7.1 Summary

- The BTC nanocomposite was synthesized by solid state method and sintered at 950 °C for different durations 3, 6, 9 and 12 h. XRD studies confirmed the presence of $BaTiO_3$ (BTO) and $CaCu_3Ti_4O_{12}$ (CCTO) as the primary phases along with CuO and $CaTiO_3$ as the minor phases in the composite. The average particle size of the BTC nanocomposite sintered for 12 h was found to be 30 ± 10 nm obtained by TEM and XRD analysis. The average grain sizes obtained by SEM analysis were found to be 269 nm, 309 nm, 342 nm, and 734 nm for sintering durations of 3, 6, 9 & 12 h respectively. The value of dielectric constant of the BTC nanocomposite sintered for 3 h is higher than that of 6, 9 and 12 h at 1 kHz and low dielectric loss sintered for higher duration (12).

- The solid state route was successfully used to synthesize CC-BT composite at lower temperature. XRD confirmed the presence of $CaCu_3Ti_4O_{12}$ and $BaTiO_3$ nanocrystalline phases co-existed in the nanocomposite. TEM bright field image showed the formation of nanoparticles with average size 40 ± 5 nm. The surface morphology demonstrated the formation of large and small grains with bimodal structure. The average and root mean square roughness were found to be 1.41 nm and 2.24 nm respectively by atomic force microscopy study. The dielectric constant of CC-BT composite was found to be 6.23×10^3 at 100 Hz. The presence of semiconducting grains and insulating grain boundaries in the composite supported the IBLC mechanism.

- In this composite, $Bi_{2/3}Cu_3Ti_4O_{12}$ primary phase formation was confirmed by XRD at a lower temperature (≤ 870 °C) compared to the conventional ceramic method. TEM demonstrated the formation of nano-particles in the range 90 ±10 nm. The average and Route Mean Square (RMS) roughness of BT-BCT 5 composite were found to be 4.3 nm and 13.0 nm respectively with the help AFM study. The sample sintered at 870 °C for 12 h exhibited very high dielectric constant (ε_r) ≈ 48904 at 100 Hz and 503 K, and its loss tangent (tan δ) ≈ 0.32 at 100 kHz and 308 K. These results show that the nanocomposite has better dielectric properties than $Bi_{2/3}Cu_3Ti_4O_{12}$ ceramic.

- A composite BC-BT with a particle size of 70±10 nm has been successfully synthesized by modified solid state route. XRD confirmed the formation of $Bi_{2/3}Cu_3Ti_4O_{12}$ and $BaTiO_3$ phases in BC-BT composite at 870 °C for different sintering durations (4, 8, 12 and 16 h). The SEM and AFM studies suggest that grain boundary effects are responsible for enhanced dielectric permittivity and low value of tan δ in the BC-BT composite sintered for short duration. The grains resistance (R_g) was found to be 37.30 Ω. The exponent value (s) of the composite was found in the range of 0.40-0.51 for the BC-BT composite. Magnetic behavior of the composite indicated a weak ferromagnetic phenomenon in M-T and M-H curve with display of ferromagnetic to paramagnetic transition.

Among the four synthesized composites, BC-BT composite has highest dielectric constant (ε_r = 3802) and lowest dielectric constant (tan δ = 0.65) at 308 K and 1 kHz.

7.2 Suggestions for future work

It is essential to study the influence and to find the proper processing parameters to obtain the above composite with optimized desirable properties .With a view to understand and improve the dielectric properties of these composites the effect of different parameters such as sintering temperature, Sintering time, ceramic composition and different processing methods for preparation etc. can be studied.

- To optimize different processing parameters it is essential to study the thermal decomposition behavior of the precursor powder, surface morphology, particle size and phase purity of the ceramics,
- For the optimization of the sintering duration to achieve enhanced densification of the sintered CCTO-BTO based composite, study of the densification and grain growth behavior during intermediate and final stage of sintering are of potential importance.
- It may be useful to study dielectric properties with different electrodes, as a function thickness of samples and samples prepared under different processing parameters such as sintering and annealing atmosphere in the presence of different gases like nitrogen (N_2), Argon (Ar)etc. during annealing of the samples and cooling rate after annealing etc. to understand higher value of dielectric constant . This will also throw light on the presence and role of oxygen vacancies.
- Materials synthesis, characterizations and processing of high dielectric constant ceramics for Capacitor applications are challenging for realization of the passive technology. The impedance study give information about grain, grain boundaries and the

electrode effects for electrical and dielectric properties of the ceramic. The detailed studies of impedance spectroscopy will be carried out for these composites.

- Studies on the identification of phases present in the composites from XRD and HR-TEM analysis is essential for further investigation.
- Atomic force microscopy studies shows that the surfaces of thin film deposition of some sample were smooth, compact and crack-free surface fully converted by grain. The corresponding watershed picture of the two dimensional figure of AFM will be helpful to study the nature of grain and grain boundaries.