Abstract

The research in the field of materials science and engineering has seen an exponential growth in recent years. Among the different fields of research, one of the fascinating domains that is garnering significant attention is the domain of wearable electronics, cutting across different segments including healthcare, human-machine interface, and energy harvesting applications. Researchers from various disciplines are actively focusing on different aspects that enhance the performance of these devices. The major and critical component for any wearable device is its sensors and power sources. While optics-based sensors are heavily used, there is a strong demand for the use of polymer nanocomposite-based sensors, as well. This is mostly guided by the freedom one can achieve in terms of the form factor of the wearable device. Similarly, for powering the wearable device, batteries are used. This also introduces a bottleneck to the form factor of the wearable device. Accordingly, there is a growing demand in the domain of self-powered wearable materials that can harness energy of their own. It is worth mentioning that polymer nanocomposites are also reported to perform well as nanogenerators under specific conditions. Accordingly, in this thesis, an effort has been made to address both the aforementioned points using polymer nanocomposites. In this thesis, liquid isoprene rubber (LIR) and its derivatives have been used as the model polymer material. Multiwalled carbon nanotubes (MWCNT) and their functionalized derivatives are used as the functional filler. Thereafter, a two-fold strategy was adopted to frame the thesis. In the first strategy, the electrical conductivity of the carbon nanotube was leveraged to make the electrically resistive type sensors utilizing the liquid isoprene rubber and carbon nanotube. While in the second strategy, on top of the electrical conductivity, tuning of the dielectric properties of the polymer composites was utilized effectively to develop self-powered materials.

Accordingly, in the first work, a functional composition was developed by utilizing the methyl ester succinic acid functionalized liquid isoprene rubber and carboxylic acid functionalized carbon nanotube. Various nanocomposites were prepared by varying the volume fraction of carbon nanotube. Thereafter, the electrical properties of the composition were tested. Further, the sensing capabilities of the functional material were evaluated. The developed sensor was capable of sensing temperature, strain, and pressure; hence, the sensitivity of various stimuli was studied. As an application, the sensors were utilized for monitoring various physiological parameters in a contact mode. Following that, in the second work, a different composition was tested for its sensing capabilities for the detection of human pulse and critical cardiovascular parameters in a contact mode. This time, an effort was made to develop a cross-talk-free sensor, indicating that the sensor is only responsive to one single stimulus. The developed composition was highly strain sensitive with an exceptionally high gauge factor, deemed necessary for the appropriate measurement of the deformation induced by the radial pulse due to the flow of blood. The previous two works were based on the contact mode of flexible sensors for healthcare monitoring applications. In the third work, a non-contact mode of temperature sensor was developed using LIR and MWCNT composition. In this particular study, the impact of crosslinking of the LIR on its electrical properties was also evaluated. In the study window, it was noted that electrical conductivity was lower when the LIR was crosslinked. However, it helped in getting better stability over multiple cycles, over the un-crosslinked samples. Thereafter, the temperature-sensing ability was tested further, and it was observed that in a non-contact mode, the optimized sample could detect the subtle changes in temperature, indicating its potential for application domains like human-machine interface (HMI). Further, the optimized sensor was leveraged for monitoring human respiration in a non-contact mode, indicating its utility in the healthcare domain. In the fourth work, a self-powered triboelectric

nanogenerator (TENG) was developed by leveraging maleic anhydride functionalized liquid isoprene rubber and amine functionalized carbon nanotubes compositions. Initially, the dielectric properties of all the nanocomposite formulations were studied. The highest output of TENG devices correlated with the bidirectional conductivity, dielectric properties, and charge transfer mechanism. Finally, the developed TENG device was integrated into a wireless communication system for the demonstration of HMI. Thus, this thesis explored the potential of LIR-CNT-based composition for applications in next-generation flexible sensors and triboelectric nanogenerators.
Keywords: *Liquid isoprene rubber, multiwalled carbon nanotube, flexible sensors, triboelectric nanogenerator, sensitivity.*