Influence of Yttrium doping on microstructure and dielectric properties of $Na_{0,5}Er_{0,5}Cu_3Ti_4O_{12}$ synthesized by the solid-state method

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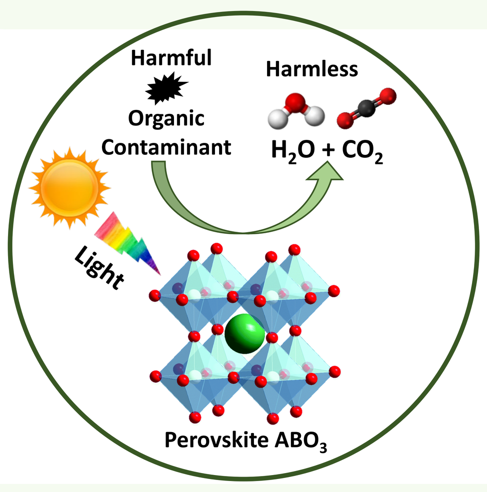
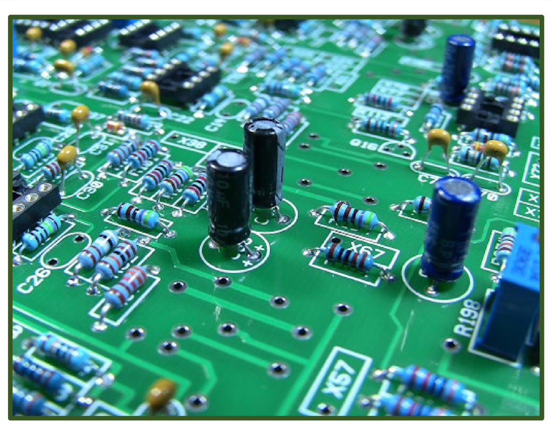
I. INTRODUCTION

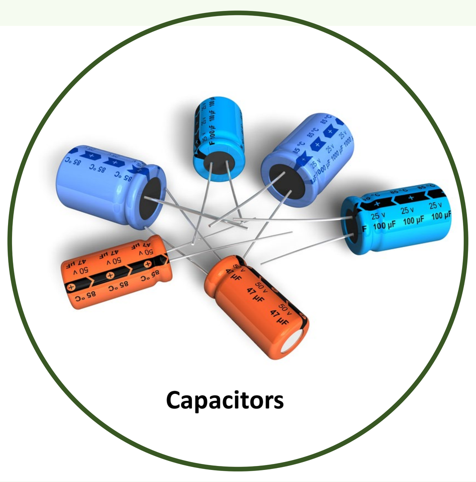
Facing ever increasing environmental issues such as global warming, air and water pollution, and fossil fuel consumption, the demand for solutions that counteract these phenomena has also increased. Batteries, dielectric capacitors and other energy storage devices are being developed to deal with these challenges in sustainable fashion [1].

$ACu_3Ti_4O_{12}$ as a type of perovskites showed a strong dielectric properties useful as energy storage and environmental devices [1].

In addition to dielectric properties ; $ACu_3Ti_4O_{12}$ could serve as photocatalytic materials with a very good performance in visible light for the treatment of wastewater which is essential to maintain a sustainable environment to the all living system [2].







