Dielectric Properties of Epoxy/CCTO 0-3 Composites for Embedded Capacitor Applications

B Samanta & P Kumar *

Department of Physics & Astronomy, National Institute of Technology, Rourkela, Odisha, India, 769008.

Introduction

Polymer–ceramic composites are used as the most suitable dielectric materials in embedded capacitors applications due to

- ❑ Effective high dielectric constant
- ❑ Low processing temperature
- ❑ High flexibility
- ❑ High breakdown strength
- ❑ Low dielectric loss
- ❑ Economical

$CaCu_3Ti_4O_{12}$ (CCTO) ceramics exhibit high dielectric constant (~10^4-10^5), which remains almost unchanged over a broad temperature and frequency range.

Epoxy-resin in a ceramic-polymer based composite provides superiority in terms of flexibility, compatibility, low processing temperature and easy fabrication into various shape.

In this present work, dielectric properties of (1-x) Epoxy resin- x CCTO composites [where x = 0, 0.1, 0.2 stands for filler volume fraction] are studied in detail and experimental and theoretical dielectric values are compared using

Skipetrov Model

$$\varepsilon_{eff} = \varepsilon_m\left[1+\frac{3f(\varepsilon_f-\varepsilon_m)}{\varepsilon_m(2+f)+\varepsilon_f(1-f)}\right]$$

Yamada Model

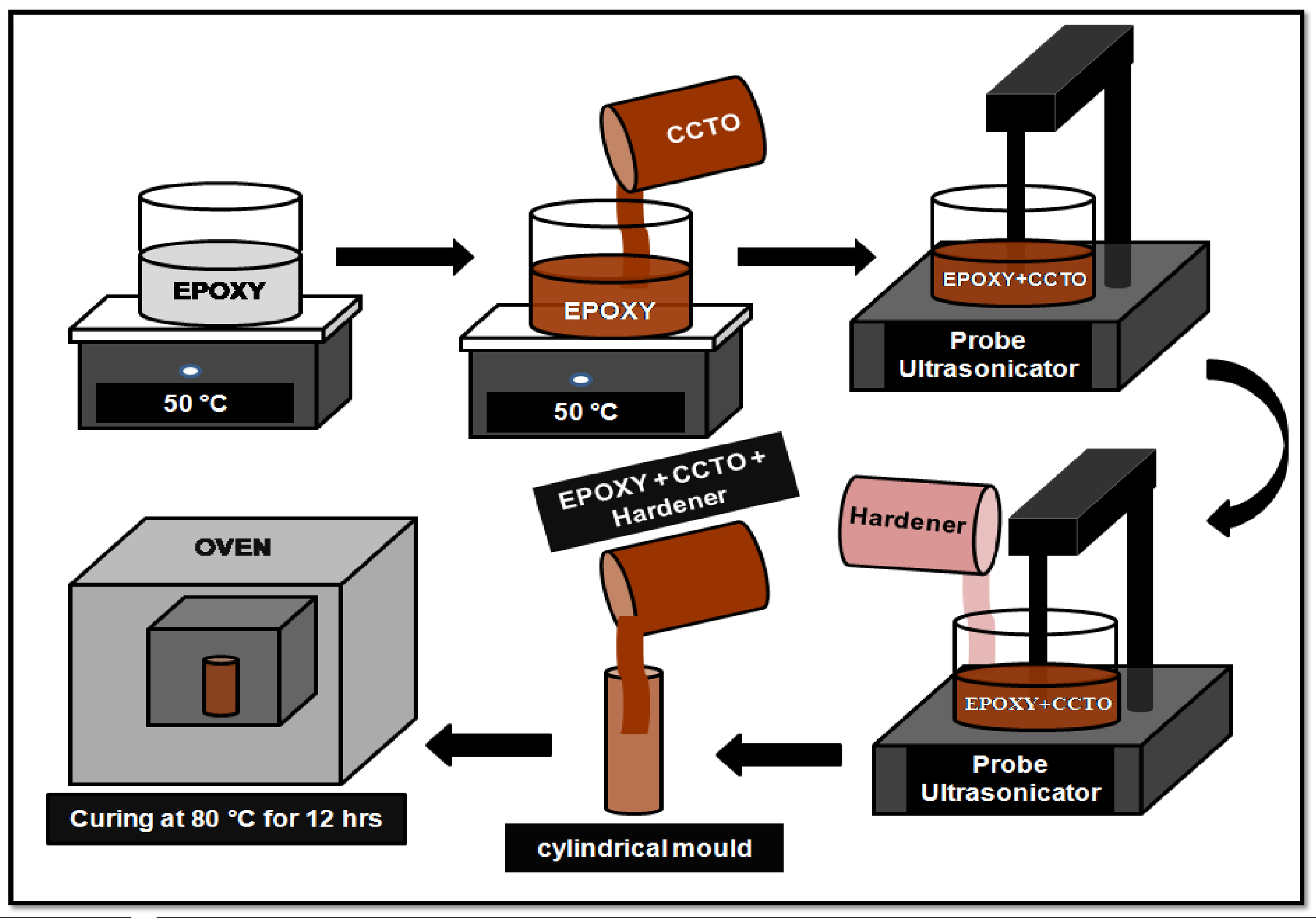
$$\varepsilon_{eff} = \varepsilon_m\left[1+\frac{\eta f(\varepsilon_f-\varepsilon_m)}{\eta\varepsilon_m+(\varepsilon_f-\varepsilon_m)(1-f)}\right]$$

