Title:	Mechanical and Thermal Energy Harvesters for Self- powered Wearable Electronics.
Authors:	Mishra., Hari Krishna.
Keywords:	Thermal Energy. Harvesters. Electronics.
Issue Date:	Aug-2023
Publisher:	IISER Mohali

Abstract: The flexible, wearable, portable and wireless electronics have triggered the demand of sustainable and renewable energy sources. It has been found that mechanical and thermal energy sources are most ubiquitous and abundant in our surroundings which would be possible to harvest for building up self-powered wearable electronics. To fabricate mechanical and thermal energy harvesters, ferroelectric materials have centered crucial attention due to their inherent piezo- and pyro-electric properties. In particular, nanoscale energy harvesters, namely nanogenerators have shown the potential to harvest tiny mechanical motion or thermal fluctuation that has broadened their applicability as self-powered sensors and expanded the spectrum of applications in the healthcare sector. Therefore, the present thesis is primarily focused on the development of mechanical and thermal energy harvesters for self-powered electronics. Then some of their real-time applications in the healthcare sector have been also demonstrated. In this context, we report an approach to nucleate the electroactive phase in poly(vinylidene fluoride), (PVDF) by incorporating silver carbonate (Ag_2CO_3) nanomaterial that shows the ability to harvest mechanical energy. We found that the inter-fragment, non-covalent, intermolecular interactions between PVDF and Ag_2CO_3 are responsible for a stable electroactive phase in the PVDF/Ag_2CO_3 composite. We have demonstrated that a flexible piezoelectric nanogenerator (FPNG) comprising of PVDF/Ag_2CO_3 nanocomposite has an excellent electrical output response (i.e., 15 V and 6 μA, under the imparting force of 7 N) mechano-sensitivity (S_m ~ 45 mV/kPa), and acoustic signal detection (S_{acou} ~13 V/Pa). Furthermore, it has also shown the ability to recognize human gestures. Furthermore, we have introduced a nanoprecipitation technique to machinate PVDF nanoparticles (NPs) with a predominant piezoelectric delta (δ) phase (which is the least studiedphase till date) using the bi-solvent phase separation technique. It is noteworthy that the δ-phase of PVDF possesses excellent piezoelectric properties which are comparable to β-phase, nevertheless, it has been rarely explored because of its ultra-high electric field (~MV/m) based processing conditions adopted so far. In this context, solvent-based phase separation approach is the most convenient and thus expected to be an industrially viable approach to scale up piezoelectric δ−PVDF nanoparticles which have enormous technological and commercial merits. As a proof of concept, a flexible piezoelectric nanogenerator (FPNG) was fabricated comprising of δ−PVDF nanoparticles. The FPNG shows the ability to track the physiological signal such as arterial pulse detection which indicates the potential utility of δ−PVDF nanoparticles (NPs) based self-powered sensors and actuators. In continuation with earlier work, we have realized that aqueous processable piezoelectric ink would be the viable approach for large-area printable device fabrication. In this connection, we have employed polydopamine (PDA) and polyethylenimine (PEI) i.e., PDA-PEI to coat the surface of PVDF NPs, which ensures the well-aqueous dispersion. Then, we fabricated a flexible piezoelectric nanogenerator (FPNG) which shows a promising electrical output as a mechanical energy harvester. It also promises physiological signal detection abilities due to superior mechanoacoustic behavior. Furthermore, FPNG has shown excellent photo-detection and piezophototronic properties under light illumination and mechanical stimuli. Thus, it is expected that the PDA-PEI coated δ-phase comprising PVDF NPs can be utilized as a piezoelectric ink for flexible optoelectronic devices. We have also considered the 2D chalcogenide material due to the emerging piezo- pyro and ferro- electric properties. In this context, monoelemental chalcogenide i.e., tellurium (Te) (group- VI A element) is selected for our study due to its superior heat transfer rate that exhibitsunprecedented pyroelectric response from 2D Te nanosheets. It promises an excellent pyroelectric coefficient (p ~ 3000 $\mu C\,m^{-2}\,K^{-1}$) and figure of merits (FOMs) (F_i ~ 2.4 nC m/J and F_v ~ 54 m^2 /C). The unprecedented pyroelectric coefficient is found to be more than 8 folds higher than well-known pyroelectric ceramics e.g., lead zirconate titanate (p ~ 347 $\mu C\,m^{-2}\,K^{-1}$). Thus, it is concluded that 2D Te is the potential candidate for thermal energy harvesting to use as a self-powered electronic device. The piezoelectric functionality of 2D Te is also studied by scanning probe microscopy-based techniques that are validated by theoretically as well. Finally, we have prepared a flexible piezo,- and pyro,- electric nanogenerator comprising PVDF/Te polymer nanocomposite. The fabricated piezo- and pyro-electric nanogenerator (HyNG) has shown an excellent mechano-sensitivity (S_m ~ 148 mV/kPa) that enables it to harvest very minute mechanical deflections and also able to sense human gestures from very tiny movements, e.g., eye blinking, elbow bending, kneed bending and finger bending. In conclusion, self- powered flexible piezo,- and pyro,- electric nanogenerators have great potential to power small- scale devices and wearable electronics where the need of external power sources could be possibly avoided.

Admin Tools

Edit...

Export Item

Export (migrate) Item

Export metadata