Monitoring Report

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Project Title : Development of electroactive polymer nanocomposites based self-charged photo-power cells: A novel and simple approach towards clean energy generation and storage

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Total Sanctioned 19,49,555 (INR) [Rec.: 12,52,057 + Non-Rec.: 6,97,498]

Total Released Amount 18,82,976 (INR)

Utilized Amount : 1,92,200 (INR)

Start Date of the 18 Jan, 2020

Duration : 41 months

End Date of the 17 Jun, 2023

Extenstion Details

Approved on	Duration
28-Feb-2023	5 Months

Approved Objectives :

Development of electroactive polymers (like PVDF and its copolymers, Poly-L-lactic acid (PLLA) etc.) based nanocomposites via incorporation of dopants (CTAB, Ag, MoS2 etc) via solution casting and in situ process. Synthesis of solar active materials like SiO2, Bi2S3, MoS2 etc.) and also some newest perovskite structures (CH3NH3PbI3, CH3NH3PbBr3 etc.). In-situ integration of the developed polymer nanocomposites and solar active materials in a single cell as self-charged photo-power units. Furthermore, low-cost devices will be designed for the large scale production to facilitate huge demands in energy sectors. Lighting of LEDs and driving of some electronic gadgets using the developed devices will also be demonstrated for practical utility purposes.

Summary of Progress :

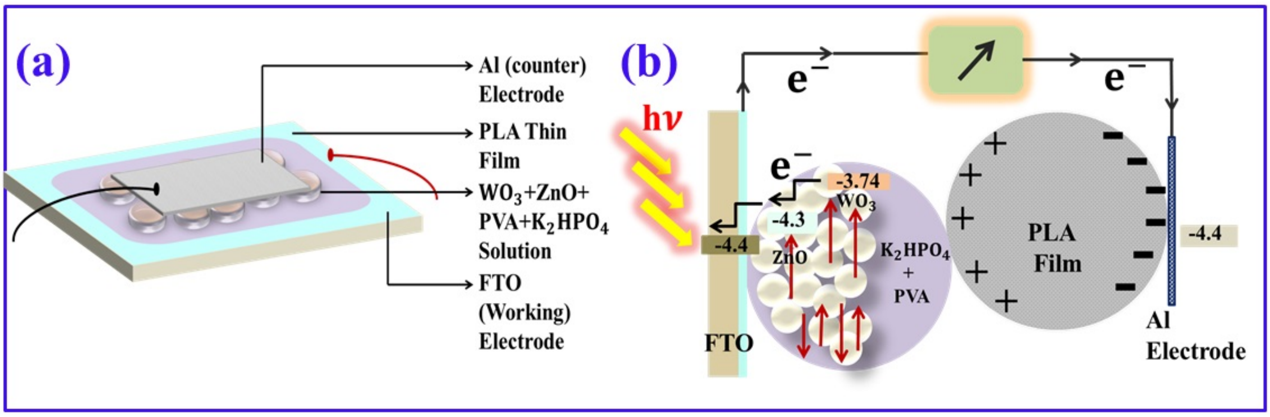
Due to Covid-19 pandemic last two years were very difficult to work on my project as the institute was closed. Now the project work is running very successfully and we believe we must achieved our proposed goals. During this small effective time span, we have developed some good number of proposed samples and achieved some very interesting and outstanding results which sounds good for our proposed applications in the field of clean energy fields. First of all, we have developed bio-polymer poly(lactic acid) thin film based K-ion associated photo-rechargeable power cell. After investigation of the charging and discharging phenomenon the maximum open circuit voltage is obtained ~1 V under light intensity ~110 mW /cm2. Then the device is discharged with a constant discharge current density ~ 0.5 mA/cm2. The sturdiness of K-ion photo-power cell is also verified by observing the charging-discharging data repeatedly for 200 cycles. It shows ~ 16 F/m2 storage capacity with energy density and power density ~2.22 mWhr/m2 and ~5 W/m2 respectively. A commercially available LED also driven by our fabricated power cell for showing its practical application possibilities. The performance of our power cell is very promising. And the work has already published in a reputed international journal "Journal of Materials Science: Materials in Electronics". Further we have fabricate of CTAB induced electroactive crystal rich and high dielectric flexible poly(vinylidene fluoride) (PVDF) thin films. Maximum dielectric constant is found to be ~ 400. Now the work on the photo-rechargeable photo-power cell is going on. We have also synthesized Bi2S3 nanowires and doped into the PVDF matrix. The Bi2S3/PVDF nanocomposites also shows outstanding crystal formation and dielectric value. Highest dielectric value is measured ~ 54. Further we have prepared photo-power cell with this sample using MnO2 nanoparticles as solar part. We see some excellent output voltage ~ 1.2 V. Now our work is going on standardized the device performances and stability. Apart from this we have developed Kaolinite/PVDF and ZrO2/PVDF nanocomposite films and get some outstanding results on piezoelectric performances. And we have developed two very effective piezoelectric nanogenerators by these two samples and achieved very outstanding voltage generation under mechanical impartation of force on developed devices. And these two works which also published in two reputed international journals "Applied Physics Letters" and "Phys. Status Solidi A". We are also developing photo-power cell using these two developed samples. Finally other proposed samples will be developed in next few months and I assure to complete the project very successfully.

