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Designing piezoelectric nanogenerator from PVDFHFP nanocomposite fibers containing cellulose nanocrystals and Fedoped ZnO

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Self-powering devices harvest energy from the environment and perform based on a maintenance free approach. These materials are of utmost significance as they solve the problems associated with the energy crisis and management, to greater extends. Advances in material science and the design of various polymer nanocomposites developed many self-powering devices that are flexible, sensitive, less power consuming and of low cost. The semi-crystalline polymer, poly vinylidene fluoride (PVDF) and its co-polymers are notable for mechanical energy harvesting because of the typical crystalline phases in their structure. Various nanoparticles are added to such polymers to enhance their dielectric and piezoelectric properties as well. Since the alignment of crystalline phases improve the energy harvesting properties, techniques such as electrical poling are practiced to enhance their applicability. Among various alignment procedures, electrospinning stands as unique since the high voltage applied to the polymer solution generates nanofiber scaffolds in perfect alignments. The present work aims to develop electrospun composite fibers in nano-dimensions for designing self-powering nanogenerators. The co-polymer of PVDF, polyvinylidene fluoride hexa fluoropropylene (PVDF-HFP) was used as the base polymer and the iron-doped zinc oxide (Fe-ZnO) and cellulose nanocrystals (CNC) as the filler reinforcements. Fe-ZnO nanostructures were obtained by hydrothermal synthesis method from the ZnO precursor, while the CNC were synthesized following the acid hydrolysis of cellulose microfibers. The optimized concentration of 20 wt.% was used for obtaining the electrospun fibers of neat PVDF-HFP and various concentrations

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of nanoparticles were mixed with this base solution. Simple solvent mixing was employed using the acetone/DMF solvent mixture to prepare the composite solutions prior to electrospinning. The electrospinning conditions were also optimized by varying the applied voltage, tip to collector distance and speed of the rotating collector. Nice fibers were obtained at a voltage of 12-13 eV and rotating collector speed of 200 rpm. Composites of CNC with PVDF-HFP, Fe-ZnO with PVDF-HFP and the hybrid material of CNC/Fe-ZnO with PVDF-HFP were prepared and properties were investigated. All the fibers were tested for the morphology, structural, thermal and dielectric properties. The mechanical energy harvesting was performed using an assembled set up containing a frequency generator, shaker and data acquisition system. At 2 wt. % of the nanofillers, the PVDF-HFP/CNC generated about 2 V, the PVDF-HFP/Fe-ZnO generated about 4 V and the hybrid nanocomposite containing both nanoparticles generated about 6 V. The filler synergy plays a major role in regulating the material properties and here the combined effect of the piezoelectric performance of the cellulose nanocrystals and the modified ZnO nanoparticles enhanced the mechanical energy harvesting capability of the final nanocomposite. A nanogenerator is designed based on the developed polymer nanocomposite fibers and the piezoelectric performance on various conditions of stretching, pressing and twisting were also investigated. In all the cases the hybrid composite showed notable performance substantiating its application in designing self-powered nanogenerators. The dielectric properties of the hybrid material showed many fold increase in its dielectric constant, making it useful in electrical energy storage. In short, the designed device by electrospinning technique is highly useful in adding to the energy management and is environmentally safe and of good efficiency.