the grain boundaries (G. B.) is shown in table (1). The table shows that the analysis is close to the stoichiometric ratio of $CaCu_3Ti_4O_{12}$. The EDS analysis inside the grain show slightly CuO-deficient and Cu/Ca ratio is 2.94. The Cu/Ca ratio at the grain boundary is 3 which is slightly higher than Cu/Ca ratio inside the grain. Normal grain growth was observed at Cu/Ca $\leq$ 2.9(19), while abnormal grain growth was observed at Cu/Ca $\geq$ 2.95, since CuO promotes densification via liquid phase sintering(20-22). Moreover, it was reported that CuO segregates at the grain boundaries even at stoichiometric composition (Cu/Ca = 3)(8 & 18). Kim *et al.*(19) analyzed the distribution and amount of intergranular liquid phase by TEM analysis. However, it was difficult to quantify the total amount of intergranular liquid by observing a very small area of the TEM specimens.

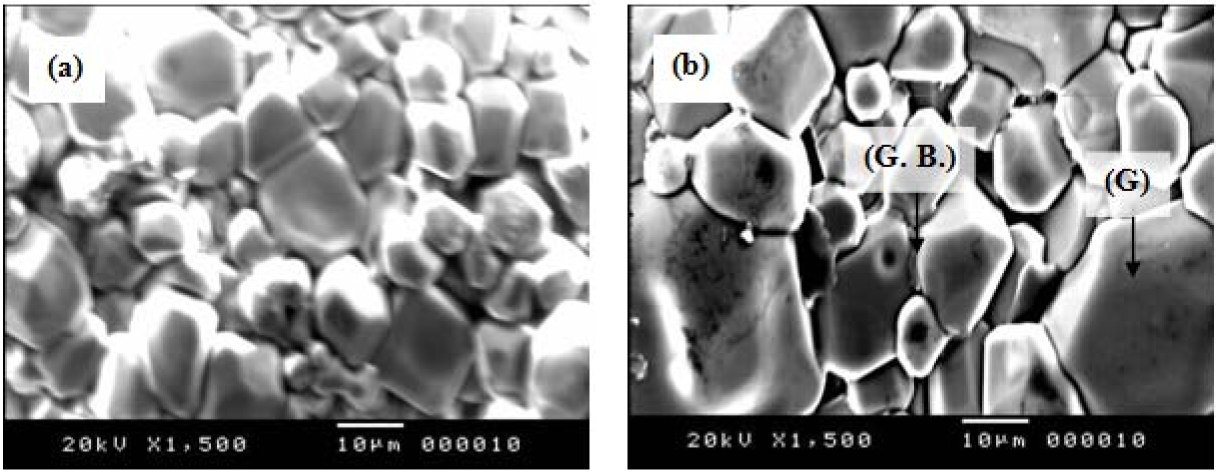


Figure 3: SEM micrograph of CCTO pellet sintered at; (a) 1050°C and (b) 1140°C for 5h.

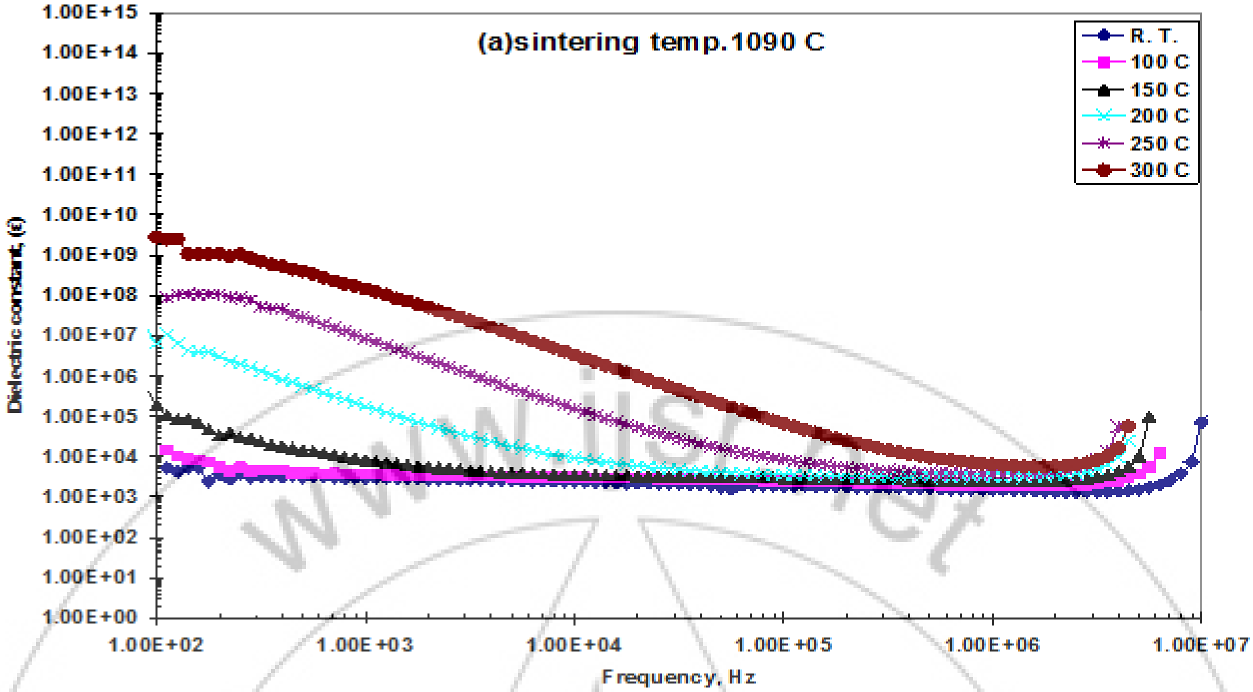
Table 1: The percentage of component elements determined by EDS

