Mapana Journal of Sciences
2021, Vol. 20, No. 1, 39-62
ISSN 0975-3303|https://doi.org/10.12723/mjs.56.3

Characterization of Multiphase Polypyrrole/Vanadium Oxide Nano Composites for a.c. Conductivity and Dielectric Properties

Harshitha R*, Nihal B Kottan†, Purnachandra Ganesh K M‡, Prajwal M Laxmeesha§, Chaluvaraju B V** and Murugendrappa M V††

Abstract

Vanadium oxide:Phase-1 and Phase-2 nano powers were synthesized from vanadium pentoxide in the presence of glucose using the hydrothermal technique. The polypyrrole/vanadium oxide (PV P-1 and PV P-2) nano composites were synthesized with 15, 30, 45 and 60 weight percents of vanadium oxide: Phase-1 and Phase-2 pyrrole, by the chemical polymerization (oxidation) method. The SEM micrographs of vanadium oxide: Phase-1 and Phase-2 nano powders have shown mixture of nano belts & rods

* Department of Physics, Bangalore Institute of Technology, Bengaluru, India; harshithagowda13@gmail.com
† B.E., Department of Mechanical Engineering, Bangalore Institute of Technology, Bengaluru, India; nihalkottan@gmail.com
‡ B.E., Department of Mechanical Engineering, Bangalore Institute of Technology, Bengaluru, India; purnachandra.feb26@gmail.com
§ M.S. Student, Department of Materials Science and Engineering, College of Engineering, Drexel University, Philadelphia, PA 19104, USA; prajwal.ml714@gmail.com
** Department of Physics, Bangalore Institute of Technology, Bengaluru, India; chaluvaraju@bit-bangalore.edu.in; bvcgowda@gmail.com
†† Department of Physics and Center of Excellence in Advanced Materials Research, BMS College of Engineering, Bengaluru, India; murugendrappamv.phy@bmsce.ac.in

and PV P-1 & PV P-2 nano composites indicate that the composites have cluster formation with almost spherical nature particles and form elongated chains at some places. Conductivity versus frequency plots have shown exponential increase in conductivity.The value of σ increases to $1.13x10^{-3}$ S/cm for 15 wt.% of VO_2 P-1 in polypyrrole & to $2.43x10^{-3}$ S/cm for 30wt. % of VO_2 P-2 in polypyrrole at 1 MHz.The higher VO_2 concentration may have increased the chain length of PPy facilitating the bouncing of charge carriers. $\sigma_{a.c.}$ and dielectric studies revealed that the nano composites may be a good a.c. conductor and low-value dielectric materials. The composites may also find applications in humidity and gas sensors, micro power generator, thermo cooling and EMI shielding.

Keywords: Polypyrrole;Vanadium Oxide; Nano Composites; Conductivity; Dielectrics.

1. Introduction

Curiosity in the growth of intrinsic conducting polymers (ICP) has increased tremendously because of their electro-chromic properties suitable for applications in batteries, functional electrodes, electrochromic devices, optical switching devices, electronic devices, sensors such as gas, bio, solid-state, humidity, microwave, electro-magnetic interference shielding [1-5] and thermo-electric power [6-8]. The conducting polymers have two major groups of applications. The first group utilizes their conductivity as its main property, while the second group utilizes the electro-activity [9].

ICPs are synthesized from techniques such as electrochemical or chemical polymerization [10]. Monomers can be oxidized by oxidizing agents, such as ammonium persulphate, ferric chloride, etc., to produce conducting polymers by using the chemical polymerization process [11]. Chemical synthesis has the benefit that it facilitates bulk production at a moderate cost.

The conducting polymer polypyrrole is derived from the pyrrole monomer. It accentuates the progress that has been made to understand, characterize complex systems and also highlight the

improvement made in their physical properties [12-20]. Polypyrrole is one of the best conducting polymers [21].

Polypyrrole has found applications in Plastic LEDs, Micro-motors, Batteries, Optical-storage, Photocopiers, Transducers, Lithography, Conductivity, Photo-conducting,Piezoelectric, Photochemical reactions, Harmonic generators, Display devices, Magnetic recording, Sensors, Super-capacitors, etc. [19-22].

Vanadium pentoxide (V_2O_5) is a brown/yellow solid; it has an amphoteric oxide and an oxidizing agent due to its high oxidation state. During the preceding few years, materials, which are synthesized based on vanadium oxides, have fascinated considerable responsiveness due to their attractive structures, properties such as electronic property, optical property and magnetic property. These are significant to such diverse domains as lubrication, chemical sensor, catalysis, cathode materials in batteries, minerals, self-lubricating applications, production of ferrovanadium and sulfuric acid [23-29], as a detector material in bolometers and micro-bolometer arrays for thermal imaging due to its high coefficient of thermal resistance, active electrode in a rechargeable lithium battery as well as solid-state micro-battery applications. Vanadium redox batteries are used for energy storage, wind farms, thermal switching and sensing [30-31].

VO_2 (metastable phase oxide) is made up of distorted VO_6 octahedra,which shared edges and corners [32]. Also, it is found to be of thought-provoking cathode properties in batteries like lithium-ion batteries [33-34]. VO_2 synthesis is normally attained through low-temperature chemical methods [32, 35-37]. VO_2 nanostructures may be synthesized using a nontoxic reducing agent. VO_2 nanowires, nanobelts, nanoribbons, nanoneedles and nanorods were respectively synthesized [38-44]. VO_2 nanobelts are synthesized using nontoxic glucose as a reducing agent.

2. Experimental Details

2.1. Synthesis

2.1.1. Synthesis of the Pure Polypyrrole (PPy)

A. R. grade pyrrole (Sisco Laboratories Pvt. Ltd., Mumbai, India) [6-8] was used. 0.3 M pyrrole solution [6-8] was taken in a beaker.0.6 M [6-8] ammonium persulphate (APS) (Sisco Laboratories Pvt. Ltd., Mumbai, India) solution was prepared and added dropwise to pyrrole solution for polymerization.The reaction was continued for 4 hours with continuous stirring. The precipitated polypyrrole was obtained. It was filtered and dehydrated using a hot air oven at 100°C. PPy was measured, and the yield was 1.8 g [6-8].

