CHAPTER-5

CONCLUSION
5.0 CONCLUSION

The aim and objectives of the work were detailed in the thesis in the Chapter I page no 53. Accordingly an exhaustive literature search was carried out on polyurea, polyurethane-urea copolymers, polyamines, epoxy-PDMS copolymers, nanoparticles and modifiers was carried out and the work on new systems was planned and to best of our knowledge were undertaken aiming at a detailed study and significant contribution in the area.

The homo and copolymers of polyurea, polyurethane, polyamines, epoxy-polydimethylsiloxane copolymers were synthesized and characterized. Their thermal, electrical and mechanical properties were studied. The nanoparticles of alumina, aluminum trihydroxide and calcium carbonate were prepared by chemical processes and the process parameters were optimized. The nanoparticles were characterized by XRD and SEM.

Attempts were made to develop composites using synthesized nanoparticles for industrial applications such as coatings and other composite materials.

The polyurea were synthesized using several combinations of aromatic isocyanate and aliphatic amines keeping in view of their applications in formulating coatings. A detailed study was carried out using different monomers incorporating hard and soft segments in polyurea chain depending upon the requirement of specific application. The homopolyurea and its copolymers were evaluated for thermal, electrical and mechanical properties such as volume/surface resistivity, dielectric constant, dissipation factor, dielectric strength, tensile strength and elongation at break respectively. Polyurea resulted in coatings of high performance properties such as abrasion resistance, better impact strength and flexibility for manufacturing coating, composites and sheets.

On evaluating the results it is evident from the results tabulated in Table 3.6, it was observed that, on increasing the soft segments the thermal stability of the polymer decreases and on increasing the hard segments the electrical properties of polyurea improve significantly.
The mechanical properties of polyurea and their copolymers were determined using universal testing machine, Hounsfield, U.K. It was also observed that the soft segments affect the tensile and elongation significantly as evident from the results included in Table 3.7.

The polyurea PT-1 to PT-4 showed better mechanical properties, both tensile strength and elongation in comparison to PU-1 to PU-8. The tensile strength was found in the range of 9.98-4.74 N/mm² and elongation at break increased from 181 to 860 % in consistence with tensile properties. These properties open a new area of application of polyurea and their copolymers for developing products for industrial applications.

The polyurethane polymers were synthesized using the aromatic isocyanate and the aliphatic diols in presence of catalyst and solvent at high temperature varying the monomer concentration to incorporate hard and soft segments in the polymer chains. The polyurethane samples were evaluated for thermal, electrical and mechanical properties. This work was carried out with an objective of comparing the properties of polyurea and their copolymers. The results are presented in Table 3.9-3.10.

The dielectric strength of polyurethane PUP-1 to PUP-3 synthesized using the polyethylene glycol and castor oil was found to be 31-34 kV/mm and resistivity was $10^{14}$ Ω. The polyurethane PUP-4 to PUP-7 synthesized using the polypropylene glycol PPG-2000 and castor oil exhibited the inferior dielectric properties compared to polyurethanes PUP-1 to PUP-3. The electrical properties decreased on increasing soft segments in polymer chain. The tensile strength of polyurethane sample was observed in the range of 6-28 N/mm² and elongation in between 180-205 %.

The polyurethane-urea copolymers were synthesized using the aromatic isocyanate and aliphatic polyols and amines. Different copolymers were synthesized varying the concentration of PPG-2000 and amines and these polymers were evaluated for thermal, electrical and mechanical properties. The effect of solvents such as MEK and toluene on synthesis of copolymers was studied. It was observed that there was no change in properties of polyurethane-urea copolymer prepared in different solvents.

The dielectric strength of the copolymers prepared using the polyoxypropylene diamines coded was PUU-1 to PUU- 6 is observed in the range of 35-44 kV/mm. The copolymers synthesized using the polyoxypropylene triamine were not having
significant dielectric properties. The incorporation of trifunctionality in the polymer led to higher cross linking and less flexibility.

The polyamines with different amino contents were synthesized as chain extenders and cross linking agents for polyurea and its copolymers. Due to their high reactivity polyurea and its copolymers formed gel immediately. Thus they were not suitable as cross linking agents from application point of view and further work on curing of polyurea resin was not carried out.

The polyamines coded as PO1, PO2 and PO3 were prepared by varying the concentration of aniline and formaldehyde while keeping the concentration of 4,4'-diaminodiphenylmethane constant. These dark resinous materials were used as a cross linking agents for commercial epoxy resin.

The synthesized polyamines have number of amino groups and each amino functional group takes part in cross linking process which results in highly cross linked 3D network structure. A detail study was carried out for curing epoxy resin using polyamines coded as PO1, PO2 and PO3 in different ratio ranging from 25 to 35% at high temperature. The products were evaluated for electrical and mechanical properties. The polyamine coded as PO3 was found to be very efficient curing agent since it contained more number of amino functional groups. It cure epoxy resin in 15 minutes whereas PO1 having lower number of amino groups took 320 minutes for curing epoxy resin under same conditions.

PO3 reduces the curing time cycle and can be used for curing the composites in 1/20\textsuperscript{th} time of PO1. It is evident that the higher production rate of epoxy composite may be obtained using PO3.
Epoxy composites are inferior in mechanical properties such as poor impact strength, brittleness etc. To overcome this problem a new matrix epoxy-PDMS was prepared incorporating PDMS content ranging from 5 to 30 %. PDMS content was optimized to achieve the high performance properties and it was observed that S-3 sample having 10% PDMS is suitable product for making epoxy composite of high impact strength. The electrical as well as impact strength of epoxy-PDMS composites improve significantly. The data are presented in Table 3.23 and Table 3.24

Epoxy-PDMS copolymers may have wide applications for manufacturing the products for electrical industries such as current transformers, potential transformers and for coating applications of high performance dielectric properties.

The nanoparticles of alumina, ATH and calcium carbonate were prepared using the wet chemical route. These nanoparticles were characterized by XRD and SEM for crystallite size and the particle size of the nanomaterials respectively. The crystallite size of alumina nanoparticles was found to be 8.19 nm to 8.36 nm. The agglomerated particle size was obtained in the range of 300-900 nm. The purity of samples was confirmed using the EDX analysis. The calcium carbonate nanoparticles were prepared using matrix mediated growth and the crystallite size obtained was 84.93 nm and agglomerated particle size in the range of 285-350 nm. These nanoparticles were modified using the quaternary compounds and were used for the preparation of nanocomposites for industrial applications.

Exhaustive studies on synthesis and characterization of polyurea and its copolymers have been carried. These polymers may have wide industrial applications such as coatings and composites in allied industries.