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Preparation of MoS_2 Nanosheets and PVDF Nanofiber

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Short Research Article

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ABSTRACT

Recently, 2D transition metal dichalcogenides (TMDCs) (e.g., MoS_2, WS_2, $MoSe_2$, WSe_2, $MoTe_2$, etc.) have been attracting a wide range for research interest due to their favorable mechanical, chemical, electrical and optical properties. Among them, MoS_2 have been widely used as a functional material in diverse fields such as lubrication, electronic transistors, batteries, photovoltaics, and catalysis. Recently it has been also observed that MoS_2 nanostructure is possessing piezoelectric functionality. On the other side PVDF nanofiber based nanogenerator is a good flexible device for scavenging mechanical energy from environment. Nanofiber can be generated by using electrospinning process. In this article a brief idea about PVDF nanofiber preparation is the key focus of this paper. Material and structural analyses on fabricated nanofibers using tools such as XRD (X-ray diffraction), FTIR (Fourier transform infrared), FE – SEM (Field emission scanning electron microscopy) toward the fundamental characterizations of piezoelectric nanofibers are also described. MoS_2 can be incorporate in PVDF for getting better performance of nanogenerator. Here MoS_2 nanosheets preparation and characterization has been done. Summarize the report by the application of nanofiber based nanogenerator as energy scavenging applications.

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Keywords: Two dimensional; hydrothermal synthesis; MoS_2; nanosheets; ultrasonication method; PVDF; nanogenerator; energy harvesting; electrospinning process.

1. INTRODUCTION

Nowadays silicon based electronic devices are becoming miniaturized for higher packing density, faster circuit speed, and lower power dissipation, though they have some limitations due to physical limit for their operation. Instead of using silicon as material, 2D transition metal dichalcogenides like molybdenum disulphide (MoS_2), tungsten disulfide (WS_2) are essential due to their wide range of electronic, optical, mechanical, chemical and thermal properties. Graphene [1,2] is also suitable for their unique properties but lack of band gap and, consequently, inability to switch off field-effect transistors (FETs) [3] makes it unsuitable for device application. Among them are insulating boron nitride [4] and semiconducting MoS_2 [5] and tungsten disulfide (WS_2) [6,7], which are gaining increasing attention as promising channel materials and gate insulators for FETs. Molybdenum disulfide (MoS_2) and related materials, such as tungsten disulfide, as well as Mo and W diselenides, are important members of the layered transition-metal dichalcogenides (TMDs) [8] and have attracted a good deal of attention recently because of their useful electronic and mechanical properties [9,10]. These materials have band gaps in the visible or near-infrared region of the electromagnetic spectrum and reportedly have potential applications as building blocks in even solar cells. Furthermore, the layered crystal structure of these materials allows tuning of their electronic properties by either doping between weakly bonded layers or fabricating thin nanostructured materials. Among TMDs, 2D MoS_2 offers a great promise for device applications. Excellent gate control, saturation, scalability, high current capability, and very low noise are among the expected salient features. Single-layer MoS_2 is a semiconductor with wide direct band gap, exhibits good electrical and transport properties, and is chemically and thermally stable, transparent, flexible, and relatively inexpensive, which all together make this material an excellent candidate for a variety of electronic and optoelectronic applications. The electronic structure of the MoS_2 single layers differs drastically from that of the bulk material. Bulk MoS_2 has an indirect band gap of 1.2 eV, a conduction band minimum (CBM) between the Γ and K points, and a valence band maximum (VBM) at the Γ point [11]. On the other hand, MoS_2 in the single-layer form exhibits a direct band gap of 1.8–1.9 eV with CBM and VBM at the K-point as a result of quantum confinement and change in the symmetry. The band gap of MoS_2 can be tuned from 1.2 eV (bulk and indirect) up to 1.9 eV (monolayer and direct) by varying the number of monolayers [12], alloying (e.g., $Mo_xW_{1-x}S_2$) [13], or forming heterojunctions such as MoS_2 /WS_2. Because the monolayer MoS_2 has a sizeable band gap, MoS_2 -based FETs can be turned off [6]. Logic circuits and amplifiers based on monolayer MoS_2 have also been demonstrated, as well as good output current saturation and high currents. There are many comprehensive reviews on transition-metal dichalcogenides [14]. PVDF nanofiber based nanogenerator [15-23], convert mechanical energy to electrical energy have been extensively studied in the application of driving low powered and self powered devices. PVDF is extensively used in a variety of electro-optical, electromechanical and biomedical application. It has four crystalline phase (α-, β-, γ-, and δ-phase). Among them alpha is non polar and other three (β-, γ-, and δ-phase) are polar phase. Beta phase is most important due to its high piezo-, pyro-, ferro-electric properties. Several methods have been discovered to induce β-phase in PVDF metal nanoparticle doping, mechanical stretching, 2D material (metal sulphide) doping etc. Mechanical stretching can generate undesired structural deformation which is not suitable for nanogenerator application. On the other hand electrospinning is one step process to induce β-phase in PVDF. Nanofiber is formed through this process.

