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Influence of processing conditions on dielectric properties of $CaCu_3Ti_4O_{12}$ thin films

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Aim of work

- Measurements of the dielectric response of various $CaCu_3Ti_4O_{12}$ (CCTO) ceramic thin films. CCTO namely possesses one of the largest values of the effective dielectric permittivity ever reported for a ceramic material in a large frequency and temperature range, and is thus a very promising material for various electronic and electromechanical applications.
- Separation of different dielectric contributions (bulk, grain boundaries, etc.).
- Investigations of the influence of processing conditions on dielectric properties of films.

Materials preparation

Method of preparation: **Chemical Solution Deposition**

Conditions: 750°C, 15 min, air, RTA. Samples consist of 6 (260 nm) or 12 (540 nm) deposited layers and were post-annealed (750°C, 15 min) in nitrogen, air, or oxygen (low, medium, or high oxygen partial pressure, respectively).

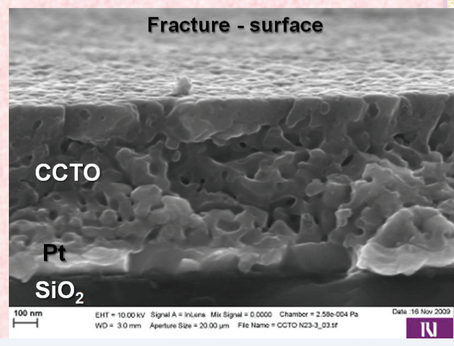


Fig.1: 12-layer sample.

Temperature scans

The main ε′ 'plateau' values and the temperature of their drop are strongly dependent on oxygen partial pressure in atmosphere during the post-annealing process.