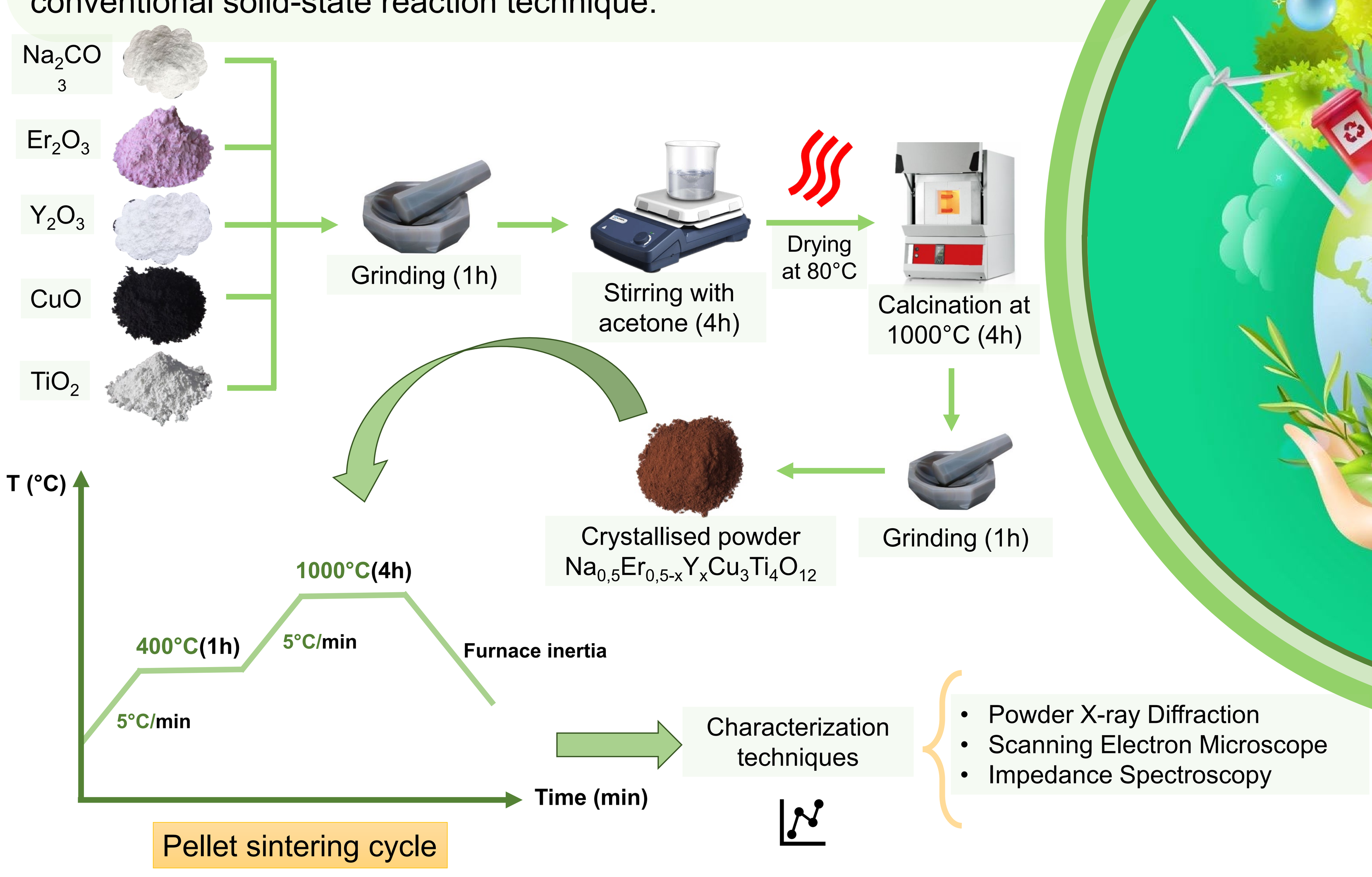
Objective :

Synthesize a novel $ACu_3Ti_4O_{12}$ perovskite type with a high dielectric constant and low dielectric losses for energy storage and study the photocatalytic properties of this material.

II. METHODOLOGY

In this research work, we first thought about elaborating $Na_{0,5}Er_{0,5}Cu_3Ti_4O_{12}$ (NECTO) ceramic but as we did not obtain the desired dielectric properties, we decided to improve them by doping the erbium with yttrium since it allows to increase the dielectric constant.

To do so, $Na_{0,5}Er_{0,5-x}Y_xCu_3Ti_4O_{12}$ (NEYCTO) ceramics were prepared by the conventional solid-state reaction technique.



III. RESULTS AND DISCUSSIONS

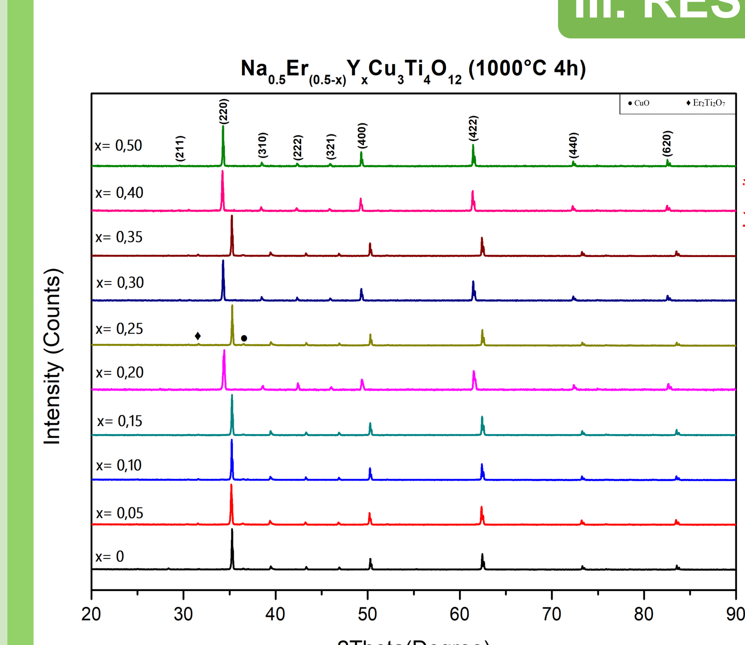


Fig.1: DRX characterization of the different compositions of $Na_{0.5}Er_{(0.5-x)}Y_xCu_3Ti_4O_{12}$ (x=0—0.5)

