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A Closer Look at the Electrical Properties of Al2O3-Embded Polypyrrole

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KEYWORDS

PPY, Al_2O_3, TGA, Semi-conductor, Mott's Hopping

ABSTRACT:

In the present work, a simple chemistry-based polymerization process was utilized to produce clean and Al_2O_3 nanoparticle-doped polypyrrole-based samples using three different Al_2O_3 doping dosages. The prepared samples were characterized using a range of techniques. The X-ray diffraction spectra of the produced samples reveal that they are quasi-crystals. The Fourier transformation infrared spectroscopy of these samples reveals the various required fundamental bands, validating the synthesis of the expected samples. Field emission scanning electron microscopy shows the morphology of the produced materials. The thermal properties of the produced samples were analyzed using thermal gravimetric analysis. Furthermore, the electrical properties of the produced samples were investigated at temperatures ranging from 293 to 393 K. The generated samples' conductivity rises with temperature, suggesting that they are semi-conducting.

Introduction

Insulators make up most polymers in literature. Polymers can behave like semiconducting materials, according to later findings [1]. Polymers have unique optical, electrical, and thermal properties that make them helpful in many industries. Polypyrrole (PPY) and other conducting polymers are popular due to their non-redox doping [2], thermal and environmental stability, high conductivity, and practicality. As a compound, PPY characteristics vary dramatically. These composites are promising for electrochromic displays [3], temperature and current sensor devices, polymeric batteries, and electromagnetic/radio frequency interface shielding in electronics like computer and cell phone casings [4]. Combining PPY with metal oxides (MOs) improves its mechanical properties, conductivity, and processability. Achieving chemical interactions between PPY and MOs makes making PPY-MO composites difficult [5]. Researchers are still developing MO and PPY composites utilizing various ways due to their increased qualities and possible applications. Conducting polymers have been used as shells around inorganic nanoparticles like Al2O3 to generate nanocomposite materials [6]. Xia and Wang made a PPY/Al_2O_3 nanocomposite using ultrasonic irradiation. Schnitzler and Zarbin used sol-gel to synthesize Al_2O_3 nanoparticles and PPY. The most common cathode choices for lithium. PPY packed with carbonaceous fillers [7], magnetic particles, or dielectric particles combines dielectric/magnetic and electrical properties. In the presence of sodium dodecyl benzenesulfonate, Song and colleagues generated PPY/NiO nanoparticles, nanobelts [8], and nanotubes. Despite multiple studies on PPY/Al_2O_3 composites, most researchers are currently working on their synthesis and characterization [9]. As far as the author knows, no TGA study has investigated dynamical characteristics for PPY/Al_2O_3 composites. Thus, a comprehensive study using varied Al_2O_3 concentrations in PPY and methods is needed [10].

Experimental Details

Sample Preparation

Pure PPY and PPY/Al_2O_3 composite samples were synthesized via chemical oxidative polymerization. Aqueous ferric chloride and pyrrole solutions at 1.25 M and 1 M molar concentrations were prepared [11]. After that, the solutions were refrigerated for two hours. After

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that, an ice bath kept the monomer solution between 0 and 4 ºC. After dropwise adding the oxidant solution to the monomer solution [12], the polymerization reaction commences quickly and lasts 24 hours. After enough time, the solution filters through filter paper [13]. Rinse the yield with 1 M HCl and acetone until the filtrate is colorless [14]. This yield was air-dried before vacuum-drying. The dried sample was ground into powder with a pestle and mortar. The 5, 10, and 15% weight percentage Al_2O_3-doped PPY composites were synthesized similarly [15].

Experimental Techniques

At a modest scanning rate of 2º/min, the Rigaku Miniflex-II diffractometer produced XRD patterns of MgKα at an angle of 2θ (10-80º). XRD measurements determined the sample crystal structure [16]. The powder sample was mixed with dry KBr at a weight ratio of 1:20 for FTIR analysis with Shimadzu IR affinity-1 8000 spectrophotometers. Surface microstructure was examined using the EVO 18 scanning electron microscope [17].