2.1.2. Synthesis of Vanadium Oxide: Phase-1 and Phase-2 (VO_2 P-1 & VO_2 P-2) Nano Powders

In a usualtechnique, 1 mmol V_2O_5 (NR CHEM Pvt. Ltd., Mumbai, India) and 0.5 mmol glucose (Thomas Baker Chemicals Pvt. Ltd., Mumbai, India) were dissolved in 30 ml distilled water. 0.5 g sodium sulfate was added to the solution later. Homogeneous yellow suspension was obtained after 20 minutes of stirring. It was transferred into a 50 ml teflon-lined autoclave, and distilled water was successively added up to 80 % of its measurements. The autoclave was sealed, and it was placed in an oven for heating at 160°C for 24 hours. The precipitate was centrifuged with distilled water and ethanol (Thomas Baker Chemicals Pvt. Ltd., Mumbai, India) for 4 times.The final sample was dried in an oven at 60°C for 24 hours at Phase-1. The obtained nano *black* powder is named VO_2 Phase-1 (VO_2 P-1) [43].

Similarly, VO_2 is again synthesized at Phase-2, and the obtained precipitated sample was dried in an oven at 100°C for 24 hours. The obtained nano *pale blue* powder is named VO_2 Phase-2 (VO_2 P-2) [43].

2.1.3. Synthesis of the Polypyrrole/Vanadium Oxide: Phase-1 and Phase-2 (PV P-1 and PV P-2) Nano Composites

0.27 g (15 weight percent) of synthesized vanadium oxide Phase-1 (VO_2 P-1) nanopowder was added to the 0.3 M pyrrole solution and mixed thoroughly. Further, 0.6 MAPS was added dropwise, with the

help of a burette, continuously to the above solution, to get a polypyrrole/vanadium oxide (15 wt. %) Phase - 1 (PV P-1 15%) nanocomposite. Similarly, for 30, 45 and 60 wt. %, 0.54 g, 0.81 g and 1.08 g of VO_2 P-1 powders were taken and the above procedure repeated to get the PV P-1 nanocomposites. The nano composites yields were 3.6 g, 2.8 g, 3.2 g and 3.8 g, respectively [6-8].

Similarly, polypyrrole/vanadium oxide Phase-2 (PV P-2) nanocomposites were synthesized using the same above mentioned procedure. The yields of the nanocomposites were 3.9 g, 4.8 g, 5.11 g and 5.78 g, respectively [6-8].

A hydraulic press was used to compress the PV P-1 and PV P-2 nanocomposites powders into pellets which have a thickness between 1 mm and 3 mm and diameter 1 cm by applying 10-13 tons pressure (Shimazdu, Japan) [13]. The compacted pellets were coated with Silver paste on both flat surfaces for the physical properties measurements. a.c. conductivity and parameters of dielectric properties were measured using the 6500B series of Precision Impedance Analyzers (Wayne Kerr Electronics Pvt. Ltd., India), in the frequency range from 20 Hz to 1 MHz, at room temperature for the composites [6-8].

2.2. Characterization

PPy, PV P-1 and P-2 composites and VO_2 samples spectra were recorded on an FTIR (Shimazdu, Japan) spectrometer, in a medium of potassium bromide, at normal temperature. The XRD patterns of the samples were recorded on an X-ray Diffractometer (Bruker AXS D8 Advance, India), using Cu $K_\propto$ radiation (λ=1.5418 Å), in the 2θ range of 5°-90°. A Scanning Electron Microscope (Jeol 6390 LV, India) was used to obtain the SEM micrographs.

3. Results and Discussion

3.1. SEM Analysis

Figures 1.a-g show the SEM micrographs of the pure polypyrrole, VO_2 P-1, PV P-1 & P-2 composites and VO_2 P-2, respectively. Fig 1.a shows an image with spherical clusters and few chains, which is typical of PPy monomer. The SEM micrograph (Figure 1.b) of VO_2

P-1 shown that the mixture of nanobelts and nanorods particles of VO_2 at Phase-1 (60°C). The SEM micrographs of PV P-1 composites (Figure 1.c-f) show theformation of spherical clusters around the vanadium oxide nanorods. The SEM micrograph (Figure 1.h) of the vanadium oxide nanopowder at Phase-2 (100°C) revealed nanorods intact. Similarly, as PV P-1 composites, the SEM micrographs of PV P-2 composites (Figure 1.h-k) are revealing of a spherical nature and clusters formation in the composites except for the PV P-2 (15 %) nanocomposites which show agglomeration of spherical particles around rod-like structures [45-53].

