SUPPORTING INFORMATION

Bio-Waste Crab Shell extracted Chitin Nanofiber Based Superior Piezoelectric Nanogenerator

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Supplementary Results and Discussions:

The degree of crystallinity Calculation: The degree of crystallinity ($\varkappa_c$) of the pure PVDF and PVDF composite films have been calculated by the formula $\varkappa_c = \Delta H_m / \Delta H_{100\%}$, (where, ΔH_m = the enthalpy of fusion of the samples and $\Delta H_{100\%}$ = the enthalpy of fusion of 100% crystallite PVDF (104.6 J/g)). The enthalpy, ΔH_m = 55.01 J/g of the CNF/PVDF composite film. From the above equation we can calculate the degree of crystallinity ($\varkappa_c$)= 52.9 which is much greater than pure PVDF film[1].

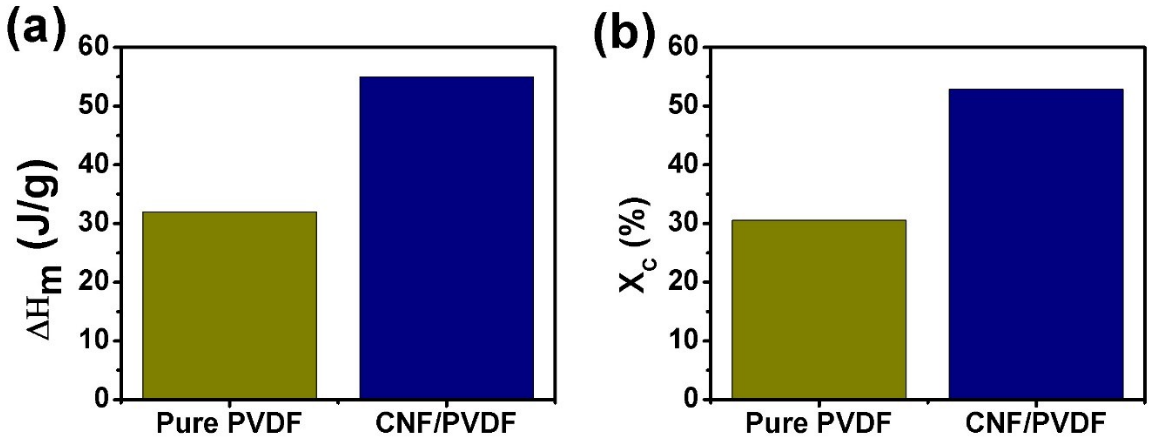

Figure S1: (a) Enthalpy of pure PVDF and CNF/PVDF composite thin films. (b) Crystallinity of pure PVDF and CNF/PVDF composite thin films.

Table S1: Extracted piezoelectric coefficients and electrostriction coefficient.

Material	Pr ($\mu C/cm^2$)	Y (N/mm^2)	Frequency (Hz)	ε_r	d_{33} (pC/N) ($d_{33}=-P_r/Y$)	Q_{33} (m^4/C^2) ($Q_{33}=d_{33}/2\varepsilon_0\varepsilon_r P_r$)
CNF	**0.178**	**187.5**	**50**	**321**	**- 9.49**	**0.932**
CNF/PVDF	**1.913**	**538**	**50**	**101**	**- 35.56**	**1.04**

External Force (F) calculation:

The applied force on the PENG by the finger has been qualitatively estimated following two equations based on momentum and energy conservation law:

$$m.g.h = \tfrac{1}{2} mv^2$$

$$\text{i.e. } v = (2gh)^{1/2} \quad \dots\dots (1)$$

$$(F\text{-}mg).\Delta t = m.v \quad \ldots\ldots(2)$$

Where, m, v, h, F represent the mass of the imparted object i.e. finger, velocity of the object when it touches the PENG, falling height of the object and applied force respectively. g is acceleration due to gravity and Δt is the time duration between two successive positive or negative peak of the voltage vs time graph.

In present work m = 1.7 kg, v = 1.384 m/s, h = 0.15 meter, and g = 9.8 m/s^2, Δt = 0.2167 s

The estimated force of the finger impartation on the PENG be F = 27.5 N.