Results and Discussion

X-ray Diffraction (XRD) Analysis

PPY and PPY/Al_2O_3 composite XRD patterns are displayed in Figure 1. Two identical peaks at 20.36 and 25.01 degrees are seen in the PPY and PPY/Al_2O_3 composite samples' XRD patterns [18], while a soldier is at 16.10 degrees. The peak strength changes significantly when Al_2O_3 nanoparticles are introduced to PPY symmetry [19], demonstrating a strong interaction between Al_2O_3 and PPY. These peaks are caused by quinoid and benzenoid rings in perpendicular and parallel orientations [20]. The processed samples' two peaks indicate a quasi-crystal structure [21].

Fourier Transform Infrared (FTIR) Analysis

FTIR spectra of pure and Al_2O_3-doped PPY composite samples are shown in Figure 2. In the FTIR spectrum, vibrations between 400 and 2000 cm-1 are apparent. Bands appear at 512, 808, 1160, 1291, 1483, and 1583 cm-1. Para-disubstituted aromatic rings and C-H out-of-plane bending vibration cause 512 and 808 cm-1 bands. An apparent band at 1291 cm-1 shows C-N stretching vibrations. Curved planes cause C-H vibration at 1160 cm- [22]. The 1460-1600 cm-1 bands are likely driven by non-symmetric C6 ring stretching modes. The peak at 2312 cm-1 is created by aromatic C-H stretching vibrations, while the band at 2950-3300 cm-1 is due to aromatic amine N-H stretching [23].

Figure 3(a-d) shows typical FESEM images for pure PPY and PPY/Al_2O_3 composite samples. FESEM images of current samples show particles with the same morphology as clean and Al_2O_3-doped PPY samples [24]. The composite samples FESEM images show no Al_2O_3 nanoparticles, possibly because they've been integrated into the PPY matrix. Here, Al_2O_3 nanoparticles are the core and PPY the shell [25].

Conclusion

PPY and Al_2O_3-doped PPY composite samples were synthesized via chemical oxidative polymerization. PPY-based pure and composite samples in the emerald salt form have significantly conducting state peaks of quinoid and benzenoid rings in their FTIR spectra. XRD patterns show that present samples are quasi-crystal. This shows that sample stability increases with Al_2O_3 nanoparticle doping. FESEM images show particles 1–10 um.

References

1 Röhrl, M., Ködel, J. F., Timmins, R. L., Callsen, C., Aksit, M., Fink, M. F., ... & Biersack, B. (2023). New Functional Polymer Materials via Click Chemistry-Based Modification of Cellulose Acetate. *ACS omega*, *8*(11), 9889-9895.

2 Roy, A., Manna, K., Dey, S., & Pal, S. (2023). Chemical modification of β-cyclodextrin towards hydrogel formation. *Carbohydrate Polymers*, *306*, 120576.

3 Kumar, V., Lal, K., & Tittal, R. K. (2023). The fate of heterogeneous catalysis & click chemistry for 1, 2, 3-triazoles: Nobel prize in chemistry 2022. *Catalysis Communications*, *176*, 106629.

4 Gerdroodbar, A. E., Alihemmati, H., Bodaghi, M., Salami-Kalajahi, M., & Zolfagharian, A. (2023). Vitrimer chemistry for 4D printing formulation. *European Polymer Journal*, *197*, 112343.

5 Hoque, M., Alam, M., Wang, S., Zaman, J. U., Rahman, M. S., Johir, M. A. H., ... & Yoon, M. H. (2023). Interaction chemistry of functional groups for natural biopolymer-based hydrogel

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(4), 631-634 | ISSN:2251-6727

design. *Materials Science and Engineering: R: Reports*, *156*, 100758.

6 Sheldon, R. A. (2023). The E factor at 30: a passion for pollution prevention. *Green Chemistry*, *25*(5), 1704-1728.

7 Meskher, H., Ragdi, T., Thakur, A. K., Ha, S., Khelfaoui, I., Sathyamurthy, R., ... & Lynch, I. (2023). A review on CNTs-based electrochemical sensors and biosensors: unique properties and potential applications. *Critical reviews in analytical chemistry*, 1-24.

8 Reddicherla, U., Ghoreishian, S. M., Kumar, K., Dhiman, D., Rani, G. M., Huh, Y. S., & Venkatesu, P. (2023). Deep eutectic solvents induced changes on the phase transition behavior of smart polymers: A sustainable future approach. *Physical Chemistry Chemical Physics*.