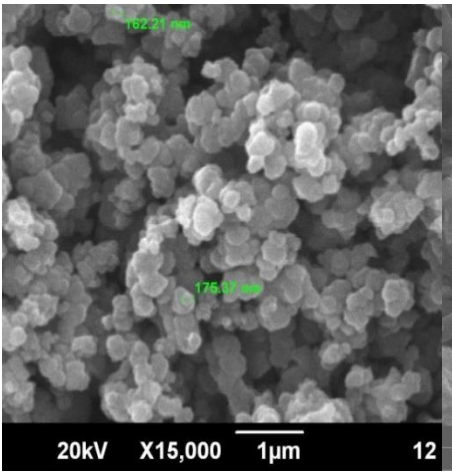

Figure 1.a:SEM micrograph of the pure PPy powder

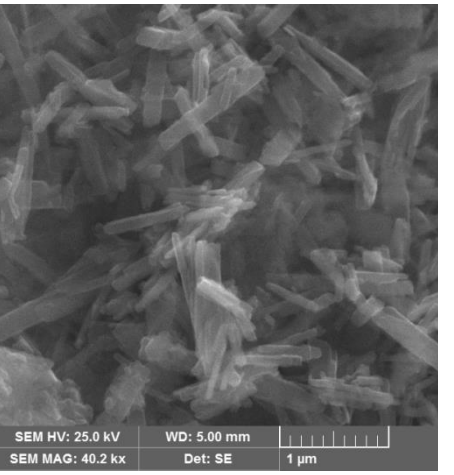

Figure 1.b:SEM micrograph of the VO_2 nano powder Phase-1

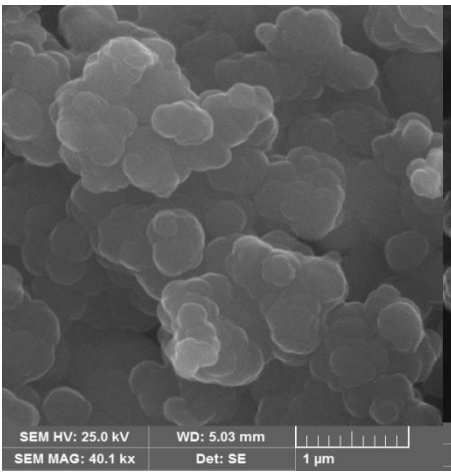

Figure 1.c: SEM micrograph of the PV P-1 (15%) nano composites

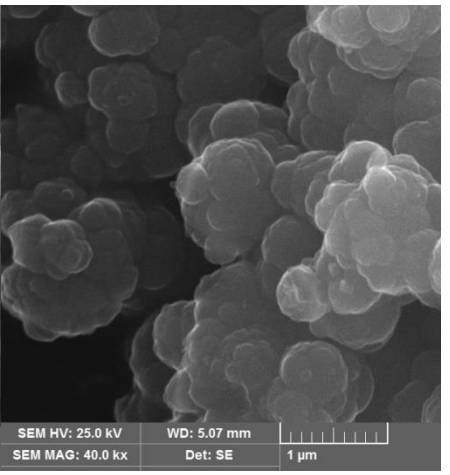

Figure 1.d:SEM micrograph of the PV P-1 (30%) nano composites

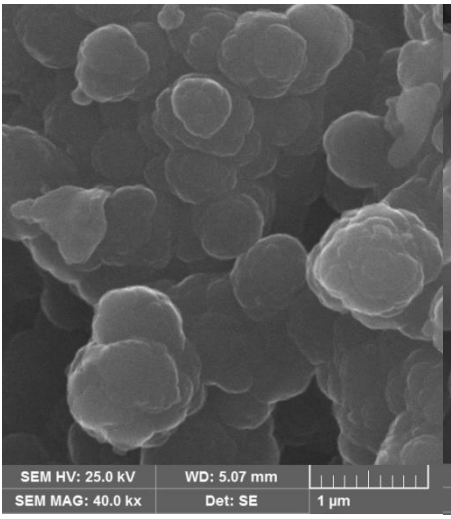

Figure 1.e: SEM micrograph of the PV P-1 (45%) nano composites

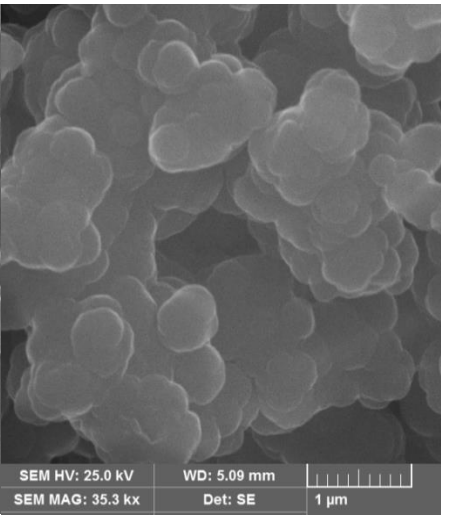

Figure 1.f: SEM micrograph of the PV P-1 (60%) nano composites

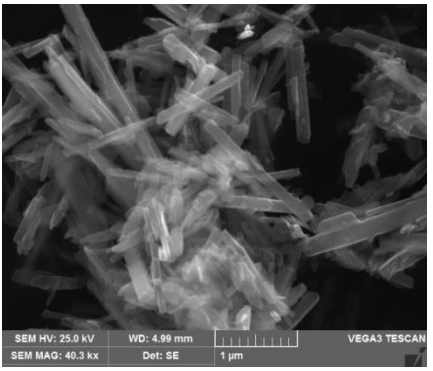

Figure 1.g: SEM micrograph of the vanadium oxide nano powder Phase-2

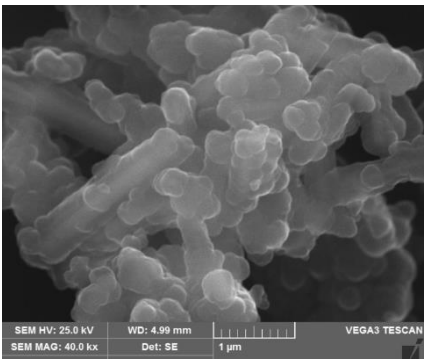

Figure 1.h: SEM micrograph of the PV P-2 (15%)nano composites

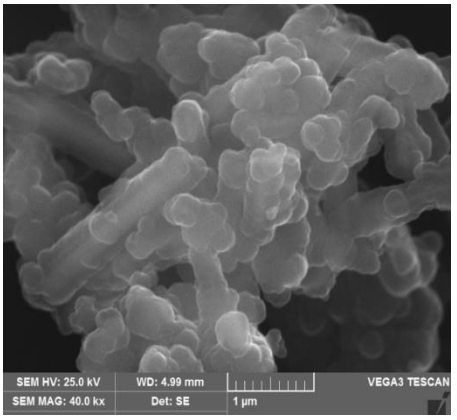

Figure 1.h: SEM micrograph of the PV P-2 (15%) nano composites

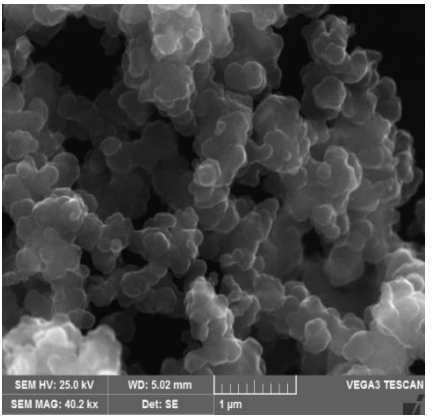

Figure 1.i: SEM micrograph of the PV P-2 (30%) nano composites

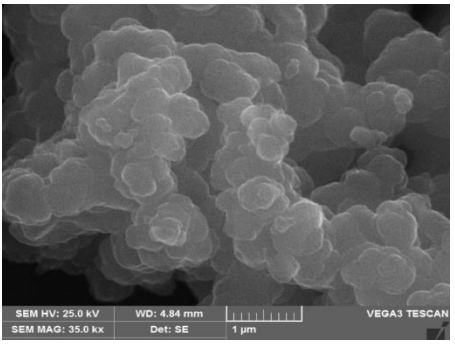

Figure 1.j: SEM micrograph of the PV P-2 (45%) nano composites

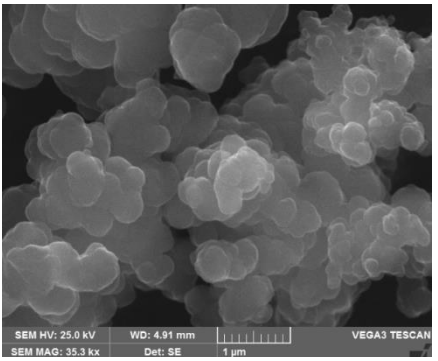

Figure 1.k: SEM micrograph of the PV P-2 (60%) nano composites

3.2.Study of a.c. Conductivity

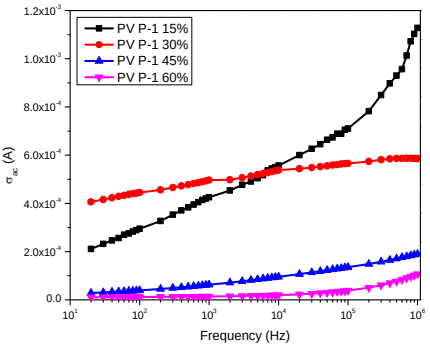

Fig. 5.a: σ_{ac} versus *f* of PV P-1 composites

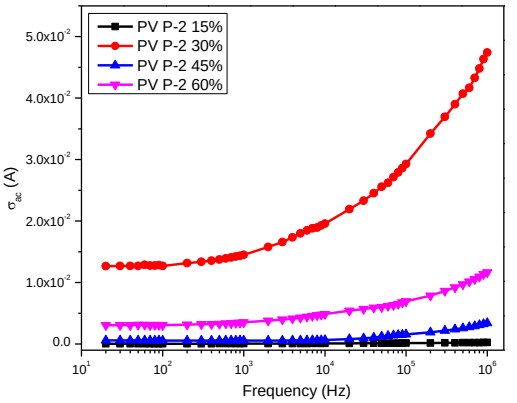

Fig. 5.b: σ_{ac} versus *f* of PV P-2 composites

a.c. conductivity rises with an increase of frequency at a given temperature for the composites. This phenomenon is a common response for intrinsically conducting polymer-based composites [54-55].Variation of the a.c. conductivity versus frequency for the PVP-1 and P-2 composites was shown in Figures 5.a and 5.b. It was observed that the conductivity increases exponentially as frequency increases at high-frequency region. It can also be seen that the value of conductivity increases for $1.13x10^{-3}$S/cm for 15% weight percent of VO_2 P-1 in polypyrrole& for $2.43x10^{-3}$S/cm for 30% weight percent of VO_2 P-2 in polypyrroleat 1 MHz. This may be due to the extended chain length of polypyrrole, which facilitates the hopping of charge carriers when the content of VO_2particles was increased for composites. The increase in conductivity for the PPy/VO_2P-1 (15%) composite