2. EXPERIMENTAL

Here MoS_2 nanosheets have been prepared by two methods.

2.1 Preparation of MoS_2 Nanosheets

2.1.1 Ultrasonication method

The MoS_2 powder and N,N-dimethylformamide (DMF) used throughout these experiments were purchased from Sigma Aldrich. The initial MoS_2 concentration experiments were performed by adding the powder to 20 ml of DMF in a 100 ml capacity, flat bottomed beaker. These samples were sonicated continuously for 60 minutes. The beaker was connected to a cooling system that allowed for cold water (5°C) to flow around the dispersion during sonication. They were 5 then centrifuged.

2.1.2 Hydrothermal method

All of the chemical reagents were of analytic purity and used directly without further purification. The ultrathin MoS_2 nanosheets were synthesized by a one-step hydrothermal reaction using hexaammonium heptamolybdate tetrahydrate and thiourea as starting materials. In a typical synthesis, 1.30 g of hexaammonium heptamolybdate tetrahydrate and 2.36 g of thiourea were dissolved in 36 ml deionized water under vigorous stirring for 30 min. To form a homogeneous solution. The solution was then transferred into a 50 ml Teflon-lined stainless steel autoclave and sealed tightly, heated at 170°C for 24 h and then naturally cooled down to room temperature. Black precipitates were collected by centrifugation and washed with distilled water and absolute ethanol for several times, and finally dried in vacuum at 60°C for 24 h.

2.2 PVDF Nanofiber Generation

For nanofiber generation electrospinning is used here. Electrospinning is a versatile technique for producing different fibrous structures out of a wide range of biocompatible and biodegradable materials. First 12wt% PVDF solution is prepared. For this DMF (dimethyl formamide) is acting as solvent. Acetone is also used with DMF in 6:4 ratios. Then this sample was loaded in syringe for electro-spinning. In Figs. 1 and 2, it has shown the basic electrospinning machine and electrospinning process.

3. RESULTS

3.1 Characterization of MoS_2

FE – SEM image has been taken of the MoS_2 nanosheets (casted on glass slide) which is prepared by ultrasonification method. From this Figure MoS_2 nanosheets are visible.

From the FE – SEM image it is observed that nanosheets has been formed by both ultrasonication and hydrothermal method. Here the quality of MoS_2 nanosheets prepared by hydrothermal method is better than ultrasonication method.