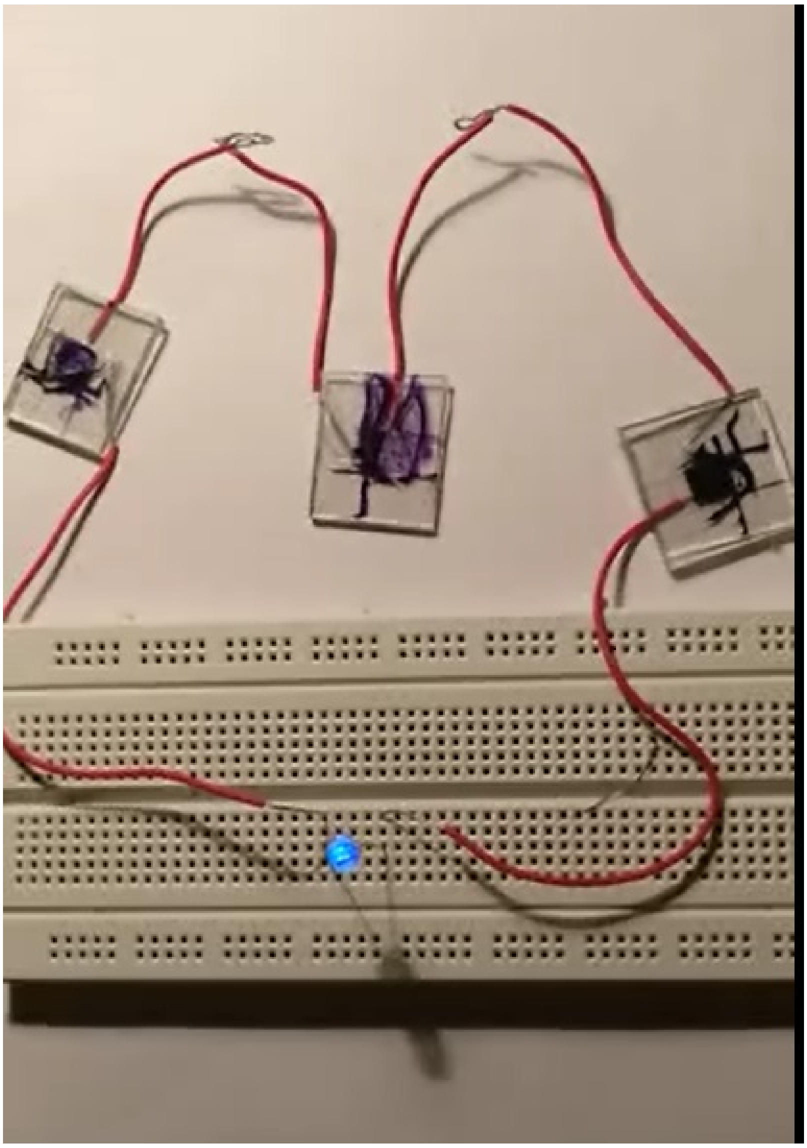
Ph.D. Produced/Likely to be	2
Technical Personnel Trained :	0
Physical Progress against approved	0 %