and the PV P-2 (30%) composite was due to the variation in the distribution of VO_2P-1 and P-2 particles, respectively, which may be supported for more number of charge carriers to hop between favourable localized sites causing an increase in conductivity. The decrease in conductivity for the rest of PV P-1 and P-2 composites may be attributed to the trapping of charge carriers in the polymer chain. Charge trapping in PPy and blends was a general universal feature of these materials. 5.85, 1.90, and $1.06x10^{-4}$S/cm were conductivity values at 1 MHz for the PV P-1 (30% 45% and 60%) composites, respectively as well as 0.0474, 0.0034 and

$0.01167x10^{-3}$S/cm were conductivity values at 1 MHz for the PV P-2 (15%, 45% and 60%) composites respectively.

Studies reveal that the PV P-2 (30%) composite has the highest conductivity among all. Hence, VO_2 P-2 particles concentration influenced the PPy in the synthesis of the above composite[56-64].

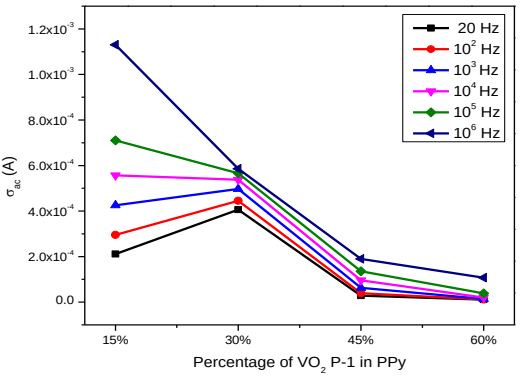

Fig. 5.c: σ_{ac} versus weight percent of PPy for PV P-1 composites

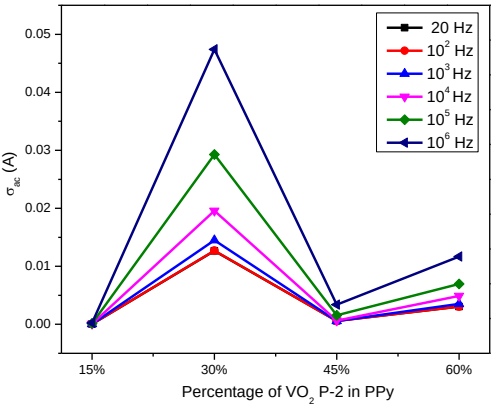

Fig.5.d: σ_{ac} versus weight percentof PPy for PV P-2 composites

Figures 5.c and 5.d were shown the variation of ac conductivity as a function of the weight percentage of VO_2 P-1 and P-2 in PPy at different frequencies. The values of the conductivity increased for 15 weight percent VO_2P-1 in PPy for PV P-1 composite as well as for 30 weight percent VO_2 P-2 in PPy for PV P-2 composite. These points were percolation thresholds, respectively, and the composites are shown to obey percolation theory. Furthermore, a decrease in the conductivity, which could be attributed to the blocking of hopping charge carriers by the presence of larger grain size vanadium oxide particles, can be observed in some composites. [56-64].

3.3Dielectric Constant and Dielectric Loss Studies

The interactions between the dispersant and matrix along with the physical properties of the matrix, influence the agglomeration of particles during polymerization. Cross-linking between polymer chains plays a major role in the way transport properties are exhibited [65]. The effect of dopant concentration on the dielectric constant, dielectric loss, and tangent loss of polypyrrole based composites was studied by varying vanadium oxide content.