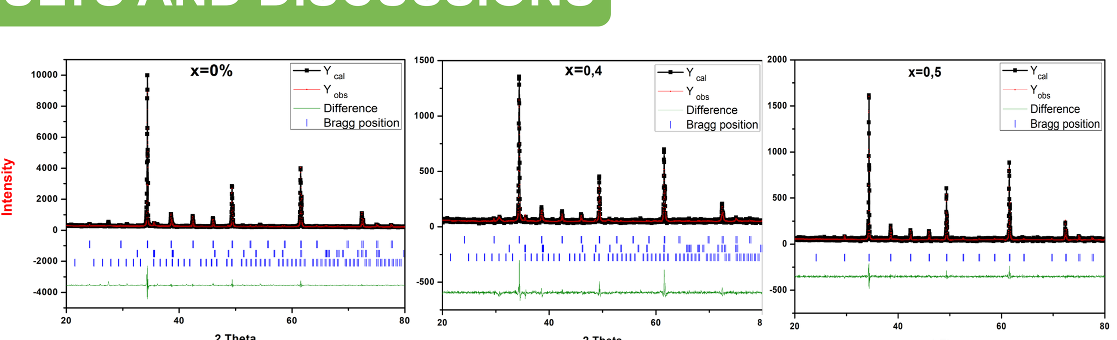


Fig.2: X-ray diffractogram of the $Na_{0.5}Er_{(0.5-x)}Y_xCu_3Ti_4O_{12}$ powder (x=0, 0.4 et 0.5) obtained by Rietveld

The diffractogram shows that, for x=0 up to x=0.4, NEYCTO ceramics crystallize in the cubic perovskite phase with the presence of two secondary peaks linked to CuO and $Er_2Ti_2O_7$. While for x=0.5, we notice the disappearance of those peaks while keeping the same crystalline phase which was confirmed by the Rietveld method.

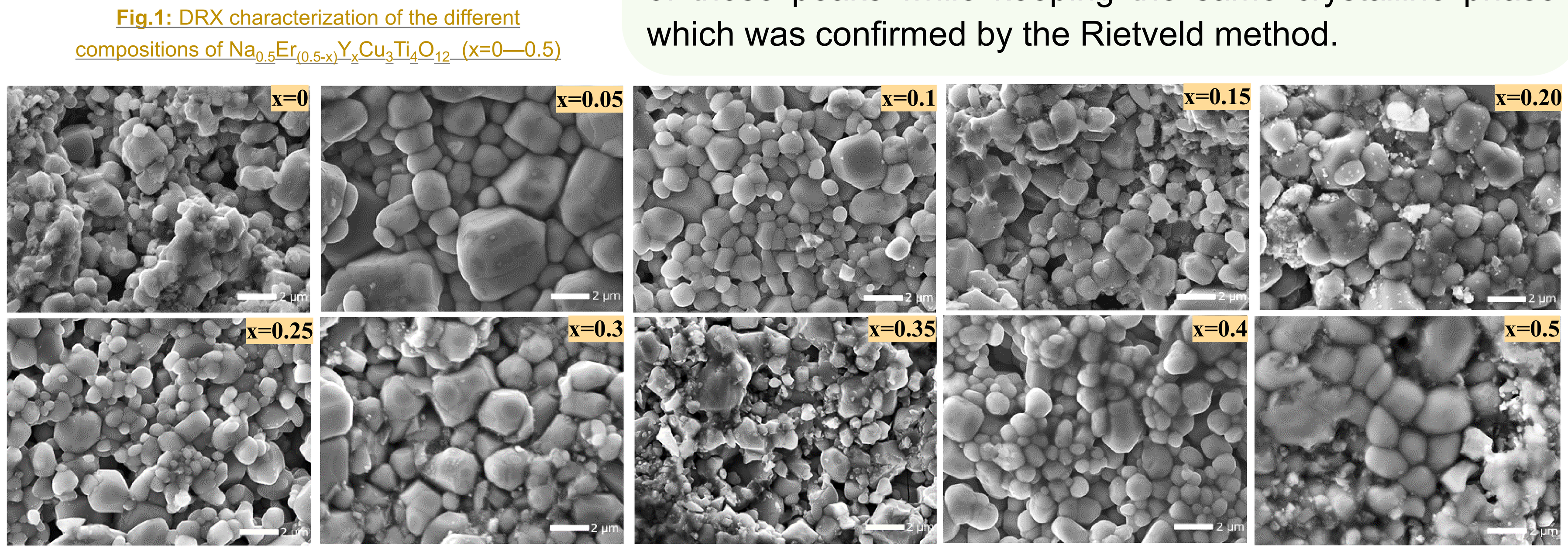


Fig.3 : SEM images of $Na_{0.5}Er_{(0.5-x)}Y_xCu_3Ti_4O_{12}$ ceramics sintered at 1000 °C for 4 hrs.