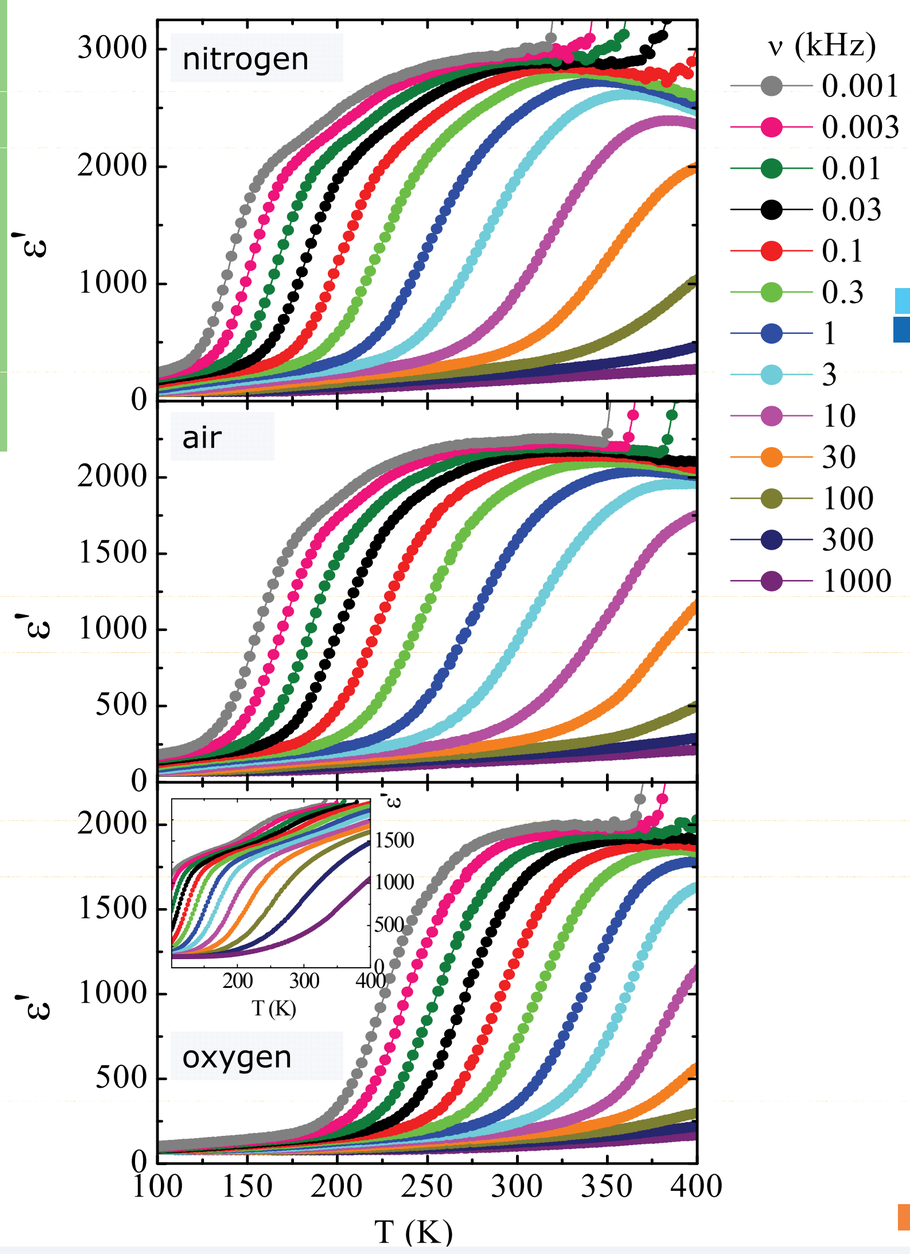


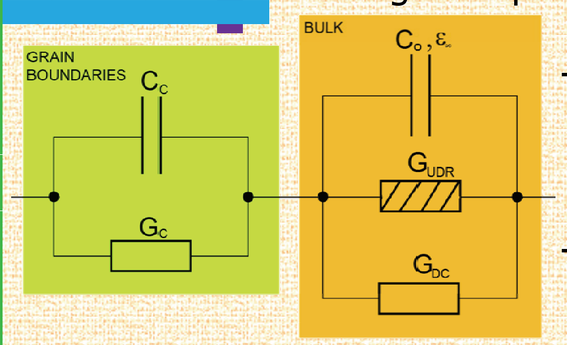
Fig.2: 12-layer samples.

In 6-layer samples (see inset) the influence of surface layers is much more pronounced.

Frequency scans

Equivalent circuit model:

- leaky capacitor – insulating grain boundaries
- intrinsic response of semiconducting grains:
  - high frequency dielectric constant,
  - frequency dependent AC conductivity (UDR) and
  - DC conductivity.



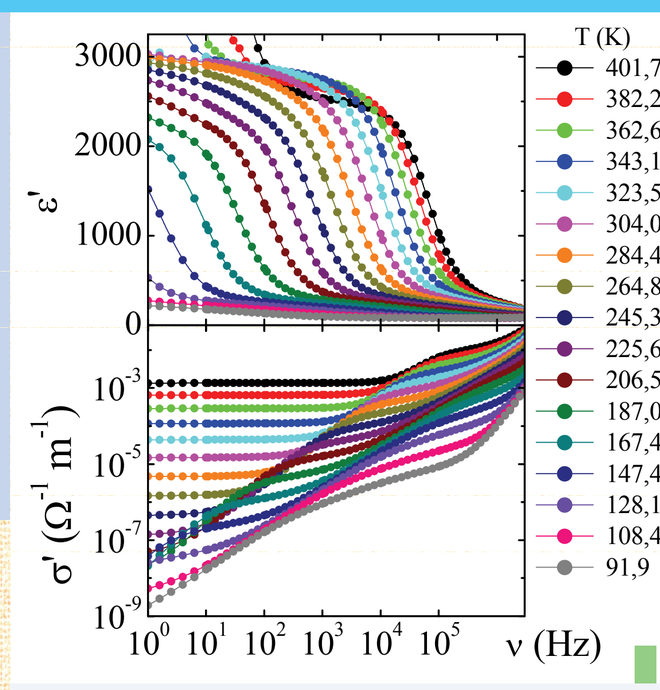


Fig.3: 12-layer sample (nitrogen).

The origin of high dielectric permittivity in CCTO ceramic thin films lies in 'electrical' heterogeneities in the microstructure [1-3]. We suggest that this is due to different distributions of Cu^+ and Cu^{2+} ions within grains and grain boundaries.

Analysis of results

Analysis in terms of equivalent circuit [3,4] reveals that post-annealing in lower oxygen partial pressure increases the conductance of both grains and grain boundaries.

In thin films it seems logical for variable range hopping to appear across the direction of space that represents the sample thickness. Variable range hopping model for 1D fully describes the charge transport behaviour in CCTO thin films.

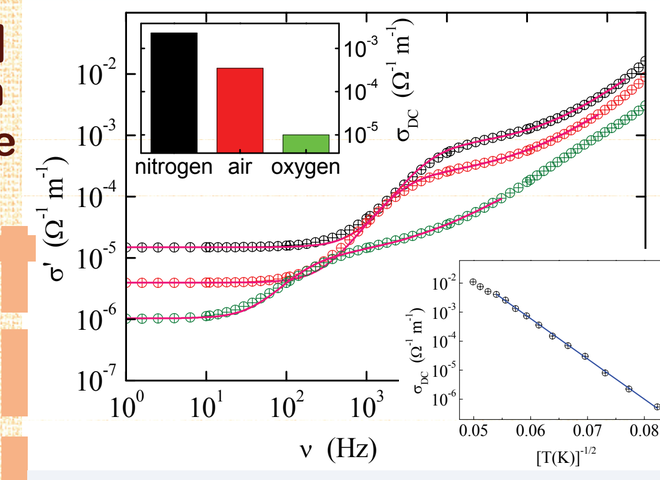


Fig.4: Analysis in terms of equivalent circuit.

References:

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Experimental results and the analysis in terms of the equivalent circuit reveal that each of the two constituents determines the dielectric behaviour of the CCTO thin film for different frequencies – insulating grain boundaries at lower and semiconducting grains at higher frequencies. The main influence on dielectric properties are the conditions under which the CCTO thin film was created.

We suggest that such dielectric behaviour arises due to different distributions of Cu^+/Cu^{2+} ions (these have been shown to strongly influence electrical properties of $ACu_3Ti_4O_{12}$ systems [5]) within grains and grain boundaries after different annealing procedures.

Ultimately, manipulating the conditions under which CCTO ceramic thin films are prepared enables us to control dielectric properties of these applicatory compelling materials.