3.3.1 Dielectric Constant Studies

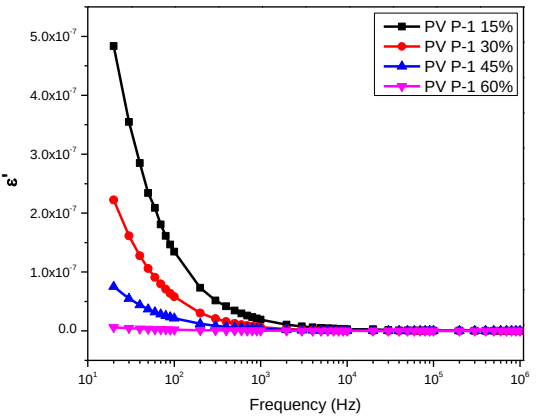

Fig. 6.a: ε' versus *f* of PV P-1 composites

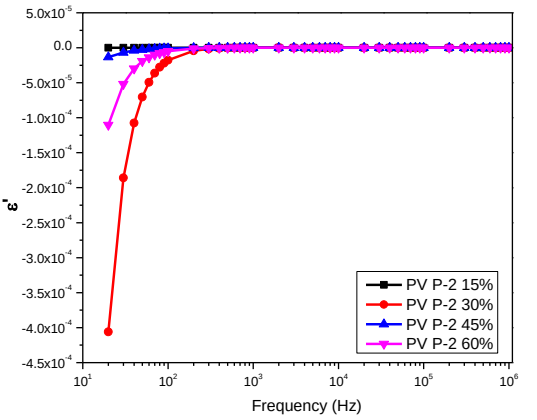

Fig. 6.b: ε' versus *f* of PV P-2 composites

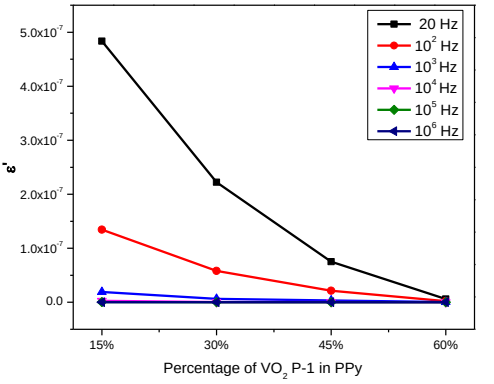

Fig. 6.c: ε' versus weight percent of PPy for PV P-1 composites

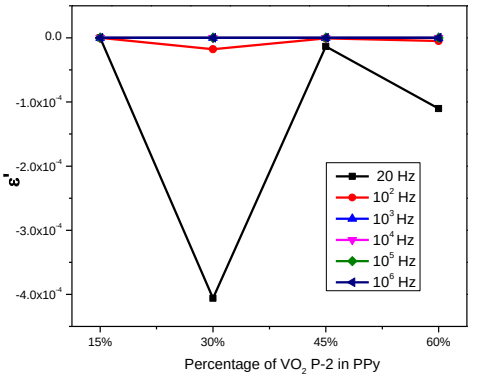

Fig.6 d: ε' versus weight percent of PPy for PV P-2 composites

The positive dielectric constant and negative dielectric constant (Fig.6.a and Fig.6.b) decreases with increasing frequency for PV P-1 and P-2 composites. The PV P-1 (15%) and V P-2 (30%) composite have shown high dielectric constant values. The negative dielectric constant is due to the increase in ac conductivity. The tendency of diploes in composite to orient themselves in the direction of applied field may cause this. Electrode and interfacial effects of the composite could be a cause for the high values of ε' at low frequency. On the other hand, the value remained a constantat the high-frequency rangewith respect to frequency.A similar trend is seen after observing the behavious of all composite from the graph and this could be due to hindrance of rotation of the dipoles at higher frequencies which leads to difficulty in reorientation [66-74].

Variations of dielectric constants with weight percents of VO_2 P-1 and P-2 particles in PPy of PV P-1 and P-2 composites as shown in Fig. 6.c and Fig. 6.d. Figures revealed that the percolation points at respective positions for all composites like in the case of ac conductivity studies [66-74].

3.3.2 Dielectric Loss Studies

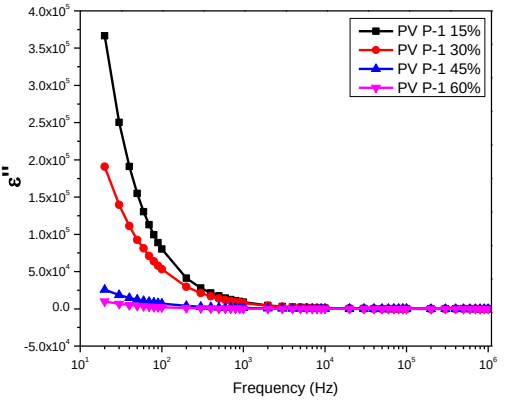

Fig. 6.e: ε'' versus *f* of PV P-1 composites

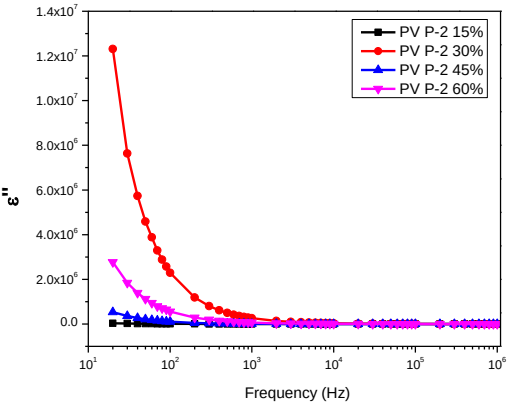

Fig. 6.f: ε'' versus *f* of PV P-2 composites

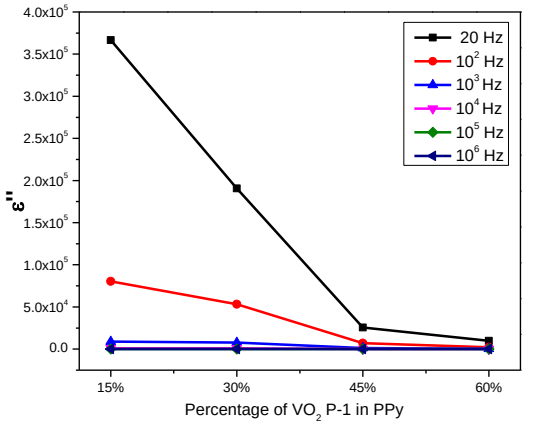

Fig. 6.g: ε" versus weight percent of PPy for PV P-1 composites

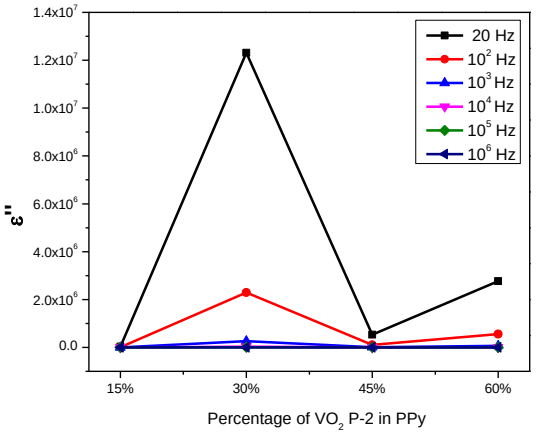

Fig.h: ε" versus weight percent of PPy for PV P-2 composites

The constant dielectric loss (Fig.6.e and Fig.6.f) decreases with increasing frequency for PV P-1 and P-2 composites. The PV P-1 (15%) and V P-2 (30%) composites have shown high dielectric loss values. Mobile charges present within the polymer backbone may explain the larger value of the dielectric loss at a lower frequency.

On the other hand, the mobile charges of PPy could be held accountable for the lower value of ε" at high frequency [66-74].

Variations of dielectric losses with weight percents of VO_2 P-1 and P-2 particles in PPy of PV P-1 and P-2 composites are shown in Fig. 6.g and Fig. 6.h. Figures revealed that the percolation points at respective positions for all composites, like in the case of constant dielectric studies [66-74].