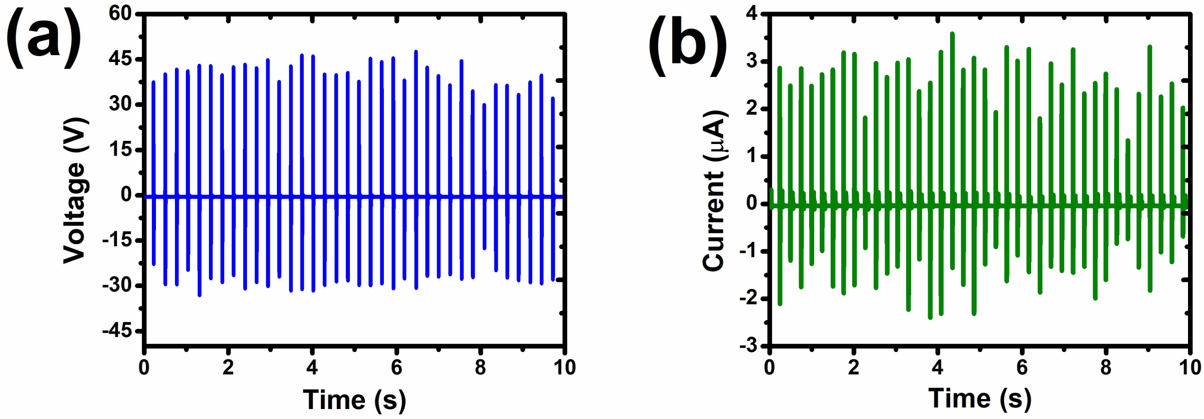
Progress Details

Research Achievement

1. Bio-polymer poly(lactic acid) thin film-based K-ion associated photo-rechargeable power cell: (a). We have developed a very simple, low-cost and bio-compatible photo induced K-ion based power cell by using an aqueous electrolyte solution of PVA-WO3-ZnO-K2HPO4 and Bio-polymer (poly(lactic acid)) film. (Figure 1) (b). The power cell shows maximum open circuit voltage is obtained ~1 V under light intensity ~110 mW /cm2. (Figure 2a & b) (c). The sturdiness of K-ion photo-power cell is also verified by observing the charging-discharging data repeatedly for 200 cycles (Figure 2d). It shows ~ 16 F/m2 storage capacity with energy density and power density ~2.22 mWhr/m2 and ~5 W/m2 respectively (Figure 2c). (d). A commercially available LED also driven by our fabricated power cell for showing its practical application possibilities (Figure 3). 2. Development of CTAB-PVDF composite: We have fabricate of CTAB induced electroactive crystal rich and high dielectric flexible poly(vinylidene fluoride) (PVDF) thin films. Maximum dielectric constant is found to be ~ 400. (Figure 4) 3. Development of Bi2S3-PVDF Nanocomposite: (a). We have also synthesized Bi2S3 nanowires and doped into the PVDF matrix. The Bi2S3/PVDF nanocomposites also shows outstanding crystal formation and dielectric value. (b). Highest dielectric value is measured ~ 54. 4. PVDF-Kaolinite Composite and Piezoelectric Nanogenerator: (a). Kaolinite clay doped PVDF film with high dielectric constant has been prepared. Now we are in process to develop another photo-power cell. (b). we have fabricate piezoelectric nanogenerator using PVDF-Kaolinite composite film. The device generates output voltages (peak to peak) of ~1.4 V, 325 mV, and 230mV under human body vibration, air flow, and water wave, respectively. (c.) Moreover, under gentle finger impartation (force, ~12.5 N), the device can generate an open circuit voltage of ~ 45V and a short circuit current of ~2.9 l A. The power density is calculated to be 43.5 mW/cm3. (Figure 5) (b) Several LEDs are lightened using our device as an energy supplier.


