# Chapter 8

# Summary and Conclusions

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The synthesis of different nanoparticles, fabrication of BMI-epoxy nanocomposites with different nanofillers and their characterization were investigated in this study. This is an attempt to develop a novel polymer nanocomposite as a substitute for ceramic insulator with enhanced electrical, thermal and mechanical properties for high dielectric application. The entire thesis focus on improving the dielectric properties of the nanocomposites by making use of nanofiller with high dielectric permittivity.

Incorporating fillers with high dielectric constant was adopted to prepare polymer composites with high dielectric properties. Barium titanate (BT) is the most common and well known ferroelectric perovskite oxide and has widespread applications due to its high dielectric constant and high piezoelectric coefficient. Attempts were made to incorporate readily available, more common, less expensive and ecofriendly material- sodium potassium tartarate tetrahydrate, commonly called Rochelle salt (RS). The nanocomposites embedded with surface hydroxylated and chemically modified nanofillers exhibit significant dielectric properties that may be ascribed to the improved interfacial interaction between the filler and the matrix, thereby increasing the uniform dispersion of nanoparticles with reduced agglomeration. These nanocomposites also exhibit high dielectric constant, low dielectric loss and good compatibility. The surface of the BT nanoparticles can be modified either by surfactant adsorptions, polymer coatings or chemical modifications to avoid aggregation and improve the dispersion capabilities of BT nanoparticles. The simplest and easiest method of surface modification, hydroxylation using $H_2O_2$ treatment was adopted to synthesise surface hydroxylated barium titanate nanoparticles (BTOH).

Throughout the study, we could arrive at the conclusion that BMI-epoxy nanocomposites with an optimum amount of nanofiller (2 and 3 weight %) showed remarkable enhancement in electrical and thermo-mechanical properties. Highest dielectric permittivity was exhibited by BMI-epoxy composite with 2 weight % of BTOH nanofiller and this may be attributed to the increased interface compatibility as a result of surface modification of the nanofiller.

Attempts were made to improve the thermo-mechanical, dielectric and electromagnetic interference shielding effectiveness (EMI-SE) of BMI-epoxy composites with different fillers such as $BaTiO_3$ (BT), Rochelle salt (RS) and surface hydroxylated $BaTiO_3$ (BTOH) with the incorporation of conductive filler, multiwalled carbon nanotube (MWCNT) as secondary reinforcement along with silane coated E glass fiber (SC-EGF) which act as primary reinforcement in BMI-epoxy composites with different fillers. Tensile strength, flexural strength and dielectric permittivity of BMI-epoxy-MWCNT nanocomposite with 2 weight % of BTOH nanofiller were increased 2.78, 1.22 and 1.50 times respectively as compared to BMI-epoxy-BTOH nanocomposite without MWCNT filler. Highest dielectric permittivity around 674 and minimum value of dielectric loss 0.017 was obtained for BMI-epoxy-MWCNT composite with BTOH nanofiller and this composite stands as a promising candidate for high dielectric applications.

## 8.1 Practical significance of this work

- Blending of BMI and epoxy resin has been done in order to overcome the brittle nature of the BMI resin as well as to overcome the poor weathering resistance and inferior moisture absorption nature of epoxy resin leading to a novel BMI-epoxy matrix with enhanced thermal degradation temperature, glass transition temperature, resistance to moisture absorption, tensile and flexural strength.
- Incorporation of nanofiller with high dielectric constant leads to enhancement in dielectric properties of the fabricated polymer nanocomposites.
- Incorporation of MWCNT leads to enhancement in thermo-mechanical, electrical and EMI-SE of BMI-epoxy composites with different nanofillers such as BT, RS and BTOH.
- Polymer nanocomposites with an optimum amount of (2 and 3 weight %) nanofiller show remarkable enhancement in dielectric, thermal and mechanical properties making BMI-epoxy nanocomposites a promising candidate for high dielectric applications and as better insulating materials.

## 8.2 Future outlook of our investigation

Even though the fabricated BMI-epoxy nanocomposites with different nanofillers such as BT, RS and BTOH nanoparticles stand as a potential candidate for high insulating and dielectric applications, according to our investigation, further works could be performed for a better understanding of various properties and applications of these nanocomposites.

The following works could be performed in order to design and explore the applicability of BMI-epoxy nanocomposites.

- Fabrication of BMI-epoxy composites using other nanofillers like strontium titanate (dielectric constant ~ 800), barium strontium calcium titanate (dielectric constant ~ 16,600) and calcium copper titanate (dielectric constant ~ 10,000) for further enhancement in dielectric properties.
- Modification of Rochelle salt crystals and BTOH to use them as nanofillers for synthesising BMI-epoxy nanocomposites with better insulating and dielectric properties.
- SAXS measurements for interphase characterisation studies.
- Impedance and ferroelectric studies of the fabricated nanocomposites.
- Fabrication of BMI-epoxy-MWCNT composites using other nanofillers like strontium titanate, barium strontium calcium titanate and calcium copper titanate for further enhancement in dielectric properties, conductivity studies and EMI-SE.