9 Baghdasaryan, O., Khan, S., Lin, J. C., Lee-Kin, J., Hsu, C. Y., Hu, C. M. J., & Tan, C. (2023). Synthetic control of living cells by intracellular polymerization. *Trends in Biotechnology*.

10 Duan, Q. Y., Zhu, Y. X., Jia, H. R., Wang, S. H., & Wu, F. G. (2023). Nanogels: Synthesis, properties, and recent biomedical applications. *Progress in Materials Science*, 101167.

11 Acebedo, B., Morant-Miñana, M. C., Gonzalo, E., Ruiz de Larramendi, I., Villaverde, A., Rikarte, J., & Fallarino, L. (2023). Current status and future perspective on lithium metal anode production methods. *Advanced Energy Materials*, *13*(13), 2203744.

12 Gong, X., Liu, Q., Wang, H., Wan, P., Chen, S., Wu, J., & Wu, S. (2023). Synthesis of environmental-curable CO2-based polyurethane and its enhancement on properties of asphalt binder. *Journal of Cleaner Production*, *384*, 135576.

13 Lee, K. J., Capon, P. K., Ebendorff-Heidepriem, H., Keenan, E., Brownfoot, F., & Schartner, E. P. (2023). Influence of the photopolymerization matrix on the indicator response of optical fiber pH sensors. *Sensors and Actuators B: Chemical*, *376*, 132999.

14 Dyer, W. E., & Kumru, B. (2023). Polymers as Aerospace Structural Components: How to Reach Sustainability?. *Macromolecular Chemistry and Physics*, *224*(24), 2300186.

15 Tang, H., Zhang, M., Zhang, Y., Luo, P., Ravelli, D., & Wu, J. (2023). Direct synthesis of thioesters from feedstock chemicals and elemental sulfur. *Journal of the American Chemical Society*, *145*(10), 5846-5854.

16 Farhan, A., Arshad, J., Rashid, E. U., Ahmad, H., Nawaz, S., Munawar, J., ... & Bilal, M. (2023). Metal ferrites-based nanocomposites and nanohybrids for photocatalytic water treatment and electrocatalytic water splitting. *Chemosphere*, *310*, 136835.

17 Lozano, P., & García-Verdugo, E. (2023). From green to circular chemistry paved by biocatalysis. *Green Chemistry*, *25*(18), 7041-7057.

18 Li, H., Pan, F., Qin, C., Wang, T., & Chen, K. J. (2023). Porous Organic Polymers-Based Single-Atom Catalysts for Sustainable Energy-Related Electrocatalysis. *Advanced Energy Materials*, *13*(28), 2301378.

19 Harth, F. M., Hočevar, B., Kozmelj, T. R., Grojzdek, E. J., Blüm, J., Fiedel, M., ... & Likozar, B. (2023). Selective demethylation reactions of biomass-derived aromatic ether polymers for bio-based lignin chemicals. *Green Chemistry*.

20 Chansoria, P., Rütsche, D., Wang, A., Liu, H., D'Angella, D., Rizzo, R., ... & Zenobi-Wong, M. (2023). Synergizing Algorithmic Design, Photoclick Chemistry and Multi-Material Volumetric Printing for Accelerating Complex Shape Engineering. *Advanced Science*, *10*(26), 2300912.

21 Barbosa, J. C., Fidalgo-Marijuan, A., Dias, J. C., Gonçalves, R., Salado, M., Costa, C. M., & Lanceros-Méndez, S. (2023). Molecular design of functional polymers for organic radical batteries. *Energy Storage Materials*, 102841.

22 Bao, Z., Xian, C., Yuan, Q., Liu, G., & Wu, J. (2019). Natural polymer-based hydrogels with enhanced mechanical performances: preparation, structure, and property. *Advanced Healthcare Materials*, *8*(17), 1900670.