4. Conclusion

Vandium oxide: Phase-1 & Phase-2 and multiphase polypyrrole/vandium oxide nanocomposites were synthesized. The obtained samples were analyzed using SEM technique. a.c. conductivity and dielectric properties studies were done successfully, which revealed in all plots. a.c. conductivity and dielectric properties studies revealed that the nanocomposites might be good ac conductor and low-value dielectric materials. The composites may also find applications in micropower generator, thermo cooling, EMI shielding, humidity and gas sensors.

Acknowledgement

The authors thank Rajya Vokkaligara Sangha and The Principal, BIT, for their cooperation and assistance, as well as Prof. Meena D. R., Head, Chemistry Research Laboratory, BIT, Bengaluru-560004 funded by Department of Science and Technology (DST), Govt. of India,for the synthesis and FTIR analyses of the samples. SEM and XRD analyses and physical properties studies were done at the Center of Excellence in Advanced Materials Research (COE), BMSCE, supported by World Bank-sponsored TEQIP.

References

[1] Tourillon G., Handbook of conducting polymers, (T. A. Skotheim, New York: Marcel Dekker) Vol. 1, 1986, p 293.
[2] Scrosati B., Encyclopedia of polymer science and engineering, (London: Chapman and Hall), 1993, Ch. **7.**
[3] Jasne S., Encyclopedia of polymer science and engineering (New York: John Wiley)1988.

[4] Om Bockris J. and Miller D., Conducting polymers: Special applications, L.Alcacer(Dordrecht: Reidel), 1989, Vol. 1.

[5] Gurunathan K., Vadivel Murugan A., Marimuthu R., Mulik U. P. and Amalnerkar D. P., Electrochemically synthesized conducting polymeric materials for applications towards technology in electronics, optoelectronics and energy storage devices, Materials Chemistry and Physics, Vol. 61, 1999, pp 173 - 191.

[6] Chaluvaraju B. V., Sangappa K. Ganiger and Murugendrappa M. V., Thermo-electric power study of polypyrrole/molybdenum trioxide composites, Polymer Science Series A, Volume 57, Number 4, July-2015, pp 467 - 472.

[7] Chaluvaraju B. V., Raghavendra U. P., Pranesha T. S. and Murugendrappa M. V., A study of thermo-electric power and transport properties of polypyrrole/ash (paddy husk) nano-composites, Journal of Material Science: Material in Electronics, Volume 28, No.15, August-2017, pp 11230 - 11242.

[8] Harshitha R., Aaditya V. B., Bharatesh B. M., Chaluvaraju B. V., Raghavendra U. P. and Murugendrappa M. V., Studies of thermo-electric power and dielectric modulus of polypyrrole/zirconium oxide-molybdenum trioxide (PZM) composites, Journal of Material Science: Material in Electronics, Volume 29, No.8, April-2018, pp 6564 - 6578.

[9] Bredas J. L., Chance R. R. and Silbey R., Comparative theoretical study of the doping conjugated polymers; Polarons in polyacetylene and polyparaphenylene, Physical Review B, Vol. 26, 1982 pp 5843 - 5854.

[10] Anuar Kassim, Zarina BteBasar and Ekramul Mahmud H. N. M., Effects of preparation temperature on the conductivity of polypyrrole conducting polymer, Proc. Indian Academy of Science (Chemical Science), Vol. 114, No. 2, 2002, pp 155 - 162.

[11] Anuar Kassim, Ekarmul Mahmud H. N. M., Lim Mei Yee and Nurain Hanipah, Electrochemical preparation and characterization of polypyrrole-polyethylene glycol conducting polymer composite films, The Pacific Journal of Science and Technology, Vol. 7, No. 2., 2006, pp 103 - 107.

[12] Paul Saville, Polypyrrole: Formation and Use, Technical Memorandum, Defence R&D Canada - Atlantic, DRDC Atlantic TM 2005-004, 2005, pp 1 - 50.

[13] Mohd Hamzah Harun, Elias Saion, Anuar Kassim, Noorhana Yahya and Ekramul Mahmud, Conjugated conducting polymers: a brief overview, JASA-2, 2007, pp 63 -68.

[14] Gyorgy Inzelt, Rise and rise of conducting polymers, Journal of Solid State Electrochemistry, Vol. 15, 2011 pp 1711 - 1718.
[15] Pron A. and Rannou P., Process able conjugated polymers: from organic semiconductors to organic metals and superconductors, Progress in Polymer Science, Vol. 27, 2002, pp 135 - 190.
[16] Toshima N. and Hara S., Direct synthesis of conducting polymers from simple monomers, Progress in Polymer Science, Vol. 20, 1995, pp 155 - 183.
[17] Chao T. H. and March J., A study of polypyrrole synthesized with oxidative transition metal ions, Journal of Polymer Science: Part A: Polymer Chemistry, Vol. 26, pp 743 - 753.
[18] Bolto B. A., Mcneill R. and Weiss D. E., Electronic conduction in polymers: electronic properties of polypyrrole, Australian Journal of Chemistry, Vol. 16, 1963, pp 1090 - 1103.
[19] Clarke T. C., Geiss R. H., Kwak J. F. and Street G. B., Highly conducting transition metal derivatives of polyacetylene, Journal of Chemical Society: Chemical Communication, Vol. 338, 1978, pp 489 - 490.
[20] Jude O. Iroh and Kirill Levine, Electrochemical synthesis of polypyrrole/polyimide conducting composite using a polyamic acid precursor, European Polymer Journal, Vol. 38, 2002, pp 1547 - 1550.
[21] Vernitskaya T. V. and Efimov O. N., Polypyrrole: a conducting polymer; its synthesis, properties and applications, Russian Chemical Reviews, Vol. 66, No. 5, 1997, pp 443 - 457.
[22] Radhakrishnan T. P., Renaissance of the plastic age, Resonance, Vol. 6, No. 2, 2001, pp 62 - 70.
[23] E. Lugscheider, O. Knotek, S. Barwulfand K. Bobzin, Characteristic curves of voltage and current, phase generation and properties of tungsten- and vanadium-oxides deposited by reactive dc MSIP-PVD process for self-lubricating applications, Surface and Coatings Technology, vol. 142-144, 2001, pp.137-142.
[24] A. Lavacchi, B. Cortigiani, G. Rovida et al., Composition and structure of tin/vanadium oxide surfaces for chemical sensing applications," Sensors and Actuators: Chemical B, vol. 71, no. 1-2, 2000, pp. 123 – 126.
[25] W. P. Griffith, Polyoxometallates as homogeneous catalysts for organic oxidations, Transition Metal Chemistry, vol. 16, no. 5, 1991, pp. 548 - 552.
[26] I. V. Kozhevnikov, Advances in catalysis by heteropolyacids, Russian Chemical Reviews, vol. 56, no. 9, pp. 811 - 825, 1987.

