current of ~2.78 mA. The device gives a synchronized output of all the combined units due to the effective design of the hybrid device. When charging a capacitor with the hybrid device, the saturation voltage increase as compared to when the capacitor is charged with individual effects. The hybrid device can effectively light up several LEDs, digital screw gauge, and a digital calculator. The output power from the hybrid device can power the electrolysis of NaOH electrolyte to generate hydrogen and oxygen gases.