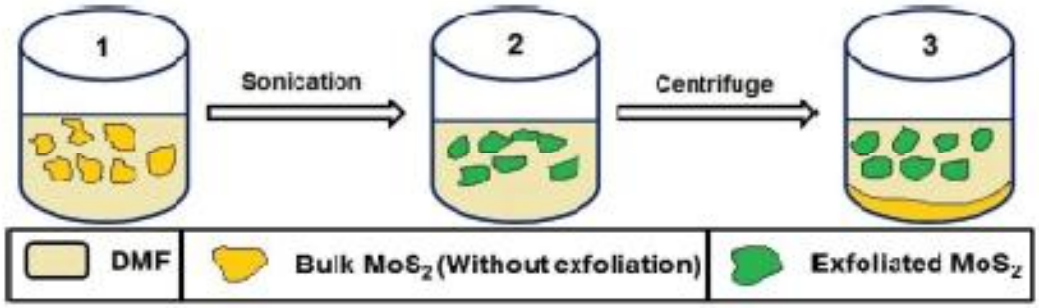

Fig. 1. Synthesis procedure of MoS_2 nanosheets

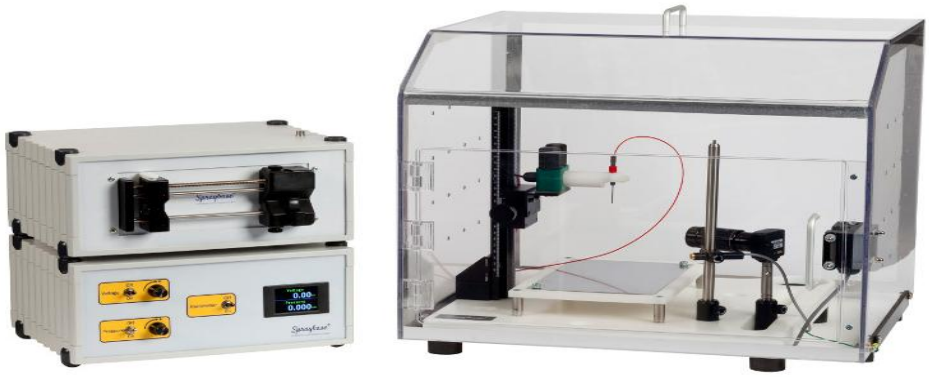

Fig. 2. Basic electrospinning machine setup

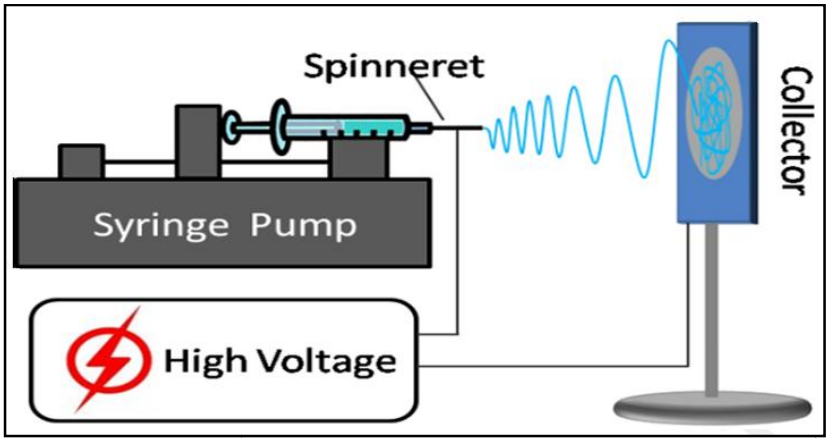

Fig. 3. Electrospinning process

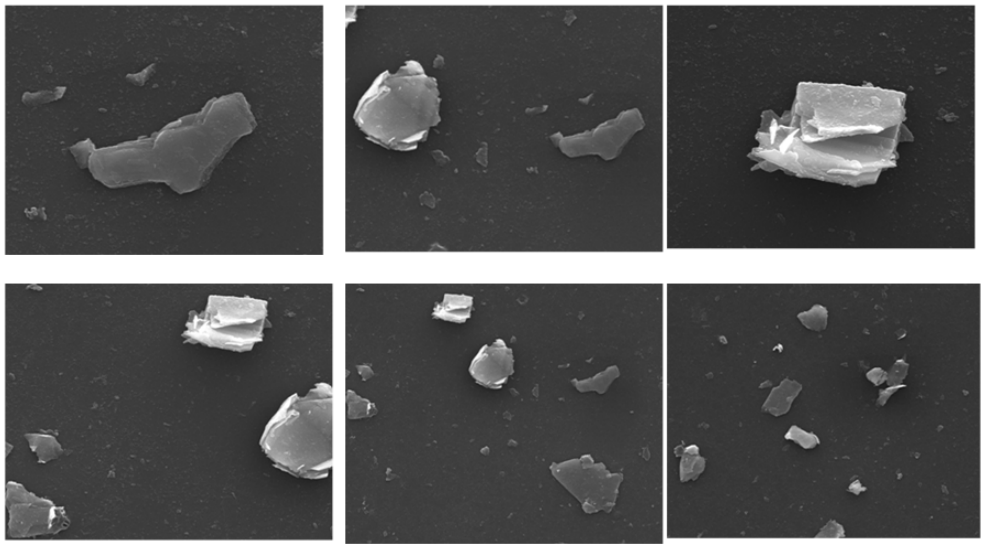

