CHAPTER 7

Conclusion

7.1 Conclusion

The present chapter is devoted to summarize and conclude the works carried out in various chapters of this thesis as discussed in the following:

Chapter1 discusses a brief introduction to porcelain insulator their application and essential raw materials. A detailed literature survey on the porcelain insulator have been carried out; it helped to identify more suitable effective material and methods for the preparation of base material for ceramic porcelain insulator.

Chapter 2 presents the method or techniques for the manufacturing of samples for ceramic porcelain insulator, its measurement, and subsequent characterization were studies.

An electrically and mechanically strong porcelain insulator were prepared by using an optimum amount of low-cost clay composition with varying concentration of SiO_2 and Al_2O_3 (in wt. %) with the base composition. The base ceramic porcelain composition contains ball clay (20 wt. %), kaolin (25 wt. %), feldspar(10 wt. %) and alumina (45 in wt. %). Chapter 3 investigates the effect of sintering temperature and SiO_2 wt. % addition on ceramic porcelain insulator. The following results were observed when alumina was replaced with silica in the base ceramic porcelain composition by 15 wt. % sintered at 1350°C with a soaking period of 2 hours.

- The ceramic particles tend closer to each other and lead to densification, reduction in porosity.

- Water absorption of the bodies decreased due to the non-availability of microcracks and pores which is filled by melting glassy content of silica with alumina.
- Bending strength of porcelain insulator bodies increases up to 129 ± 5 MPa, the compressive strength of 202 ± 5 MPa and tensile strength of 36 ± 3 MPa were observed for sample sintered at 1350°C.
- The measured value of dielectric strength (KV/mm) for the above composition is 20.14 ± 1 KV/mm.
- Dielectric constant lies in between 5.75 to 4.9, and dielectric loss measured 0.05 to 0.12 within the microwave frequency range (from 2 to 20 GHz) at room temperature.

After further addition of 10 wt. % silica, the strength decreases because of the excess silica present in the composition start to developing a β- cristobalite phase. The β-cristobalite phase of silica is dependent on the sintering temperature and increases with the increasing temperature. There is a change in phase transformation from β to α-cristobalite phase when sample starts to cool down, this phenomenon occurs due to the volume contraction happened during this time and leads to micro-crack generation in the sintered samples. Composition A3 and A4 gives better result according to the mechanical and electrical point of view.

In chapter 4, ZrO_2 concentration (from 0 to 30 wt. %) reinforcement with the composition A4 for increasing the mechanical as well as electrical properties of ceramic porcelain insulator (CPI). The effect of sintering temperature and ZrO_2 wt % is analyzed. XRD analysis revealed the different crystalline phase formed in sintered samples are the zircon ($ZrSiO_4$), β-cristobalite m-ZrO_2, and t-ZrO_2 phase. The peak intensity of β-cristobalite phase going to decreases as we increase the concentration of ZrO_2 for all the samples sintered at 1250°C and 1350°C. Samples with 20 wt. % ZrO_2 content resulted in higher bending, compressive and tensile strength, bulk density with least porosity compared to those containing 30 wt. % ZrO_2. The following effects were observed when alumina was replaced with zirconia in the base electrical ceramic porcelain composition by 20 wt. % sintered at 1350°C with a soaking period of 2 hours.

- The water absorption and porosity dropped to a minimum due to the unavailability of microcracks and pores which is filled by melting glassy content of silica with zirconia-alumina composite.
- The measured value of MOR and compressive strength for PI were 138 ± 5 MPa and 221 ± 10 MPa, respectively observed.

The composition having 30 wt. % ZrO_2, AC dielectric constant lies in between 5.1 to 4.4 and dielectric loss 0.09 to 0.1 is measured for the microwave frequency range of 4 to 20 GHz at room temperature for the sample sintered at 1350°C. The value of AC dielectric constant is observed to be increasing with the increase in ZrO_2 concentration and decreases with the increment of the operational frequency range. As we raise the temperature, from 30° to 190°C the dielectric and loss value start growing slowly. At 6 GHz, for all the prepared samples yield good dielectric value with minimum dielectric loss is achieved.

- The maximum approximate real dielectric permittivity (ε′) value for a sintered (1350 °C) sample having ZrO_2 (30 wt. %) at 100 KHz, 1 MHz is 15, and 14.7 respectively were observed at room temperature. The value of ε′ is perceived to be increasing with ZrO_2 content and decreases with the increment of frequency (from 20 Hz to 1 MHz) range.