[27] A. R. Armstrong, C. Lyness, P. M. Panchmatia, M. S. Islam, and P. G. Bruce, The lithium intercalation process in the low voltage lithium battery anode, Nature Materials, vol. 10, no. 3, pp. 223 - 229, 2011.

[28] L. Mai, L. Xu, C. Han et al., Electro-spun ultra-long hierarchical vanadium oxide nanowires with high performance for lithium ion batteries, Nano Letters, vol. 10, no. 11, pp. 4750 - 4755, 2010.

[29] H. T. Evans and J. A. Konnert, The crystal chemistry of sherwoodite, a calcium 14-vanadoaluminate heteropoly complex, American Mineralogist, vol. 63, no. 9-10, pp. 863 - 868, 1978.

[30] Shama Islam, G. B. V. S. Lakshmi, Azher M. Siddiqui, M. Husain and M. Zulfequar, Synthesis, electrical conductivity and dielectric behavior of polyaniline/V_2O_5 composites, International Journal of Polymer Science, doi: 10.1155/2013/307025.

[31] Greenwood, Norman N.; Earnshaw, Alan (1984). Chemistry of the Elements. Oxford: Pergamon Press. pp. 1140, 1144.

[32] G. Grymonprez, L. Fiermans, and J. Vennik, Structural properties of vanadium oxides, Acta Crystallographica, vol. A33, no. 5, pp. 834 - 837, 1977.

[33] A. M. Kannan and A. Manthiram, Synthesis and electrochemical evaluation of high capacity nanostructured VO_2 cathodes, Solid State Ionics, vol. 159, no. 3-4, pp. 265 - 271, 2003.

[34] C. Tsang and A.Manthiram, Synthesis of nanocrystalline VO_2 and its electrochemical behavior in lithium batteries, Journal of the Electrochemical Society, vol. 144, no. 2, pp. 520 - 524, 1997.

[35] K. F. Zhang, S. J. Bao, X. Liu, J. Shi, Z. X. Su, and H. L. Li, Hydrothermal synthesis of single-crystal VO_2(B) nanobelts, Materials Research Bulletin, vol. 41, no. 11, pp. 1985 - 1989, 2006.

[36] X. Wu, Y. Tao, L. Dong, Z. Wang, and Z. Hu, Preparation of VO_2 nanowires and their electric characterization, Materials Research Bulletin, vol. 40, no. 2, pp. 315 - 321, 2005.

[37] Z. Chen, S. Gao, L. Jiang, M. Wei, and K. Wei, Crystalline VO_2 (B) nanorods with a rectangular cross-section, Materials Chemistry and Physics, vol. 121, no. 1-2, pp. 254 - 258, 2010.

[38] G. Armstrong, J. Canales, A. R. Armstrong, and P. G. Bruce, The synthesis and lithium intercalation electrochemistry of VO_2 (B) ultra-thin nanowires, Journal of Power Sources, vol. 178, no. 2, pp. 723 - 728, 2008.

[39] X. Liu, G. Xie, C. Huang, Q. Xu, Y. Zhang and Y. Luo, A facile method for preparing VO_2 nanobelts, Materials Letters, vol. 62, no. 12-13, pp. 1878 - 1880, 2008.

[40] L. Mao and C. Liu, A new route for synthesizing VO_2 (B) nanoribbons and 1D vanadium-based nanostructures, Materials Research Bulletin, vol. 43, no. 6, pp. 1384 - 1392, 2008.
[41] F. Sediri, F. Touati and N. Gharbi, From V_2O_5 foam to VO_2 (B) nanoneedles, Materials Science and Engineering B, vol. 129, no. 1-3, pp. 251 - 255, 2006.
[42] C. V. S. Reddy, E. H. Walker Jr., S. A. Wicker Sr., Q. L. Williams, and R. R. Kalluru, Synthesis of VO_2 (B) nanorods for Li battery application, Current Applied Physics, vol. 9, no. 6, pp. 1195 - 1198, 2009.
[43] Shibing Ni, Haibo Zeng and Xuelin Yang, Fabrication of VO_2 (B) nano belts and their application in lithium ion batteries, Journal of Nanomaterials, 2011, doi:10.1155/2011/961389.
[44] Wang Yuan-Hong, Liu Heng,Zhu Ding, Guo Zai-Ping, Liu Hua-Kun and Dou Shi-Xue, Preparation and electrochemical performance of hollow spherical polypyrrole/V_2O_5 composite, Trans. Nonferrous Met. Soc. China 21 (2011) 1303-1308.
[45] A. Rherari, M. Addou, M. Haris, J. Mater. Sci.: Mater. Electronics, 28 (21) (2017) 15762-15767.
[46] Vijaya Jadkar, Amit Pawbake, Ravindra Waykar, Ashok Jadhavar, J. Mater. Sci.: Mater. Electronics, 28 (21) (2017) 15790-15796.
[47] Wissem Ben Soltan, Mohamed Saber Lassoued, Salah Ammar, Thierry Toupance, J. Mater. Sci.: Mater. Electronics, 28 (21) (2017) 15826-15834.
[48] P. L. Deepti, S. K. Patri, R. N. P. Choudhary, J. Mater. Sci.: Mater. Electronics, 28 (21) (2017) 16071-16076.
[49] Chaluvaraju B. V., Sangappa K. Ganiger, Murugendrappa M. V., Polym. Sci.: Ser. B, 56(6) (2014) 935-939.
[50] Zigang Shen, Dong Li, J. Mater. Sci.: Mater. Electronics, 28 (18) (2017) 13257-13266.
[51] M. Jose, M. Elakiya, S. A. Martin Britto Dhas, J. Mater. Sci.: Mater. Electronics, 28 (18) (2017) 13649-13658.
[52] Chaluvaraju B V, Sangappa K Ganiger and Murugendrappa M V, Thermo-Electric Power, A. C. Conductivity, Dielectric Properties and Humidity Sensing Study of the Polypyrrole/Tantalum Pentoxide Composites, Springer: Journal of Material Science: Material in Electronics, Volume 27, No.1, 2016, pp 1044 - 1055.
[53] Madhusudhana H C, Shobha Devi S N ,Nagabhushana B M, Chaluvaraju B V, Murugendrappa M V , Hari Krishna Rajan, Nagabhushana H and Radhip N R, Effect of Fuels on Conductivity, Dielectric and Humidity Sensing Properties of ZrO_2 Nanocrystals

Prepared by Low Temperature Solution Combustion Method, Journal of Asian Ceramic Societies, Volume 4, pp 309 - 318, 2016.