Fig. 4. FE – SEM image of MoS2 nanosheets (casted on glass slide) prepared by ultrasonication method

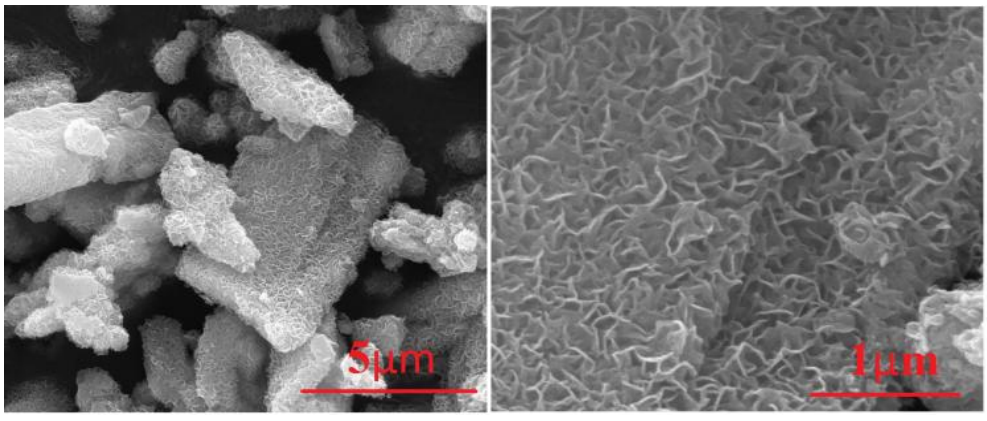

Fig. 5. FE – SEM image of MoS2 powder prepared by hydrothermal method

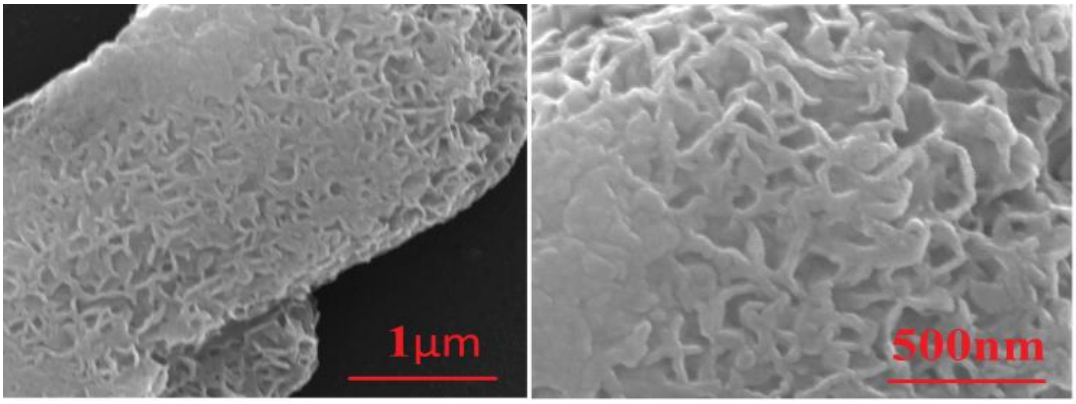

Fig. 6. FE – SEM image of MoS2 nanosheets (casted on glass) prepared by hydrothermal method