23 Plank, M., Frieß, F. V., Bitsch, C. V., Pieschel, J., Reitenbach, J., & Gallei, M. (2023). Modular Synthesis of Functional Block Copolymers by Thiol–Maleimide "Click" Chemistry for Porous Membrane Formation. *Macromolecules*, *56*(4), 1674-1687.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(4), 631-634 | ISSN:2251-6727

24 Das, M., Parathodika, A. R., Maji, P., & Naskar, K. (2023). Dynamic chemistry: the next generation platform for various elastomers and their mechanical properties with self-healing performance. *European Polymer Journal*, *186*, 111844.

25 Wu, G., Zhou, H., Zhang, J., Tian, Z. Y., Liu, X., Wang, S., ... & Lu, H. (2023). A high-throughput platform for efficient exploration of functional polypeptide chemical space. *Nature Synthesis*, *2*(6), 515-526.

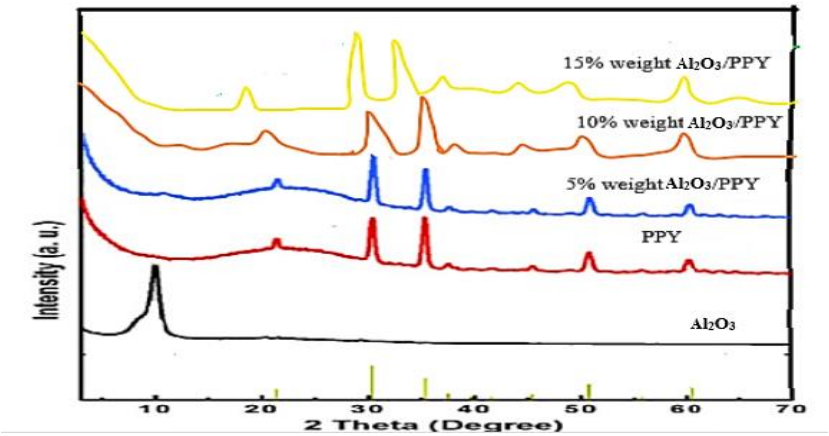

Figure 1: XRD patterns of PPY and PPY/Al_2O_3 composites

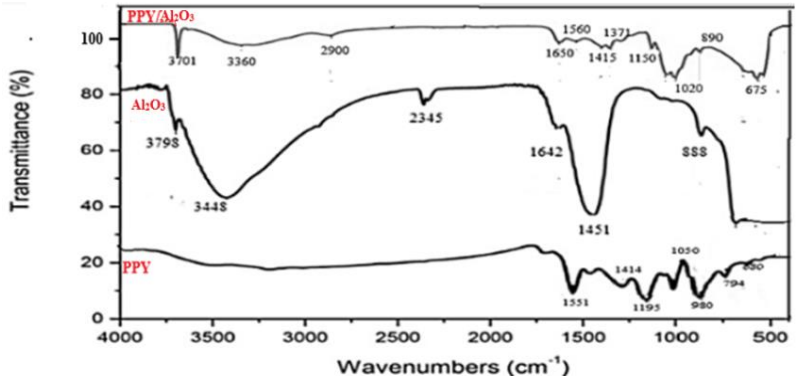

Figure 2: FTIR spectra of PPY and PPY/Al_2O_3 composites

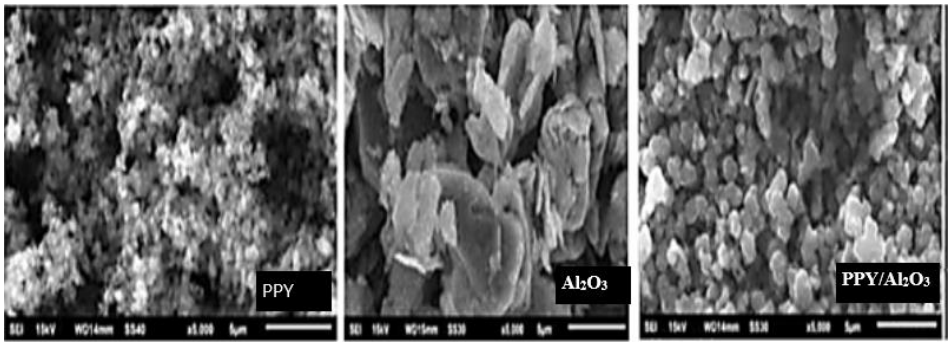

Figure 3: FESEM images of PPY and PPY/Al_2O_3 composites