# Abstract

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**Title:** Fabrication of Flexible Hybrid Energy Harvester for Powering Low-Powered Devices

**Submitted by:** Sri Sourav Maity

The rapid surge in portable electronic devices, wearable multimedia gadgets, and various medical apparatus, has created a flourishing demand for energy generation technologies that are slim, lightweight, portable, and flexible. Here we have developed high-performance piezoelectric assisted triboelectric hybrid energy harvesters (HEH) with specific attributes, including increased output properties in terms of output voltage and current, flexibility, and versatile functionality. Innovative applications for HEH technology that can offer cost-effective, safe, convenient solutions to address energy challenges, specific sensing, and smart applications were explored. As functional layers for HEH devices PVDF and PDMS were utilized due to their high negative surface charge density. To induce higher piezoelectricity inside the polymer matrix, ceramic inclusion strategy was implemented. At first, ceramic Barium Titanate ($BaTiO_3$)-based filler material, the strontium-doped $BaTiO_3$ was characterized. Optimized composition ($Ba_{0.6}Sr_{0.4}TiO_3$) in terms of high dielectric permittivity, low loss tangent, and low leakage current was used as a filler in PVDF for piezoelectric energy harvesting and mechanosensing. The limitation posed by BST40's centrosymmetric crystal structure was addressed by introducing $(Ba_{0.85}Ca_{0.15})(Ti_{0.90}Hf_{0.10})O_3$ (BCHT) particles. These BCHT particles had a notably high piezoelectric charge coefficient of 333 pC/N and were incorporated as fillers to create flexible BCHT/PVDF composites. The BCHT/PVDF functional layer was utilized to efficiently fabricate a piezo-tribo hybrid energy harvester for biomechanical movement sensing. It was also well suited in applications like smart switches for controlling smart home appliances and in smart parking sensors which can efficiently differentiate any "vacant" or "filled" state in a parking slot. The idea of piezoelectric-assisted triboelectric hybrid energy harvester was again implemented in another HEH device where lead-free morphotropic phase boundary composition $BaTi_{0.89}Sn_{0.11}O_3$ (BTS) was used as filler material. Due to four phase coexistence, BTS showed

piezoelectric charge coefficient ($d_{33}$) of ~ 412 pC/N. BTS loaded PDMS consisted hybrid energy harvester device was utilized for biomechanical energy harvesting, writing pad sensing, and as a power source for wireless power transmission. Hence, this thesis is set to introduce a groundbreaking dimension to the realm of piezo-tribo hybrid energy harvesting. The proposed multifunctional solutions incorporate biomechanical movement sensing, writing pattern detection, leveraging the device as a power source for wireless power transmission, and integrating the fabricated device into wireless smart home and smart parking sensor applications. This contribution is anticipated to significantly impact self-powered electronics, robotics, real-time healthcare monitoring, and advancements in artificial intelligence technologies.

Sourav Maity
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Signature of the candidate with the date

Dr. Shrabanee Sen
Principal Scientist
Functional Materials and Devices Division
CSIR-Central Glass & Ceramic Research Institute
Kolkata - 700 032

Shrabanee Sen.
12/12/23.

Signature of the supervisor with the date and seal