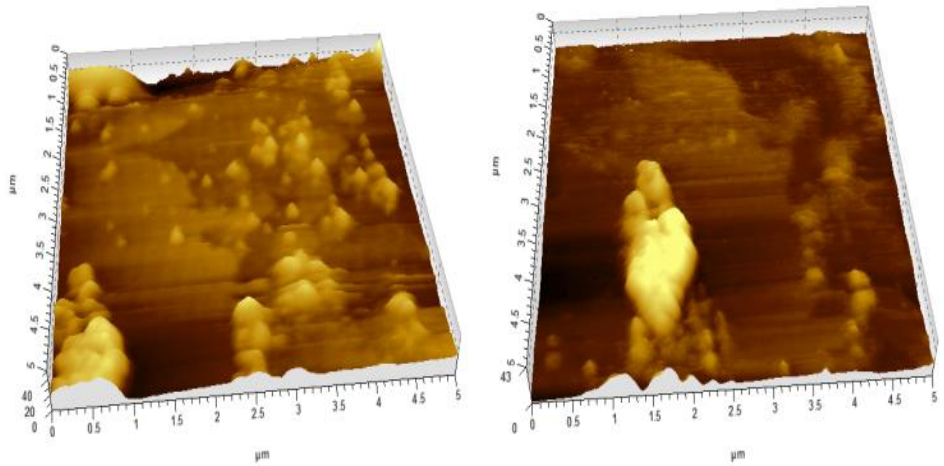

Fig. 7. AFM images of a single-layer MoS2 film: 5 µm × 5 µm area

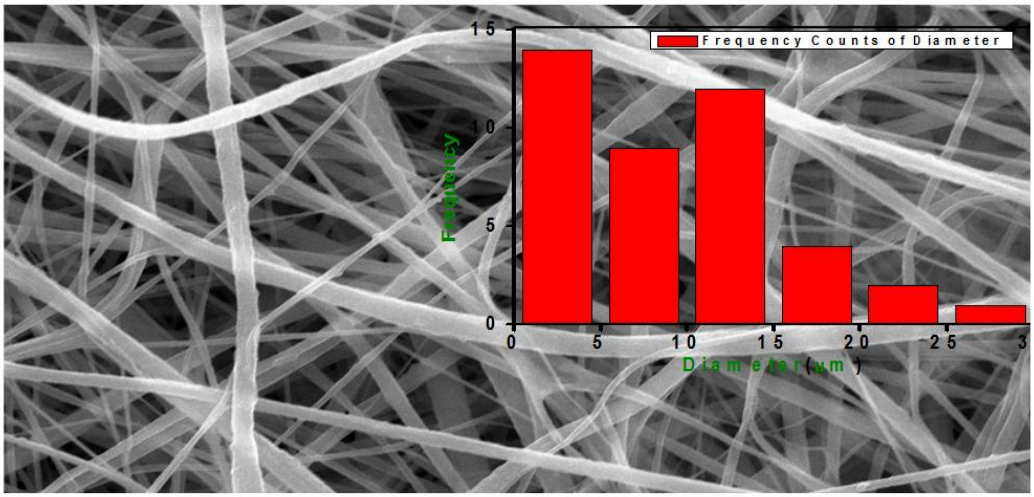

Fig. 8. FE – SEM image of electrospinning fiber

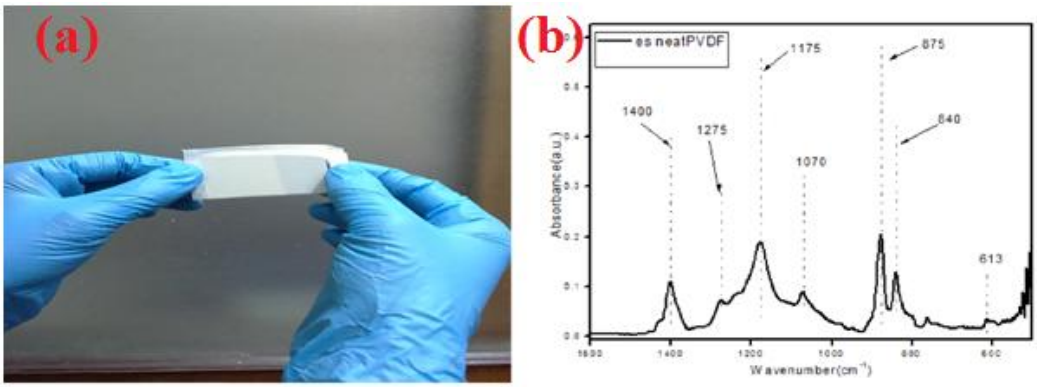

Fig. 9. (a) Electrospinning fiber, (b) FTIR spectrum of nanofiber

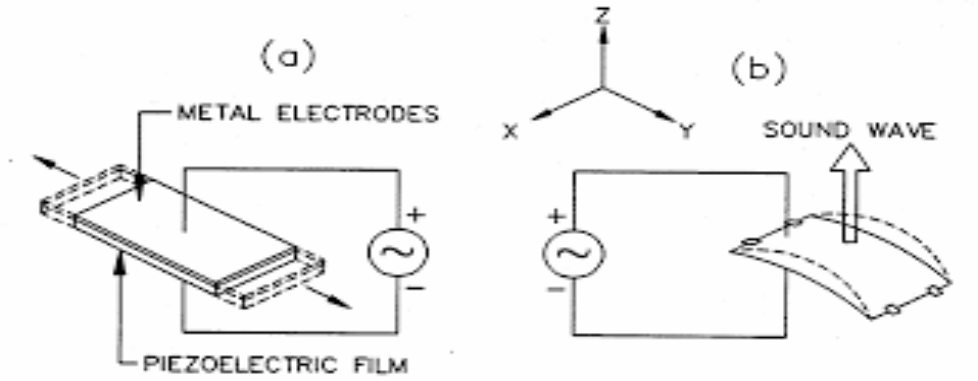

Fig. 10. Basic system for detecting small object

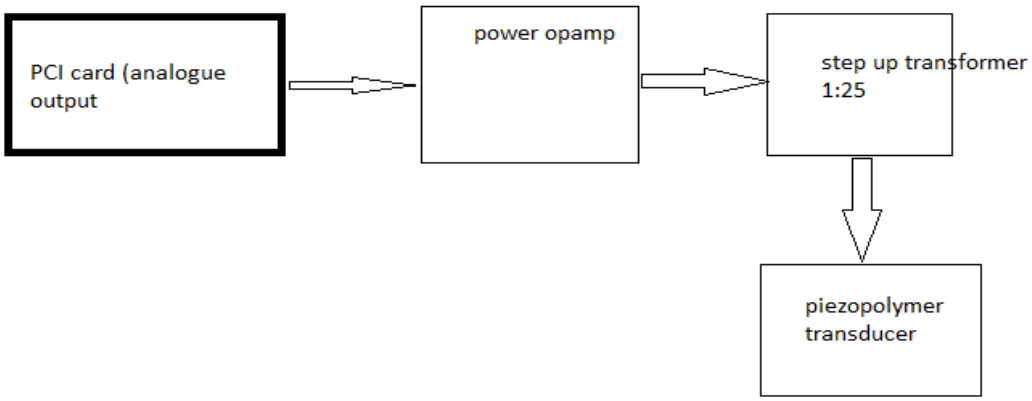

Fig. 11. Transmitter block diagram

3.2 Nanofiber Characterization

Nanofiber is characterized by different tools such as X – ray diffraction, FE – SEM, FTIR spectroscopy instrument. From XRD tools crystal structure can be determined. From SEM (Scanning electron microscopy), morphological structure (diameter distribution of nanofiber) is determined. Different phase of PVDF (α-, β-, γ-, and δ-phase) are identified by Fourier Transformed Infrared Spectroscopy instrument.