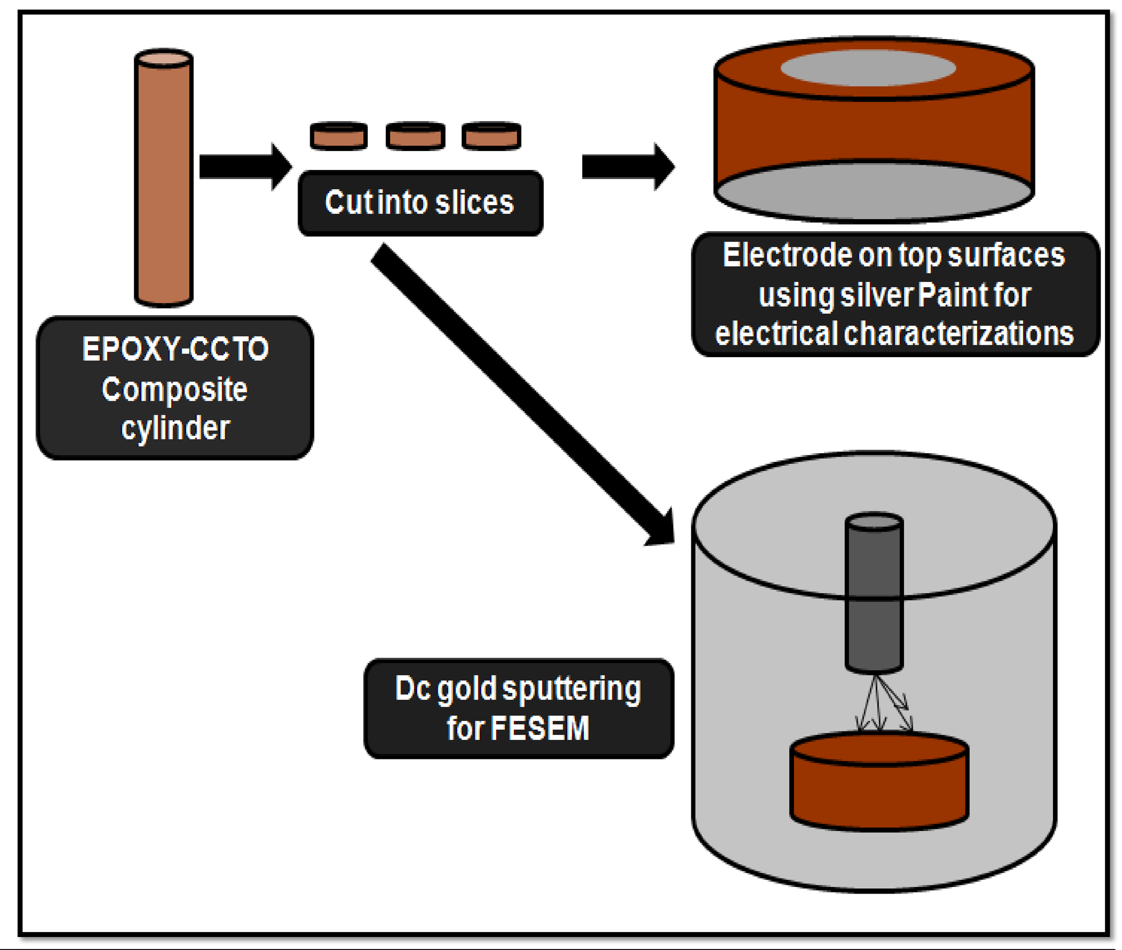
Material Processing

CERAMIC PROCESSING

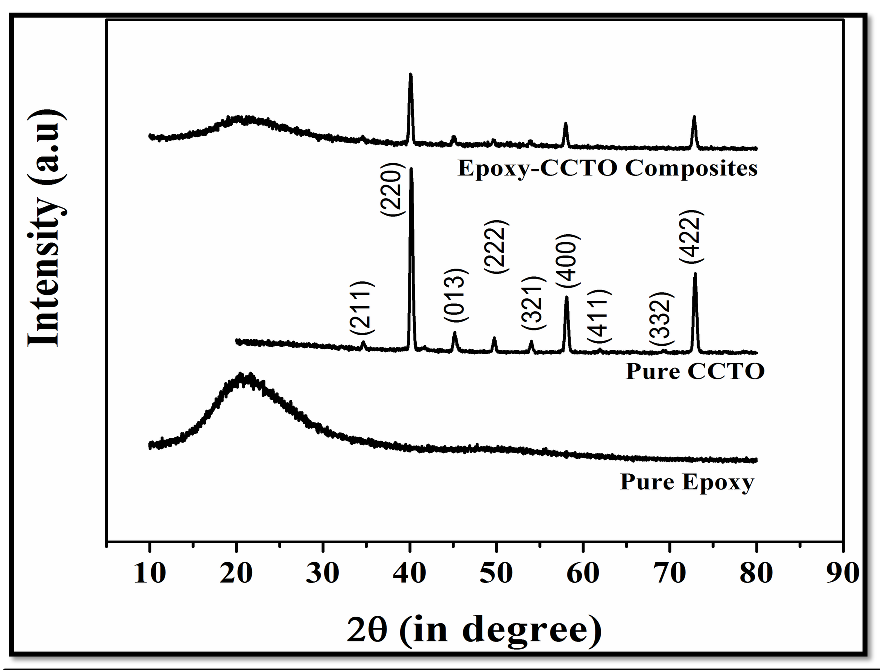
$CaCO_3$, CuO, TiO_2 Proper weighing and mixing → Milling by zerconia balls in acetone media & drying → Microwave calcinations at 850°C for 15 minutes (heating rate 20°C/min & cooling rate 10 °C/min) & Hand grinding of calcined powder for 3 hrs → X-ray diffraction for phase confirmation of $CaCu_3Ti_4O_{12}$