Element	*Grain (G) Atomic %.*	*Grain boundary (G. B.) Atomic %.*
Ca	4.61	4.89
Cu	13.56	14.68
Ti	19.15	20.02
O	62.68	60.41

The frequency dependence of the dielectric constant (έ) and the loss tangent (tan δ) of $CaCu_3Ti_4O_{12}$ ceramic sintered at 1090 °C are shown on Fig. (4). Dielectric constant (έ) of $CaCu_3Ti_4O_{12}$ ceramics sintered at 1090 °C (Fig. 4-a) indicates weak frequency dependence in the range of 100 Hz to 1 MHz at room temperature and at 100 °C with a giant dielectric constant of about 10^4. As the measuring temperature increases the giant dielectric constant increases to be more than 10^9 at 300 °C and frequency 100 Hz. Figure (4-b) shows that, dielectric loss (tan δ) of $CaCu_3Ti_4O_{12}$ is also of weak frequency dependence in the range of 100 Hz to 1 MHz at room temperature and at 100 °C. As the measuring temperature increases the dielectric loss increases and becomes more frequency dependent. The dielectric loss (tan δ) slightly increases from about 0.3 to about 0.5 when the measuring temperature increases from room temperature to 100 °C at low frequency. A further increase in the dielectric loss (tan δ) takes place when the measuring temperature increases above 100 °C.

Figure (5) shows the frequency dependence of dielectric properties of $CaCu_3Ti_4O_{12}$ ceramic sintered at 1140°C in the frequency range of 100 Hz to 1MHz. The dielectric constant shows significant frequency dependence at all measuring temperatures. The giant dielectric constant is significantly higher than that of the $CaCu_3Ti_4O_{12}$ ceramic sintered at lower temperature (1090°C). This increase in the dielectric constant of the sample sintered at 1140°C may be attributed to the presence of semiconducting secondary phases (23), such as CuO or Cu_2O. Since the conductivity of Cu_2O ($\approx 10^{-3}\ \Omega^{-1}\ cm^{-1}$) is much higher than that of CuO ($\approx 10^{-5}\ \Omega^{-1}\ cm^{-1}$) (23), the giant dielectric constant for the sample sintered at 1140 °C is much higher than that in the samples sintered at 1090 °C due to the transformation of the secondary phase of CuO to Cu_2O upon increasing the sintering temperature.

The dielectric loss (tan δ) of $CaCu_3Ti_4O_{12}$ samples sintered at 1140 °C is also weak frequency dependent in the range of 100 Hz to 1 MHz at room. While at 100 °C the dielectric loss slightly decreases with increasing frequency up to 1MHz then tends to increase. The samples sintered at 1140°C were found to give a higher dielectric loss than the samples sintered at 1090 °C. The dielectric loss noticeably increases by increasing the measuring temperature from room temperature to 100 °C. A significant increase in the dielectric loss takes place by further increase in measuring temperature.