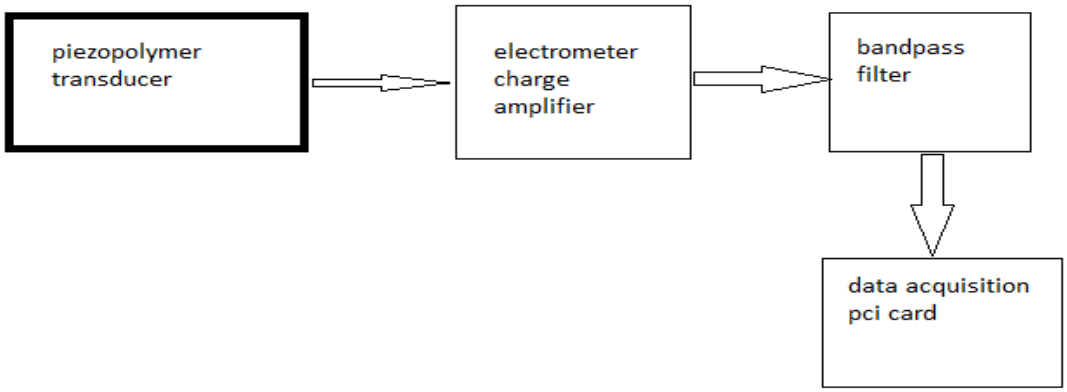

Fig. 12. Receiver block diagram

Table 1. Absorption FTIR bands characteristics of α, β and γ PVDF

	α	β	γ
Wavenumber (cm^{-1})	408	510	431
	532	840	512
	614	1279	776
	766		812
	795		833
	812		840
	833		1234
	840		
	855		
	976		
	1234		

4. DISCUSSION

4.1 Application of PVDF Nanofiber

Electrospinning nanofiber is used as a piezoelectric material in nanogenerator application. PVDF nanofiber based nanogenerator is flexible device, scavenging mechanical energy from environment into electrical energy. These nanogenerator can generate electrical voltage from different mechanical source like finger tapping, breathing, air/water flowing, body movement, walking e.t.c. This nanogenerator is useful to power up self powered devices. PVDF nanofiber based nanogenerator is also flexible, so it is possible to place anywhere in human body such that it generates power from every body movement. PVDF nanofiber based nanogenerator can be used for location of small objects. The design works by virtue of fact that the ends of piezo film are firmly clamped. Any changes in the radius(r) of the hemicylindrical can be seen as a change in the length (l) of piezo film since l=πr. Due to the piezoelectric properties of pvdf film, changes in length (l) are approximately proportional to the voltage across the thickness of the film. Thus, the clamped piezopolymer can function in two ways, shown in Figs. 10, 11 and 12.