COMPOSITE PROCESSING AND ELECTRODING

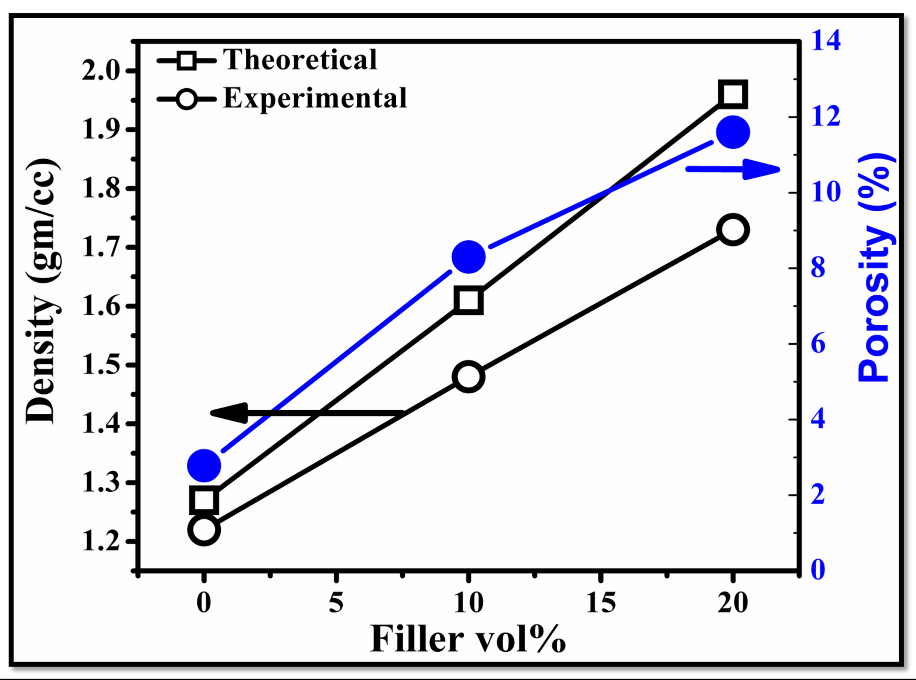




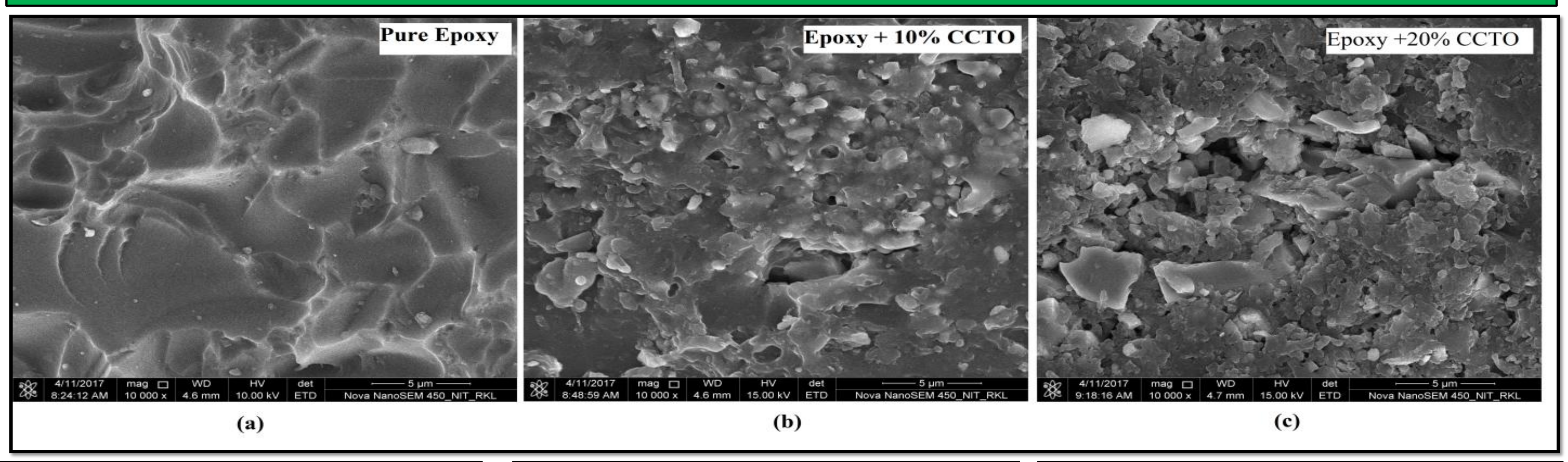
X-Ray Diffraction



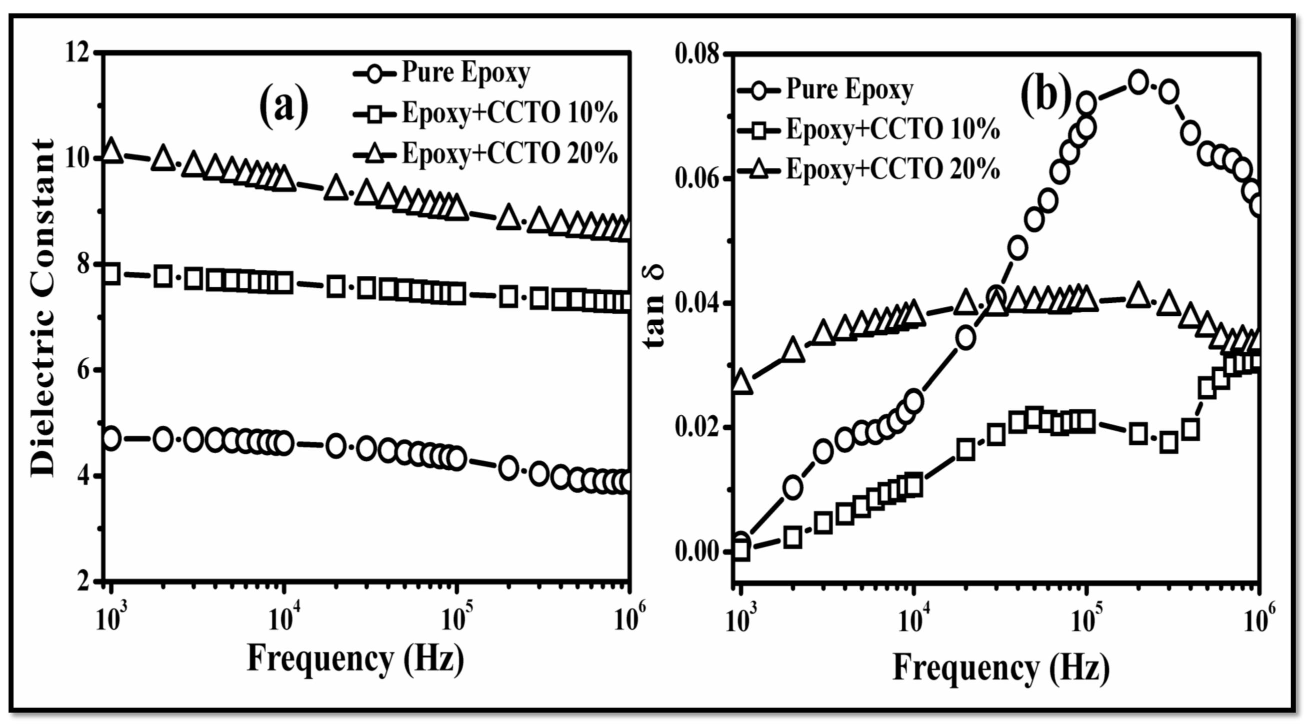
Density

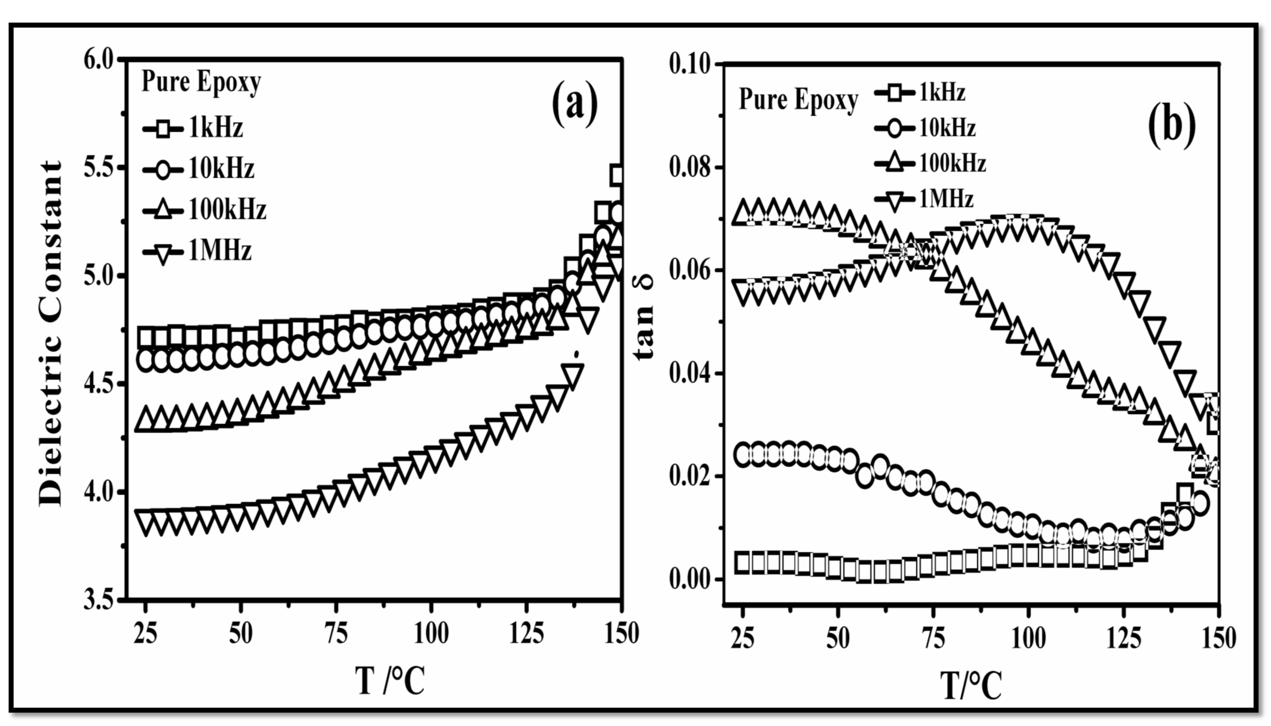


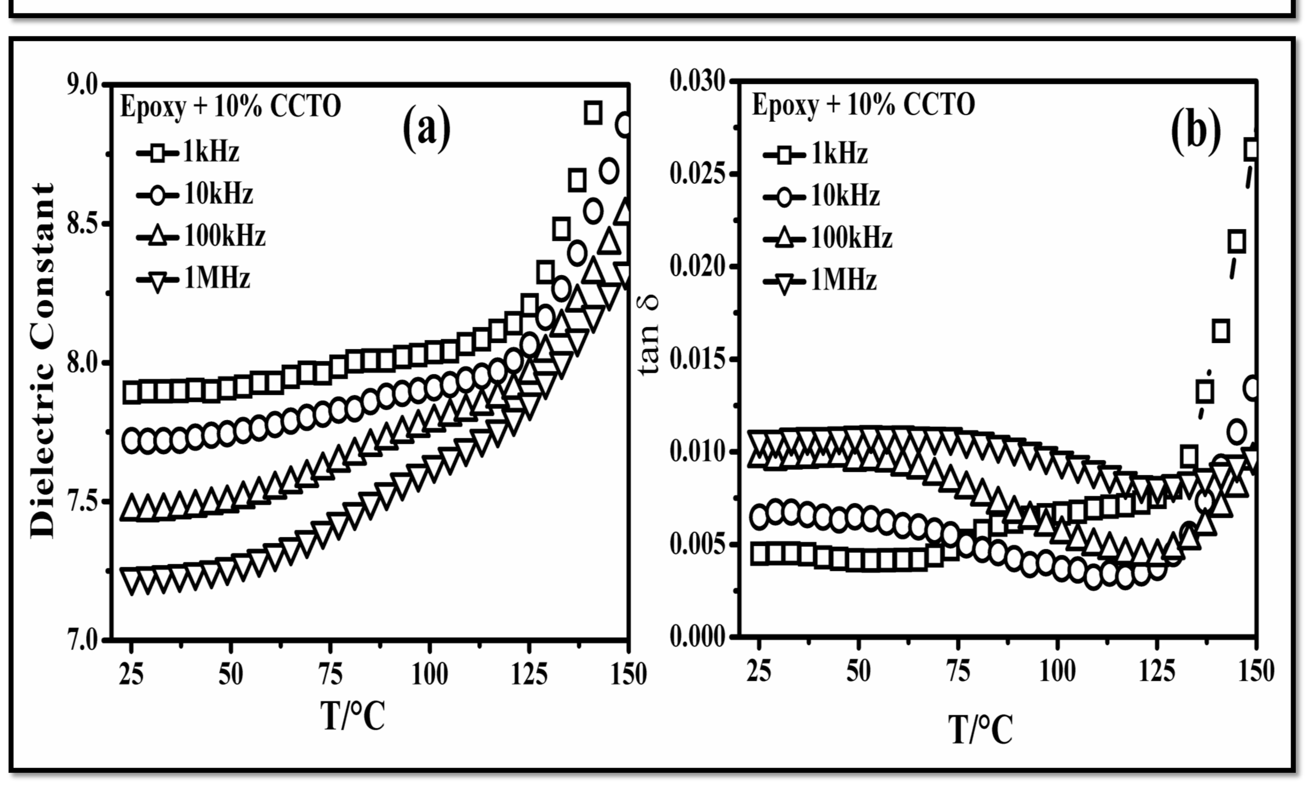
FESEM Micrograph

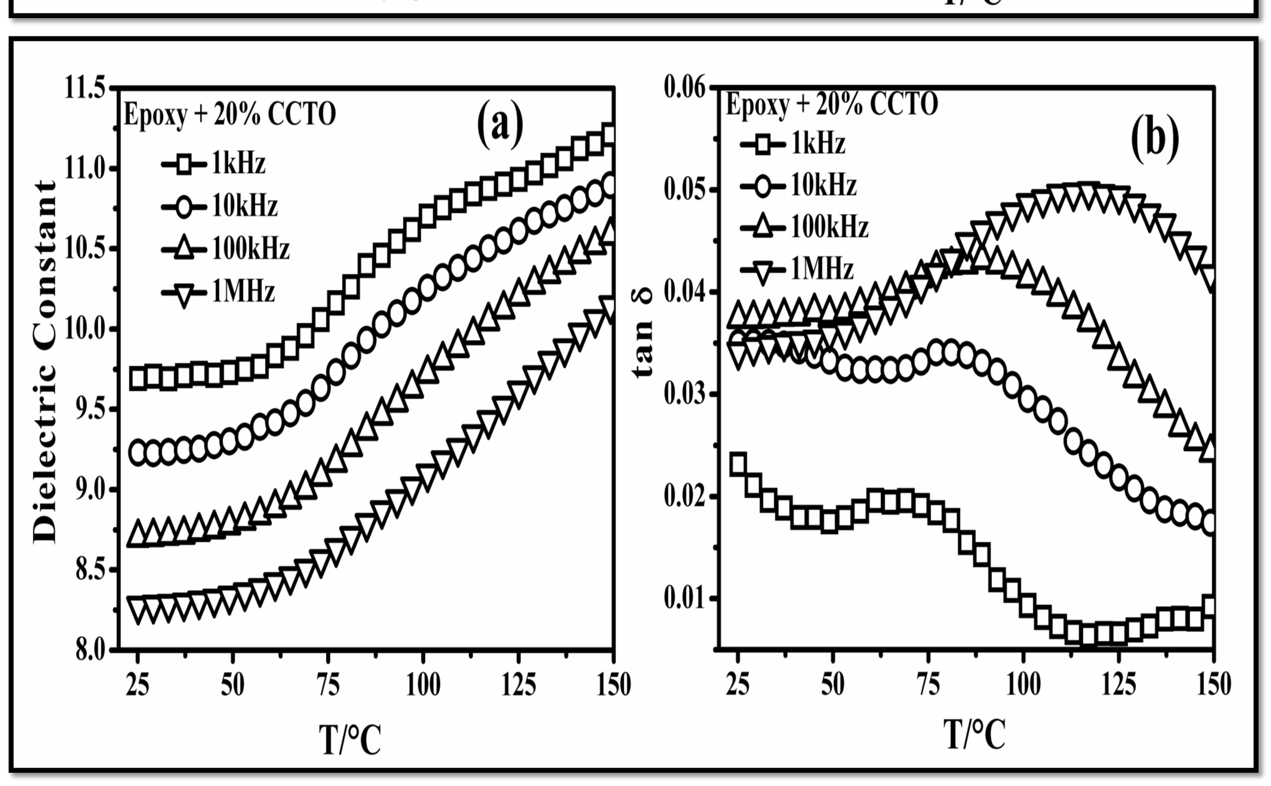