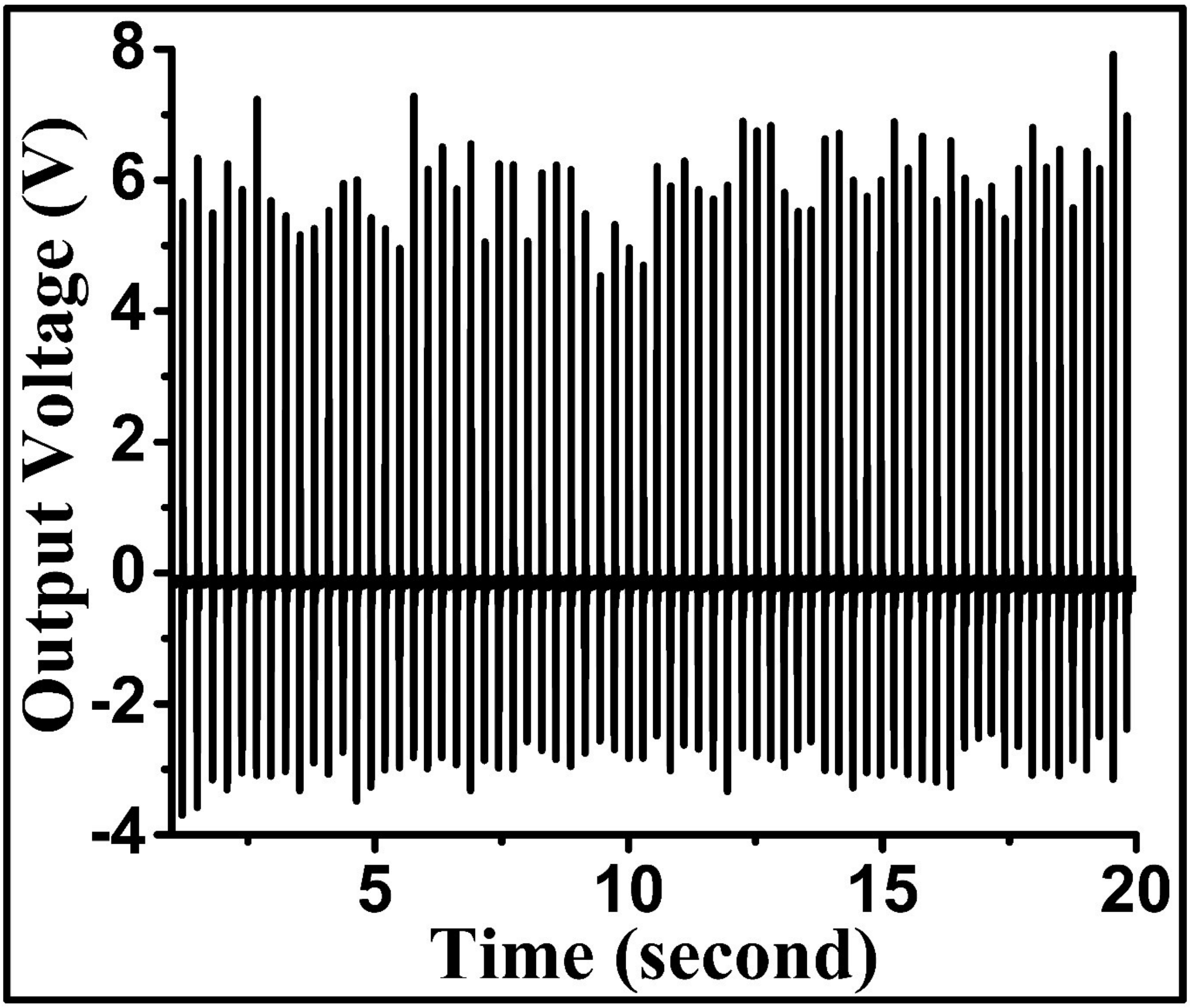

Figure S2: Open circuit output Voltage of pure PVDF thin film based piezoelectric nanogenerator.

Power density calculation:

The output performance i.e. power density has been computed from the following equation,

$$Power\ density = \frac{Power\ (IV)}{operative\ volume\ of\ PENG}$$

For CNF thin film,

Isc= 0.12 µA, V_{oc}= 22 V

Power density= 97 µW/cm^3

Power density for PVDF/CNF thin film = 6600 µW/cm^3, where I_{sc}=1.913 µA and V_{oc}= 49 V.

Table S2: Comparison of output performance and power density of the fabricated PENG with the previously reported bio based PENGs.

Bio-materials based PENG	**Force**	**Open-circuit (Voc) voltage**	**Short-circuit (Isc) current**	**Power Density**
Microfibre–nanowire hybrid structure for energy scavenging[2]	Not supplied	3 mV	4 nA	76 mW/m^2
Flexible ZnO–Cellulose Nanocomposite for Multisource Energy Conversion[3]	Bath sonication	0.08 V	1.25 µA	0.12 µW/cm^2
Virus-based piezoelectric energy generation[4]	34 N	0.4 V	6 nA	Not supplied
Flexible piezoelectric nanogenerators based on a fiber/ZnO nanowires/paper hybrid structure for energy harvesting[5]	Not supplied	17 mV	0.40-0.52 nA	0.0002 µW/cm^2
Bioinspired piezoelectric nanogenerators based on vertically aligned phage nanopillars[6]	30 N	140.8 mV	9.5 nA	0.3 nW
Novel Piezoelectric Paper-Based Flexible Nanogenerators Composed of $BaTiO_3$ Nanoparticles and Bacterial Cellulose[7]	0.1 MPa	14 V	1.14 µA	0.64 µW cm^{-2}

Enhanced electromechanical behavior of cellulose film by zinc oxide nanocoating and its vibration energy harvesting[8]	14 N	500 mV	1.5 μA	0.36 μW/cm^2
High-performance bio-piezoelectric nanogenerator made with fish scale[9]	0.17 MPa	4 V	1.5 μA	
Efficient natural piezoelectric nanogenerator: Electricity generation from fish swim bladder[10]	~1.4MPa	10 V	51 nA	0.23 μW/cm^2
Bio-assembled, piezoelectric prawn shell made self-powered wearable sensor for non-invasive physiological signal monitoring[11]	5.2 kPa	4 V	1 nA	0.041 μW/cm^2
Bio-waste onion skin as an innovative nature-driven piezoelectric material with high energy conversion efficiency[12]	34 kPa	18 V	166 nA	1.7 μW/cm^2
Present work	27.5 N	49 V	1.9 μA	6600 μW/cm^3

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