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In situ synthesized SrF_2/polyvinylidene fluoride nanocomposite film based photo-power cell with imperious performance and stability

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ABSTRACT

A self-charged photo-power cell, named as light sensitive energy storage device has been developed in a simplified way for application as a portable photo-charged power bank. The Photo-Power Cell is fabricated by assembling a photoelectrode (FTO) involving a dye-sensitized solar part as photo-electrons generator, combined with the electroactive and high dielectric SrF_2-PVDFNCfilm as storage unit. Electroactive β phase crystallization and large interfacial polarization between the SrF_2 NPs and poly (vinylidene fluoride) matrix result in high dielectric value ~ 5141 of the nanocomposite film. The device is charged by up to 1.48 V under visible light illumination (~110 mW/cm^2) with a constant discharge current density ~1.64 mA/cm^2. The photogenerated charge and power density of the photo-power cell are found to be ~24.3 W/m^2 and 2400 C/m^2 respectively. Our photo-power cell shows maximum areal specific capacitance ~1600 F/m^2 with 92% energy storage efficiency. The achieved overall efficiency (%) is found ~ 2.57. The charging-discharging stability is also tested for a long time span of 12 weeks. The efficacy and durability of our fabricated device has also been demonstrated by glowing up 24 commercially available blue light emitting diodes for 10 days with same intensity by charging one time under light.

1. Introduction

A major concern for sustained development of our modern society is renewable energy creation and reservation [1]. Replacement of conventional fuel sources like coal, petrol, gas etc. is very important for the overall improvement of global economy due to the increased ecological impairment and fast exhaustion of fuel resources [2–5].Under this circumstances, the researchers worldwide are looking for a simple, cost-effective and scalable mechanism for clean and reliable energy extraction from natural energy resources like wind, sunlight, water, biomass energies etc. with simultaneous storage of that energy in the same unit [6–8].

Recently, fabrication of piezoelectric nanogenerators, solar cells, metal O_2 batteries have proved very promising for harnessing electrical energy from clean and renewable sources like living systems, mechanical, solar and chemical respectively [9,10]. More-recently hybrid devices capable of both electrical energy generation and storage with superior power density and stability have been reported with success [11–13]. In such hybrid devices, an extra storage unit is not necessary, which makes them not only more cost-effective but also promising in the field of portable electronics.

Development of nanocomposite materials based photo-power units have been gaining interest among researchers for example, a poly (vinylidene fluoride) (PVDF)/ZnO nanocomposites (NCs) based photo-power unit was proposed by Zhang et al. (energy density $E = 1.4$ mW h kg^{-1}) [14]. Later, perovskite structure and dye-sensitized solar cell based few photovoltaic cells with storage ability was reported [15–17]. Wee et al. suggested an organic photovoltaic integrated with carbon nanotube based supercapacitor with low power loss [18]. Power density, storage stability and durability of an integrated photo-power unit are the necessary factors for practical utilization. Proper designing and integration of dye-sensitized solar energy conversion part and high dielectric polymeric film into a single unit has potential to surpass the critical deficiency associated with traditional power utilization [14].Our

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previous attempts of designing such type of two electrode photo-power cells with high dielectric PVDF composites demonstrated both energy conversion as well as storage in one unit [19,20].

Electroactive and high dielectric polymer NCs have been progressively appreciated by the scientists due to their versatile utilization in the domain of piezoelectric nanogenerators, capacitors, thin film transistors, grid levelling, rail runs, non-volatile memories, sensors, actuators and also in biomedical fields [21–24].Though, extensive researches have been carried out to design PVDF based piezoelectric nanogenerators [25,26], but the utilization of high dielectric PVDF or PVDF based NCs as energy storage unit in hybrid photo-power banks are very limited to the best of our knowledge.

PVDF ($[-CH_2-CF_2-]_n$) and its copolymers are very promising electroactive semicrystalline thermoplastic polymer with superior piezoelectric, pyroelectric, ferroelectric properties, thermal stability and chemical resistance. Five crystalline polymorphic phases α, β, γ, δ *and* ε have been recognized in PVDF amongst which β phase is the most electroactive [27–30]. Existence of matrix of the orthorhombic unit cells and *all trans*(TTTT) planar zigzag chain conformation in electroactive β polymorph leads to optimum dipolar moment per unit cell and consequent highest piezoelectric, ferroelectric, pyroelectric and dielectric properties in comparison to the other phases of PVDF [27,28].