Dielectric properties

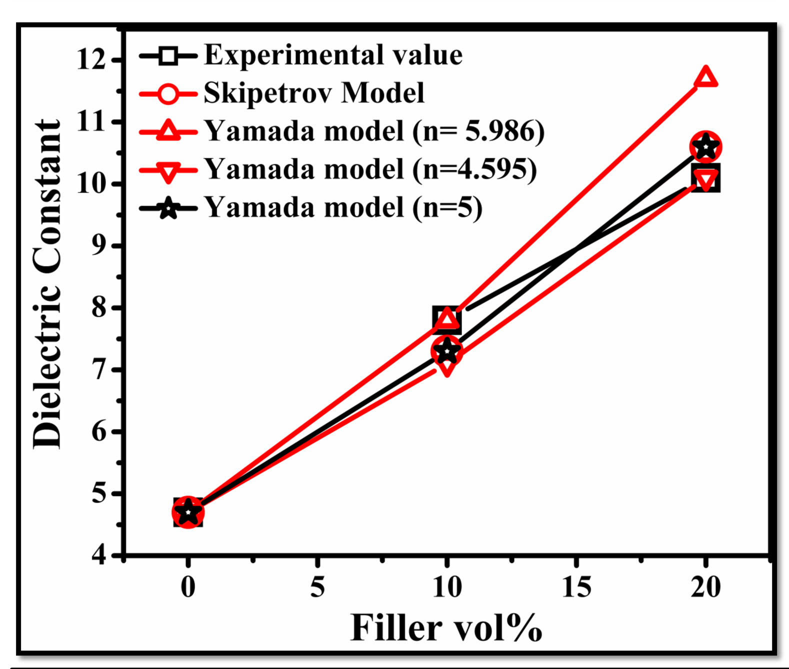








Skipetrov & Yamada model



Conclusions

❑ Maximum Dielectric constant at RT for 20 vol% CCTO loading is ~ 10 (at 1 kHz) with significant low dielectric loss ($\tan\delta_{max}$ ~ 0.04 at ~200 kHz)

❑ Dielectric constant, extracted using Yamada model, is in close accordance with the experimental values

❑ Easy and user friendly fabrication procedure, flexibility and good dielectric behavior of these biphasic (0-3) particulate composites make them good candidates for charge storage device and capacitor applications

References

❑ M. A. Subhramaniam et. al. Dielectric Constant in $ACu_3Ti_4O_{12}$ and $ACu_3Ti_3FeO_{12}$ Phases, Journal of Solid State Chemistry, 2000, 151, 223–325

❑B. Samanta, et al. Effect of sintering temperature and Cu-rich secondary phase on dielectric properties of microwave processed $CaCu_3Ti_4O_{12}$ ceramics. Ferroelectrics, 517 (2017) 46-57

❑ D. S Saidina et al. Dielectric and thermal properties of CCTO/epoxy composites for embedded capacitor applications: mixing and fabrication methods. J Mater Sci. Mater Electron, 2015, 26, 8118–8129

❑C.W. Nan et al. Comment on ''Effective dielectric function of a random medium''. Physical Review B., 2001, 63: 176201

❑ T. Yamada et al. T. Piezoelectricity of a high-content lead zirconate titanate /polymer composite. J. Appl. Phys, 1982, 53(6), 4328-4332