1. As a transmitter when voltages are applied on it.
2. As a receiver when airborne acoustic waves impact it.

5. CONCLUSION

In this study, a facile and scalable approach for fabricating ultrathin MoS_2 nanosheets was presented by the reaction of hexaammonium heptamolybdate tetrahydrate and thiourea at temperature of 170°C for 24 h. MoS_2 nanosheets has been prepared by ultrasonication method also. MoS_2 nanosheets with thickness ~10 nm and lateral size of about 300-500 nm were successfully synthesized. The reaction time and temperature plays a crucial role in the formation of ultrathin MoS_2 nanosheets. Considering the simple synthetic process, it is believed that the approach presented here can be extended to synthesize other metal sulfides nanomaterial also. On the other hand PVDF based nanogenerator is also important for converting mechanical energy into electrical energy. On the other side, incorporation of MoS_2 in PVDF nanofiber can increase the performance of nanogenerator.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Binoy Bera, Madhumita Das Sarkar. PVDF based piezoelectric nanogenerator as a new kind of device for generating power from renewable resources. IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE). 2017;4(2):01-05.
2. Novoselov KS, Geim AK, Morozov SV, Jiang D, Zhang Y, Dubonos SV, Grigorieva IV, Firsov AA. Electric field effect in atomically thin carbon films. Science. 2004;306:666-669.
3. Schwierz F. Graphene transistors. Nature Nanotechnology. 2010;5:487-496.
4. Dean CR, Young AF, Meric I, Lee C, Wang L, Sorgenfrei S, Watanabe K, Taniguchi T, Kim P, Shepard KL, et al. Boron nitride substrates for high-quality graphene electronics. Nature Nanotech. 2010;5:722-726.
5. Novoselov KS, Jiang D, Schedin F, Booth TJ, Khotkevich VV, Morozov SV, Geim AKP. Natl. Acad. Sci. USA. 2005;102: 10451-10453.
6. Bhandavat R, David L, Singh G. Synthesis of Surface-functionalized WS_2 nanosheets and performance as Li-Ion battery anodes. The Journal of Physical Chemistry Letters. 2012;3(11):1523.
7. Sasaki Shogo, Kobayashi Yu, Liu Zheng, Suenaga Kazutomo, Maniwa Yutaka, Miyauchi Yuhei, Miyata Yasumitsu. Growth and optical properties of Nb-doped WS_2 monolayers. Applied Physics Express. 2016;9(7):071201.
8. Sallen G, Bouet L, Marie X, Wang G, Zhu CR, Han WP, Lu P, Tan PH, Amand T, Liu BL, Urbaszek B. Robust optical emission polarization in MoS_2 monolayers through selective valley excitation. Physical Review B. 2012;86(8):3–6.
9. Wang G, Marie X, Gerber I, Amand T, Lagarde D, Bouet L, Vidal M, Balocchi A, Urbaszek B. Giant enhancement of the optical second-harmonic emission of wse_2 monolayers by laser excitation at exciton resonances. Physical Review Letters. 2015;114(9).
10. Xiao D, Liu GB, Feng W, Xu X, Yao W. Coupled spin and valley physics in monolayers of MoS_2 and other group-VI Dichalcogenides. Physical Review Letters. 2012;108(19).
11. Chhowalla M, Shin HS, Eda G, Li LJ, Loh KP, Zhang H. The chemistry of two-dimensional layered transition metal dichalcogenide nanosheets. Nature Chemistry. 2013;5:263-275.
12. Splendiani A, Sun L, Zhang Y, Li T, Kim J, Chim CY, Galli G, Wang F. Emerging photoluminescence in monolayer MoS_2. Nano Lett. 2010;10:1271-1275.
13. Lebegue S, Eriksson O. Electronic structure of two-dimensional crystals from ab initiotheory. Phys. Rev. B. 2009;79:115409.
14. Radisavljevic B, Whitwick MB, Kis A. Addendum: Small-signal amplifier based on single-layer MoS_2. Appl. Phys. Lett. 2012;101:043103.
15. Bai S, Xu Q, Gu L, Ma F, Qin Y, Wang ZL. Single crystalline lead zirconate titanae nano/micro-wire based self-powered UV sensor. Nano Energy. 2012;1:789–95.
16. Bera B. Literature review on electrospinning process (A fascinating fiber fabrication technique). Imperial Journal of Interdisciplinary Research (IJIR). 2016;2(8).
17. Xue XY, Wang S, Guo W, Zhang Y, Wang ZL. Hybridizing energy conversion and storage in a mechanical-to-electrochemical process for self-charging power cell. Nano Lett. 2012;12:5048–54.
18. Binoy Bera, Madhumita Das Sarkar. Gold nanoparticle doped PVDF nanofiber preparation of concurrently harvesting light and mechanical energy. IOSR Journal of Applied Physics (IOSR-JAP). 2017;9(3): 05-12.
19. Binoy Bera, Madhumita Das Sarkar. Piezoelectricity in PVDF and PVDF based piezoelectric nanogenerator: A concept. IOSR Journal of Applied Physics (IOSR-JAP). 2017;9(3):95-99.
20. Binoy Bera, Dipankar Mandal, Madhumita Das Sarkar. Sensor made of PVDF/graphene electrospinning fiber and comparison between electrospinning PVDF fiber and PVDF/graphene fiberimperial. Journal of Interdisciplinary Research (IJIR). 2016;2(5).
21. Binoy Bera, Dipankar Mandal, Madhumita Das Sarkar. Porous silicon and its nanoparticle as biomaterial: A review.

Imperial Journal of Interdisciplinary Research (IJIR). 2016;2(11):4.

22. Binoy Bera, Nanoporous silicon prepared by vapour phase strain etch and sacrificial technique. International Journal of Computer Applications (0975 – 8887), International Conference on Microelectronic Circuit and System (Micro). 2015;42-45.

23. Xudong Wang. Piezoelectric nanogenerators — harvesting ambient mechanical energy at the nanometer scale. Elsevier Nano Energy. 2012;1(1):13-24.

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