(a)
Al (counter) Electrode
PLA Thin Film
WO3+ZnO+ PVA+K2HPO4 Solution
FTO (Working) Electrode
(b)
hν
e−
e−
e−
-3.74
WO3
-4.3
ZnO
-4.4
K2HPO4 + PVA
PLA Film
-4.4
FTO
Al Electrode




(a)
Voltage (V)
Time (s)
60
45
30
15
0
-15
-30
-45
0
2
4
6
8
10
(b)
Current (μA)
Time (s)
4
3
2
1
0
-1
-2
-3
0
2
4
6
8
10

Methodology

1. Synthesis of the samples: The samples are synthesized through simplest solution casting method as proposed in the project proposal. The polymer and dopant are mixed together in presence of solvents and the dried in a hot air oven to evaporate the solvent. And finally after drying we get the polymers (PVDF or PLLA) based samples. One example of PLA film synthesis is like the following: Initially, the plain PLA film is prepared by as a dielectric medium to develop the KPPC. To synthesize the PLA film, we have used dimethylformamide (DMF) as a solvent. In the 5 ml solution of DMF, 4% PLA (200 mg) is added and then the mixture is stirred very well for 6 hours. Then this solution is casted in a small petri dish which is placed in a dust-free hot air oven for overnight at 80 to obtain the thin PLA film of thickness ~ 20 m. 2. Synthesis of poly(lactic acid) thin film-based K-ion associated photo-rechargeable power cell: Previously prepared pure PLA films are used to integrate the unique photo-rechargeable system KPPC as an insulating medium. The photo-sensitive part of the device is processed by mixing 40 mg/ml PVA, 10 mg/ml ZnO, 10 mg/ml WO3, and 20 mg/ml K2HPO4 in water with continuous stirring for overnight at 60. After that the texture of the combined photo-active electrolyte solution will be sticky and then a very small amount of this concentrated gel-like solution will be poured on the acting electrode FTO coated glass on which the counter electrode aluminium (Al) attached with insulating PLA thin film is pasted. The effective area of the device is (0.2 cm x 0.2 cm) i.e. 0.04 cm2. To characterize the device performance two wires are joined in between the electrodes. 3. Characterization of the samples and devices: The morphology and microstructures of the samples have been studied by a field emission electron microscope (FESEM) (INSPECT F50, Netherland). Further, the formation and investigation of different polymorphs of PVDF or PLA and thermal behaviour of the samples have been done utilizing X-ray diffractometer (Model-D8, Bruker AXS Inc, Madison, WI), Fourier transform infrared spectrophotometer (FTIR-8400S, Shimadzu), differential scanning calorimeter (DSC-60, Shimadzu (Asia Pacific) Pte. Ltd., Singapore) respectively. Dielectric measurements are carried out recording the capacitance (C) and tangent loss (tan) data of the sample a digital LCR meter (Agilent, E4980A). 4. Measurements of Device performances: The output

characteristics of self-charged photo-power cells are measured by an electrometer (Keysight- B2985A) and digital multi-meter (Agilent U1252A) and cyclic voltammetry technique (PGSTAT 101, Auto Lab). As due to the Covid-19 pandemic instruments purchase are delayed we have measured CV data from Jadavpur University. And now our instrument purchase is going on and we expect the purchase of instruments will be completed within few months.

Work to be done under the project

TThe following work to be done in upcoming time 1. synthesis and characterization of MoS2 and Ag doped PVDF samples and some solar active materials SiO2, CH3NH3PbI3 etc. for using in photo-power cell fabrication. 2. Fabrication of some more photo-chargeable devices using CTAB/PVDF, MoS2/PVDF nanocomposites as proposed in the project proposal. 3. And finally some practical demonstration of remaining proposed devices by lighting of LEDs and driving of some electronic gadgets for practical utility purposes. 4. As I reported to SERB earlier due to Covid-19 the instruments purchase have been delayed. Now the purchase process has been started and I assure that the Instruments must be completed purchased within few months. Also as the appointed JRF was resigned due to his personal reasons in the period of Covid-19 pandemic and the College was closed that time, so we can not appointed new JRF at that time. Now we are also in process of appointing new Fellow and the new JRF would be appointed within 3-4 weeks.