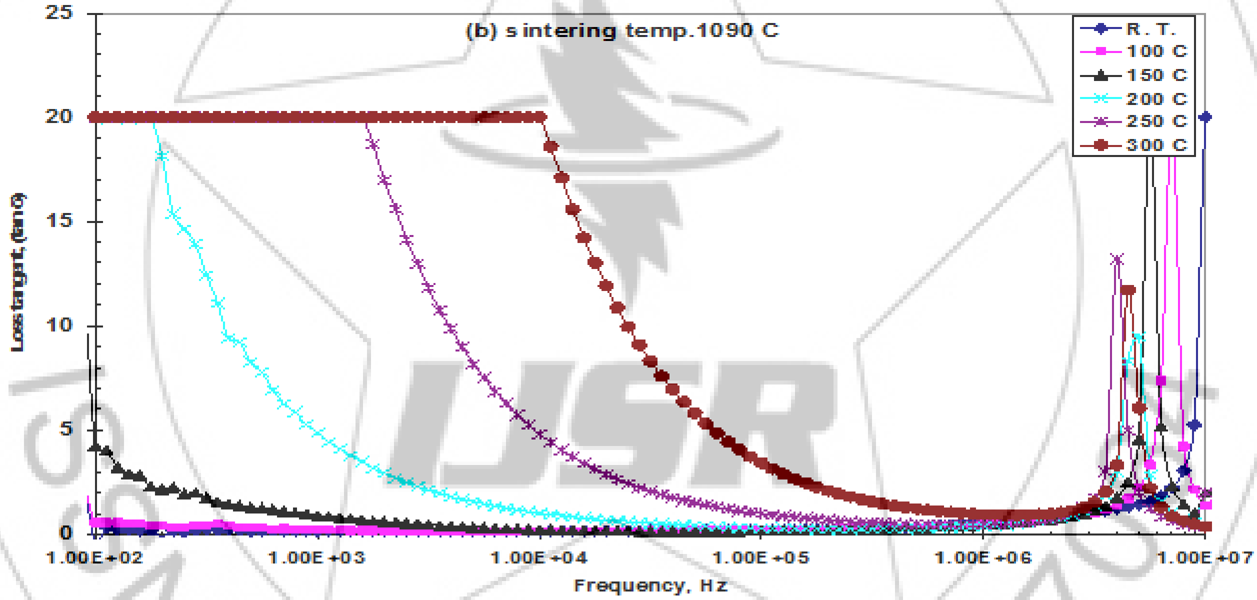


Figure 4: Frequency dependence of dielectric properties of $CaCu_3Ti_4O_{12}$ ceramics sintered at 1090 °C at different measuring temperatures, (a) dielectric constant and (b) loss tangent factor

