

ABSTRACT

The advancement of smart and wearable electronic textiles has significantly impacted various industries, including healthcare, sports, defense, and consumer technology. These innovative fabrics integrate electronic functionalities into traditional textiles, enabling applications like real-time health monitoring, adaptive clothing, and interactive fashion. A key challenge in developing smart textiles is achieving flexibility, durability, and efficient electrical conductivity while maintaining the comfort and mechanical properties of conventional fabrics. This study explores the development of electrically conductive fibers by incorporating different morphologies of conducting polymeric nanostructures as fillers into traditional textile fibers. Various fabrication methods, including wet spinning, are examined to enhance fiber performance in terms of conductivity, mechanical strength, and flexibility. The findings highlight the importance of material selection, processing techniques, and structural design in optimizing the electrical and mechanical properties of these fibers. By advancing the integration of conductive materials in textiles, this research contributes to the evolution of next-generation wearable electronics, offering new possibilities for functional, durable, and adaptable smart fabrics.

In the first part of the study, the chemical oxidative method was used for the synthesis of poly(pyrrole) (PPy) nanostructures, i.e., poly(pyrrole) nanoparticles (PPyNPs) and poly(pyrrole) nanotubes (PPyNTs). The PPyNTs showed a 60-90 nm diameter and average length of 8-10 microns. Meanwhile, PPyNPs were formed in clusters. To make them

usable, sonication was carried out. After sonication, the clusters could be broken down, and the size of the NPs was observed to be approximately 100-200 nm in diameter using DLS. The bulk electrical conductivity of PPyNPs and PPyNTs compressed in a pellet form was 17 ± 0.2 and 90.9 ± 0.6 S/cm, respectively.

Electrically conductive composite fibers of nylon 6 (Ny)-poly(pyrrole) nanotubes (PPyNTs) by solution spinning were successfully fabricated. The incorporation of PPyNTs in nylon 6 was found to increase the electrical conductivity of the composite fibres significantly. The high aspect ratio of PPyNTs could provide a good electrically conductive network and show a percolation threshold at a low concentration of ~ 2 wt% of PPyNTs in the nylon matrix compared to that of PPyNPs. The composite fibers exhibited good DC electrical conductivity of ~ 0.002 S/cm at only 6 wt% of PPyNTs. The influence of PPyNT concentration on the morphology and physical, chemical, and electrical properties of the fibers have been investigated.

In the next part of the thesis, with the aim of preparing stretchable conducting composite fibres, nylon-6 was replaced with polyurethane. The rheological behavior of polymer solutions plays a crucial role in fabricating composite fibers via solution spinning. This study investigates the influence of poly(pyrrole) (PPy) nanostructures, including PPyNPs and PPyNTs, on the viscoelastic and shear-thinning properties of polyurethane (PU)-based dopes. The dispersion stability of PPy nanostructures in N, N-dimethylformamide (DMF) was optimized using controlled sonication, followed by rheological characterization through steady-state and oscillatory shear measurements. The viscosity of PU solutions

increased significantly with PPyNT incorporation, exhibiting strong shear-thinning behavior due to polymer-filler interactions and the formation of percolated networks at higher concentrations. Frequency sweep experiments demonstrated a transition from liquid-like to solid-like behavior as PPyNT content increased, with crossover points in storage (G') and loss (G'') moduli shifting towards higher frequencies. In contrast, PPyNP-filled solutions exhibited lower viscosities and minimal shear-thinning, indicating reduced filler interaction and weaker percolation effects. These results provide valuable insights into the processing parameters necessary for optimizing fiber spinnability and structural integrity. The enhanced rheological response of PPyNT-based solutions highlights their potential for developing stretchable, conductive composite fibers suitable for wearable electronic textiles and advanced functional materials.

Polyurethane (PU) and poly(pyrrole) nanostructures were used to fabricate stretchable and flexible composite fibers. Two nanostructures- poly(pyrrole) nanoparticles (PPyNPs) and nanotubes (PPyNTs) were compared as additives in the range of 2 to 12 wt%. The aspect ratio of nanostructures profoundly affected the rheology, spinning behavior, and properties of the resulting fibers. With the same amounts as PPyNPs, the PPyNTs exhibited better spinnability, higher mechanical properties, and significantly greater electrical conductivities. The composite fibers with 12 wt% of PPyNTs showed a high conductivity of 0.21 S/cm compared to 8.6×10^{-8} S/cm with 12 wt% of PPyNPs. Further, the fibers showed high stability in repeated deformations. The fibers may find applications as connecting wires in wearable e-textiles. Thus, using poly(pyrrole) nanotubes, flexible and stretchable composite fibers could be developed by solution spinning.