[54] Sangappa K. Ganiger, Chaluvaraju B. V., K. S. Ganigerand Murugendrappa M. V., Synthesis and Characterization of Polypyrrole/Strontium Arsenate (Ceramics) Nano composites, Malaysian Polymer Journal, Vol. 10, No. 1, 2015, pp 9-15.

[55] Dutta P., S. Biswas, M. Ghosh, S. K. De, S. Chatterjee, The dc and ac conductivity of polyaniline and polyalcohol blends, Synthetic Metals, Vol. 122, 2000, pp 455 - 461.

[56] Z. M. Elimat, W. T. Hussain and A. M. Zihlif, PAN-based carbon fibers/PMMA composites: thermal, dielectric, and DC electrical properties, Journal of Materials Science: Materials in Electronics, December 2012, Volume 23, Issue 12, pp 2117 - 2122.

[57] Yiqun Wang, Jianfeng Yang, Shiyi Zhou, Wentao Zhang and Ren Chuan, Electrical properties of graphene nanoplatelets/ultra-high molecular weight polyethylene composites, Journal of Materials Science: Materials in Electronics, January 2018, Volume 29, Issue 1, pp 91 - 96.

[58] R. Megha, Y. T. Ravikiran, B. Chethan, H. G. Raj Prakash, S. C. Vijaya Kumari and S. Thomas, Effect of mechanical mixing method of preparation of polyaniline-transition metal oxide composites on DC conductivity and humidity sensing response, Journal of Materials Science: Materials in Electronics.

[59] Sangappa K Ganiger, Chaluvaraju B V and Murugendrappa M V, A Feasibility Study on Polypyrrole/Zinc Tungstate (Ceramics) Nano Composites for D. C Conductivity and as a Humidity Sensor, Materials Today: Proceedings, Volume 5, No.1, Part 3, 2018, pp 2803 - 2810.

[60] Chaluvaraju B V, Sangappa K Ganiger and Murugendrappa M V, Synthesis, Characterization and D.C. Conductivity Study of Polypyrrole/Molybdenum Trioxide Composites, Springer: Polymer Science Series B, Volume 56, Number 6, December-2014, pp 935 - 939.

[61] Z. M. Elimat, A. M. Zihlif and G. Ragosta, DC electrical conductivity of poly(methyl methacrylate)/carbon black composites at low temperatures, Journal of Materials Science: Materials in Electronics, November 2008, Volume 19, Issue 11, pp 1035 - 1038.

[62] Sangappa K. Ganiger, Chaluvaraju B. V., K. S. Ganiger and Murugendrappa M. V., Synthesis and Characterization of Polypyrrole/Strontium Arsenate (Ceramics) Nano composites, Malaysian Polymer Journal, Vol. 10, No. 1, 2015, pp 9-15.

[63] Himanshu Narayan, Angela M. Montano, Monica L. Hernandez, July A. Hernandez, Claudia P. Gonzalez, Cesar A. Ortiz, Synthesis, characterization and ac-conductivity measurements of polyaniline based composites with fly-ash and clinker,Journal of Material Environmental Science, Vol. 3, No. 1, 2012, pp 137 - 148.

[64] de Oliveira H. P., M. V. B. dos Santos, C. G. dos Santos and C. P. de Melo, Electrical properties of PVA/PPy blends, Synthetic Metals,Vol. 135-136, 2003, pp 447 - 448.

[65] Naveen Kumar, Narayan Bastola, Sanjeev Kumar, Rajeev Ranjan, J. Mater. Sci.: Mater. Electronics, 28 (14) (2017) 10420-10426.

[66] V. R. Kolbunov, A. S. Tonkoshkur and I. V. Gomilko, Electrical and dielectric properties of polymer composite based on vanadium dioxide, Journal of Materials Science: Materials in Electronics, June 2017, Volume 28, Issue 11, pp 8322 - 8328.

[67] Lulu Lv, Liang Huang, Pengli Zhu, Gang Li, Tao Zhao, Jianping Long, Rong Sun and Chingping Wong, SiO_2 particle-supported ultrathin graphene hybrids/polyvinylidene fluoride composites with excellent dielectric performance and energy storage density, Journal of Materials Science: Materials in Electronics, September 2017, Volume 28, Issue 18, pp 13521 - 13531.

[68] Dandan Yang, Haiping Xu, Wei Yu, Jingrong Wang and Gangkai Jiang, Solution-processed Ni–CNTs filled ferroelectric P(VDF–TrFE) composites with improved dielectric properties and thermal conductivity, Journal of Materials Science: Materials in Electronics, January 2018, Volume 29, Issue 1, pp 63 - 69.

[69] Changhai Zhang, Qingguo Chi, Lizhu Liu, Yang Chen, Jiufeng Dong, Tao MaXuan Wang and Qingquan Lei, Nano-Fe_3O_4 deposited $CaCu_3Ti_4O_{12}$/poly(vinylidene fluoride) composites with enhanced dielectric properties, Journal of Materials Science: Materials in Electronics, February 2017, Volume 28, Issue 3, pp 2502 - 2510.

[70] YanliSu, Yiqi Gu and Shane Fen, Composites of NBCTO/MWCNTs/PVDF with high dielectric permittivity and low dielectric loss, Journal of Materials Science: Materials in Electronics, February 2018, Volume 29, Issue 3, pp 2416 - 2420.

[71] Muhammad Qasim, Ahmad Naseeb, Ishtiaq Ahmad and Ghulam Mustafa, Synthesis, structural and high frequency dielectric properties of polypyrrole (PPy)/holmium ferrite composites, Journal of Materials Science: Materials in Electronics, March 2018, Volume 29, Issue 5, pp 3884 - 3890.

[72] Sangappa K Ganiger, Chaluvaraju B V and Murugendrappa M V, Synthesis, Characterization and Dielectric Property Studies of

Polypyrrole/Zinc Tungstate (Ceramic) Composites, IJIRSET, Volume 3, Issue 6, 2014, pp 13934 - 13946.

[73] M. T. Ramesan and V. Santhi, In situ synthesis, characterization, conductivity studies of polypyrrole/silver doped zinc oxide nanocomposites and their application for ammonia gas sensing, Journal of Materials Science: Materials in Electronics, December 2017, Volume 28, Issue 24, pp 18804 - 18814.

[74] Chaluvaraju B V, Sangappa K Ganiger, Pranesha T S and Murugendrappa M V, Experimental Study on A. C. Conductivity of the Polypyrrole/Ash (Paddy Husk) Nano Composites, Materials Today: Proceedings, Volume 5, No.1, Part 3, 2018, pp 2496 - 2502.

Conflict of Interest statement

No Conflict of Interest

Author contribution statement

All authors are equally contributed at different levels.