Zirconia is expansive according to the economical point of view, so we aim to decrease the concentration of zirconia. For that purpose, we take a composition A3 (from chapter 3) and adding zirconia concentration (from 0 to 10 wt. %). The whole goal of studies is to understand the effect of sintering behavior on physical, electrical, mechanical, thermal and dielectric properties of alumina-based porcelain after doped with zirconia concentration (0 to 10 wt.%). The following things were observed when alumina was replaced with zirconia in the base porcelain composition by 7.5 wt. %.

- The bulk density increased and porosity decreased when zirconia content was increased to 7.5% due to the intense bond formation of zirconia, silica, and alumina composite.
- The percentage of water absorbed by the sintered samples decreased because of the decrease in porosity. As the porosity declined, there was less space inside the sample, and it becomes difficult for the water to penetrate inside the body.
- The linear shrinkage showed a steady rise in between from ~8% to 9% due to the densification of the particles as they were sintered at high temperature.
- XRD analysis of the powdered samples confirms the various phases were detected.
- It has been found that the maximum bulk density, the bending, tensile and compressive strength values of porcelains sintered at 1350°C for 2 hours were 2.63 g/cm^3, 141±5 MPa, 40±3 MPa and 216±10 MPa, respectively. The difference between compression strength and bending strength was attributed to the difference in stresses distribution in the samples.
- The highest observed AC dielectric strength is 23.96 ± 1 KV/mm, which is sintered at 1350°C.

If the amount of zirconia is further increased (up to 10%), it was observed that the bulk density and linear shrinkage had a steep fall. At the same time, the porosity and the water absorption in the samples increased. These changes decrease the strength and longevity of the ceramic porcelain material. Studying the results of the various tests, it was concluded that replacing alumina (35 to 27.5 wt. %) with 7.5 wt. % zirconia in the base porcelain composition provided the best results in both physical, mechanical as well as electrical properties of the sintered samples.

In chapter 6, barium titanate ($BaTiO_3$) is used as a dopant in the base composition of CPI for improving the electrical properties of the resultant material. The following things were observed when zirconia was replaced with BT in the base porcelain composition by 0.5 wt. %.

- It has been found that the maximum bulk density, the bending, tensile and compressive strength values of porcelains sintered at 1350°C for 2 hours were 2.65 g/cm^3, 144 ± 5 MPa, 40.50 ± 3 MPa and 223 ± 5MPa respectively
- The dielectric strength value observed for 0.5 wt. % BT addition is 24.80 ± 0.5 KV/mm.

After further addition of BT (on 1 and 2 wt. %) on base, composition found that mechanical properties of insulator decreases but electrical properties increase significantly, i.e., AC relative permittivity at low and microwave frequency, and AC dielectric strength of insulator increases.

The investigated porcelain insulator having a base composition (i.e., ball clay, kaolin, feldspar, SiO_2, Al_2O_3 and ZrO_2 in wt. %) doped with $BaTiO_3$ (i.e., 0.5 wt. %) sintered at 1350°C, shows the best result according to mechanical, electrical performance and economical aspect. A significant improvement in both mechanical and electrical properties makes the novel insulators useful for high voltage application.

7.2 Scope for Future Work

Global ceramic porcelain Insulator market is expected to rise in the forthcoming years as the scope, product types, and its applications are increasing across the globe.

- The use of ceramic porcelain insulators mainly in the electric power industries, sub-station, and distribution & transmission lines because of its numerous benefits such as better contamination performance, having reduced construction costs, materials readily available, low or no maintenance, high mechanical and electrical resistance and compact design. It is best for use in compact line post insulators, and protect against seismic waves, and contamination.
- The investigated ceramic insulator having enormous potential to serve as a high strength refractory material as well as having good dielectric constant with minimum loss, hence used in microwave frequency applications.
- The investigated ceramic insulator composition provides a high value of dielectric constant with minimum dielectric loss within microwave frequency, i.e., offer better insulation property. This insulator may be used in the antenna; the main problems are the rapid rise in dielectric loss factor consequence issue in thermal runaway. This thermal runaway is controlled by using the investigated ceramic insulator composition.