Herein, we have designed a cost-effective, simple, highly efficient and durable two electrode light sensitive energy storage device (LSESD) by using *in situ* synthesized SrF_2nanoparticles (NPs) incorporated giant dielectric PVDF thin film (named as PSR) associated with an organic dye phenosafranine-polyvinyl pyrrolidone (PSF-PVP) film and zinc oxide (ZnO) and titanium dioxide (TiO_2) NPs as a solar part (Fig. 1). This solar component and the high dielectric PSR film forms the key part of solar energy conversion and photo-generated electrical energy storage respectively.

2. Experimental

2.1. Materials

The materials that are used in our present work are poly (vinylidenefluoride) (PVDF) pellets (Aldrich, Germany. M_w: 275,000 GPC, M_n : 71,000), Strontium nitrate (CDH, India), Ammonium fluoride (Merck, India), dimethyl sulfoxide, (DMSO) (Merck, India), polyvinyl pyrrolidone (PVP) (Loba Chemie), ZnO and TiO_2 NPs, Ortho-phosphoric acid (H_3PO_4) (Merck, India), Phenosafranine (PSF) (Sigma Aldrich, Germany), FTO coated glass (Sigma Aldrich, Germany).

2.2. In situ synthesis of SrF_2/PVDF nanocomposite films

Initially, a solution of PVDF (4%) in DMSO was prepared by

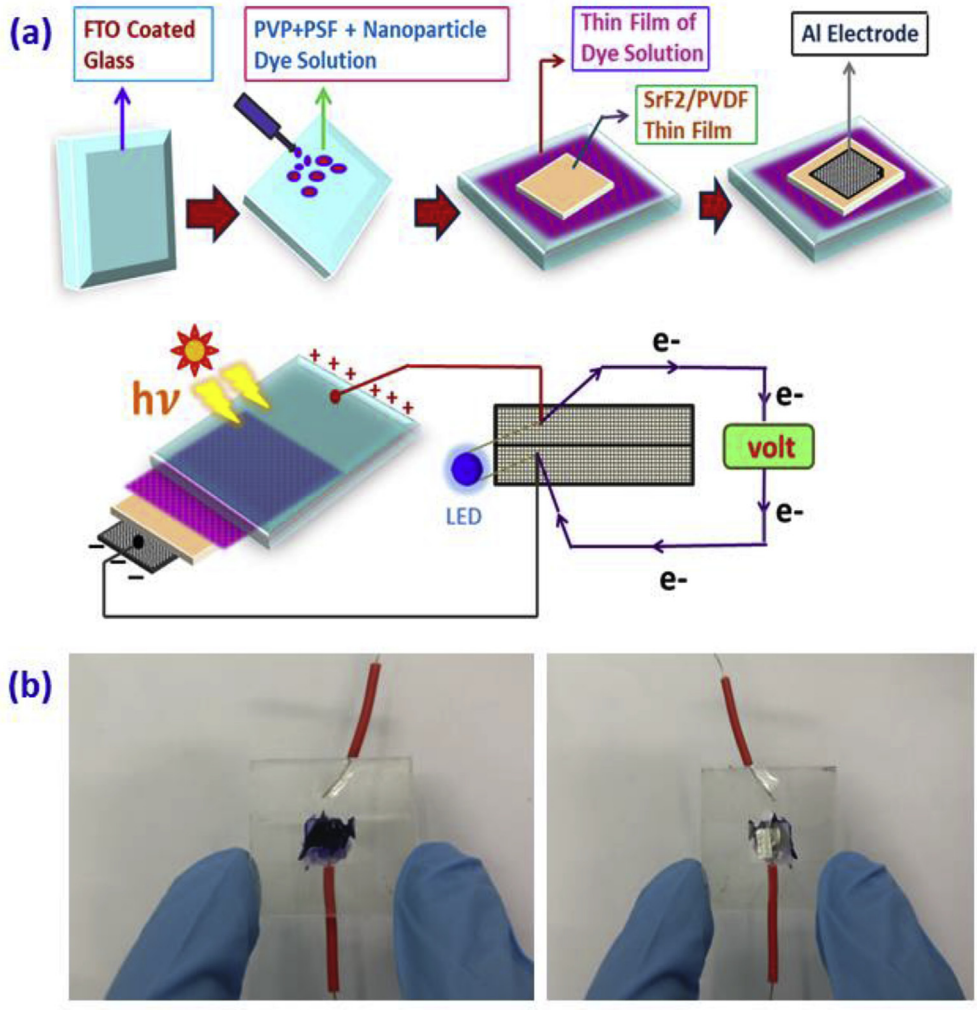

Fig. 1. (a) Schematic diagram of the fabrication process of the LSESD. (b) Digital image of the LSESD.