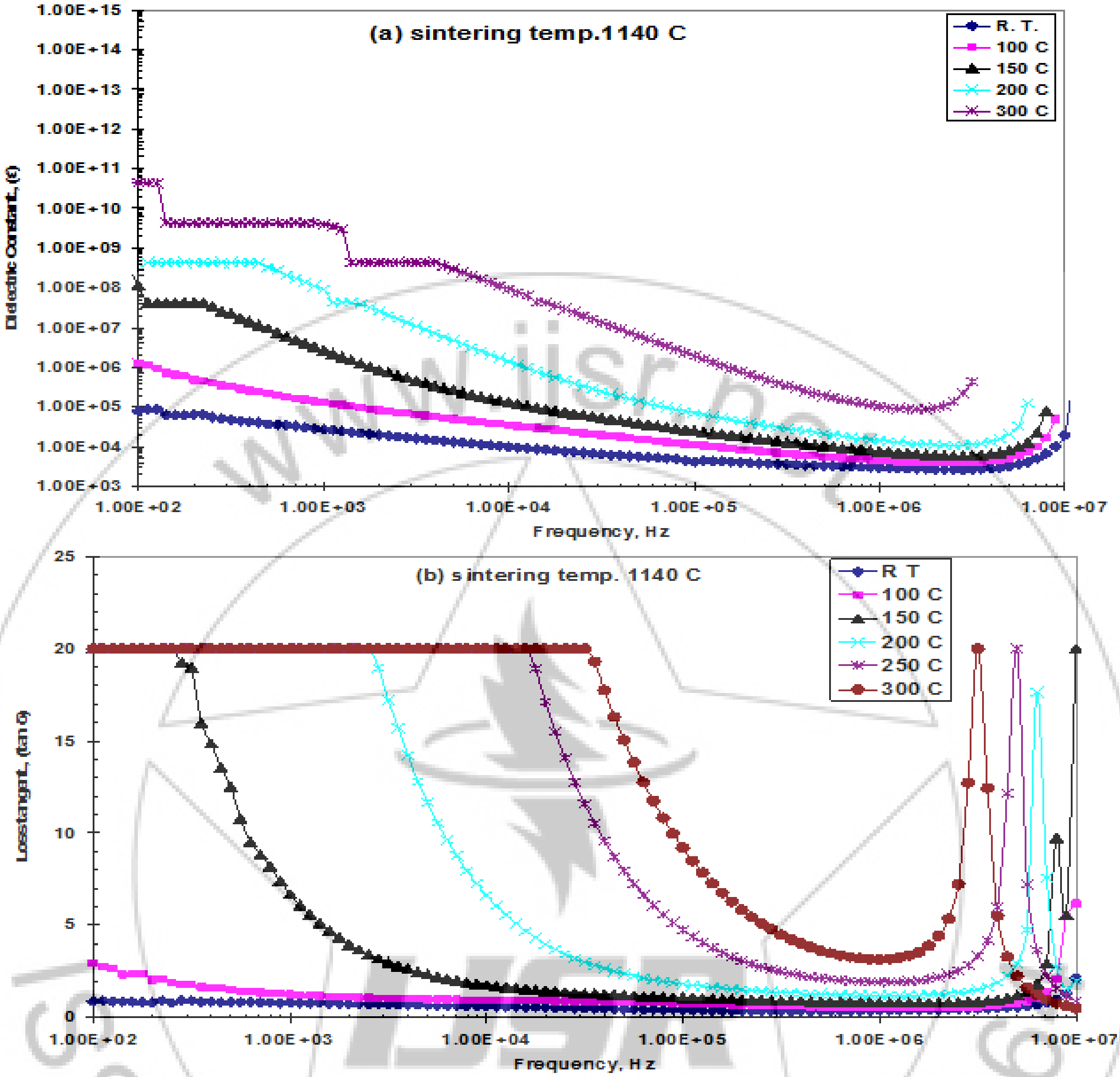


Figure 5: Frequency dependence of dielectric properties of $CaCu_3Ti_4O_{12}$ ceramics sintered at 1140 °C at different measuring temperatures, (a) dielectric constant and (b) loss tangent factor

4. Conclusion

Polycrystalline single phase of CCTO ceramics were successfully prepared by conventional solid-state reaction method. XRD patterns showed no change in the crystal structure phase for the two sintering temperatures. The SEM showed normal grain growth in CCTO samples sintered at 1090 °C, while abnormal grain growth was observed in samples sintered at 1140 °C. The chemical composition determined by EDS is close to the stoichiometric ratio of $CaCu_3Ti_4O_{12}$. Dielectric constant **(K')** of CCTO ceramic sintered at 1090 °C indicates weak frequency dependence in the range of 100 Hz to 1 MHz, and it becomes significantly frequency dependent when sintered at 1140 °C. The dielectric constant value is about 10^4 for samples sintered at 1090 °C while it is greater than 10^5 for samples sintered at 1140°C measured at room temperature and 100 Hz. The dielectric loss (tan δ) is about 0.3 for samples sintered at 1090 °C while it is close to 1 for samples sintered at 1140 °C.

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Electrical Insulating Properties of the Compound Calcium Titanate and Copper ($CaCu_3Ti_4O_{12}$) Record the Interaction in the Solid State

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Research Summary

Ceramics were prepared from calcium titanate and copper $CaCu_3Ti_4O1_2$ (CCTO) way interaction in the solid state. Has been studied composition crystallizes the fine structure and electrical properties of the ceramics sintered at different temperatures. X-ray diffraction has been shown not to change the composition of the samples with crystallizes change the degree of sintering temperature. Electron Microscopy showed overwhelming natural growth in the size of the grains in the samples sintered at temperatures of 1090° C while the temperature back growth. Above normal in samples sintered at temperatures of 1140° m heat. Showed chemical analysis device EDS matching chemical composition of the ceramic output of the chemical formula $CaCu_3Ti_4O_{12}$. Electrical measurements have shown that in the samples sintered at temperatures of 1090 ° m be affected by the value of fixed- temperature electrolysis (K ') weak frequency in Range from 100 Hz to one MHz, and the $ 10 4, while this vulnerability becomes valuable in the samples sintered at temperatures of 1140 ° m temperature where the value More than 10 5 measured at room temperature and the frequency of 100 Hz. The electrical loss coefficient (tan δ) of about 3, the first samples and approaching samples per second.