Suggestions for commercial application

The practical utilization of our developed devices are affirmed by driving a blue LED using as power source. Thus, we believe that our study provides cost-effective and environment friendly prototype devices for the development of next generation superior renewable energy harvester from mechanical energy, biomedical kits and self-charged photon induced self-charged power bank for daily life utilizations. The developed photo-power cells may be commercialized in large scale by proper design and engineering to facilitate huge demands in energy sectors. We hope, It is possible to construct a sustainable and benign nation or world by making sensible clean energy choices.

Any Other Scientific Information

As PVDF and PLLA are very good electroactive material so the piezoelectricity of our developed materials are very promising for piezoelectric field. Thus, our developed materials are very powerful candidates for piezoelectric nanogenerator designed. We have already developed piezoelectric nanogenerator using PVDF/kaolinite composite which shows outstanding output voltage generation under gentle mechanical energy impartation on the device. So, Piezoelectric nanogenerators will also developed by the developed materials as a side work. And I am happy to inform that one of my Ph,D. scholar has worked on this piezoelectric nanogenerator field. And this side work is also carried out under the assistance of this project.

Scope/Status of Prototype/Product/Technology :

Technology Developed :

Prototype/Product Prepared

Technology Commercialized :

Is Technology Socially

Technology Transferred :

Contribution of Industry :

Technical Contribution :

Financial Contribution :

List of Publications (only from SCI indexed journals) :

Title of the Paper	List of Authors	Journal Details	Month &	Volume	Status	DOI No	Impact Factor
Bio-polymer poly (lactic acid) thin film-based K-ion associated photo-rechargeable power cell	Sanoar Molla, Farha Khatun, and Pradip Thakur* (PI)	Journal of Materials Science: Materials in Electronics (International)	Feb-2024	(1-7)	Published	10.1007/s10854-021-07385-1	2.478
Sustainable and superior polymeric piezoelectric nanogenerator for sensing human body vibration, air flow, and water wave	Ujjwal Rajak, Farha Khatun, Prosenjit Biswas, and Pradip Thakur* (PI)	APPLIED PHYSICS LETTERS (International)	Feb-2021	118 (053502-4)	Published	10.1063/5.0034879	3.791
Self-Polarized ZrO2/Poly (vinylidene fluoride-cohexafluoropropylene) Nanocomposite-Based Piezoelectric Nanogenerator and Single-Electrode Triboelectric Nanogenerator for Sustainable Energy Harvesting from Human Movements	Md. Minarul Saikh, Nur Amin Hoque,* Prosenjit Biswas, Wahida Rahman, Namrata Das, Sukhen Das,* and Pradip Thakur* (PI)	PHYSICA STATUS SOLIDI A-APPLICATIONS AND MATERIALS SCIENCE (International)	May-2021	218 (2000695)	Published	10.1002/pssa.202000695	1.981
Electroactive CTAB/PVDF composite film based photorechargeable hybrid power cell for clean energy generation and storage	Sanoar Molla, Farha Khatun, Ujjwal Rajak, Biswajoy Bagchi, Sukhen Das and Pradip Thakur* (PI)	Scientific Reports (International)	Feb-2024	12 (22350)	Published	https://doi.org/10.1038/s41598-022-26865-w	4.996

Equipment Details :

Equipment Name	Cost (INR)	Procured	Make & Model	Utilization %	Amount Spent	Date of Procuremen
Laptop	1,18,000	No		0	0	
Handheld Digital Multimeter	82,600	No		50	0	
Cyclic Voltammetry	4,99,376	No		70	0	