All the sintered samples show that the grains have a cubic and rounded shape. So the Yttrium doping did not change the morphology of the grains. Moreover, based on the measurement of the mean grain size by "The Mean Linear Intercept Method", all the samples have comparable grain sizes which are about 0.8-1.4 µm.

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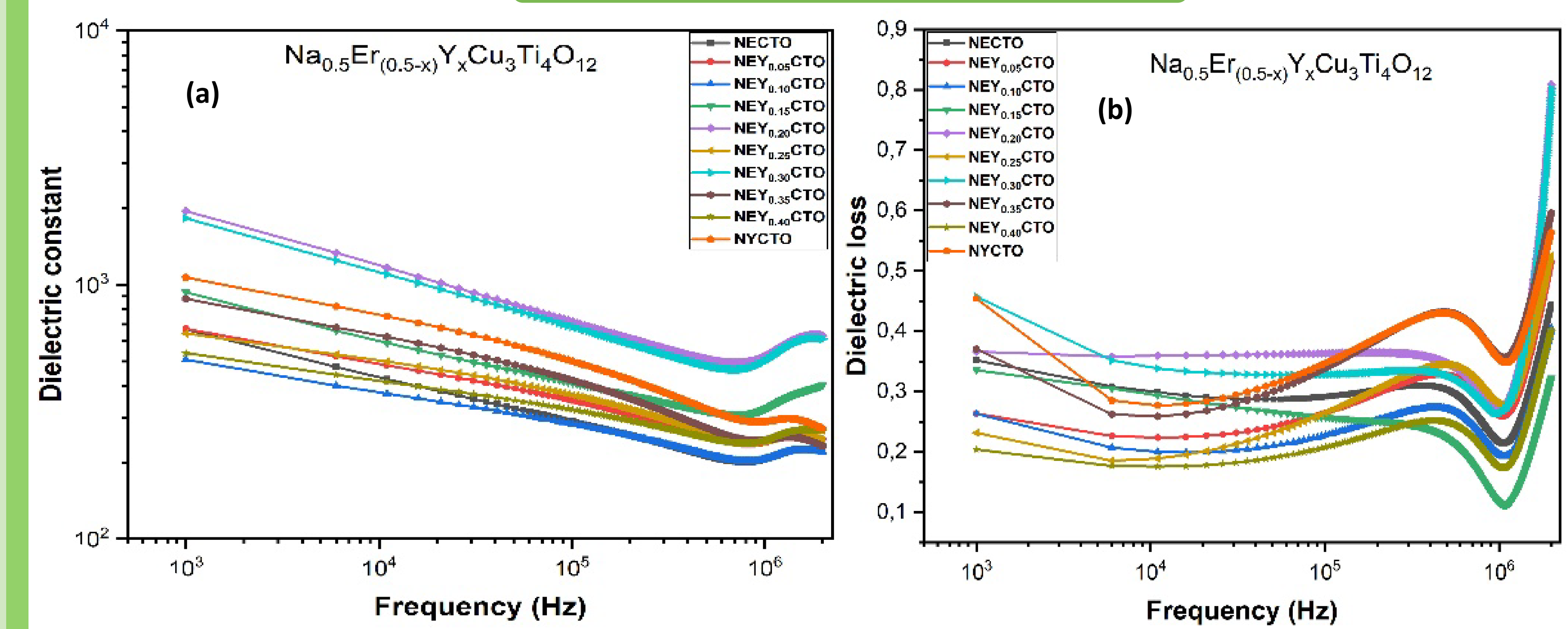

Fig.4 : : Evolution of the dielectric constant (a) and Dielectric losses (b), at room temperature, as a function of frequency for $Na_{0.5}Er_{(0.5-x)}Y_xCu_3Ti_4O_{12}$ (x=0 à 0.5)

- The dielectric constant ε_r of NEYCTO (a) was found to be the range from ~1×10^3 to ~4×10^2 with the frequency increasing for x=0.15 which was higher than that of undoped NECTO.
- The dielectric loss of NECTO ceramics (b) decreased from 0.35 to 0.3 at 10^3 Hz and from 0.2 to 0.1 at 10^6 Hz with yttrium doping content x=0.15.

- As shown in the Figure 6, an arc of a circle with the center below the real axis Z' is present in all the samples which prouves the contribution of both ceramic's grains and grain boundaries [3].

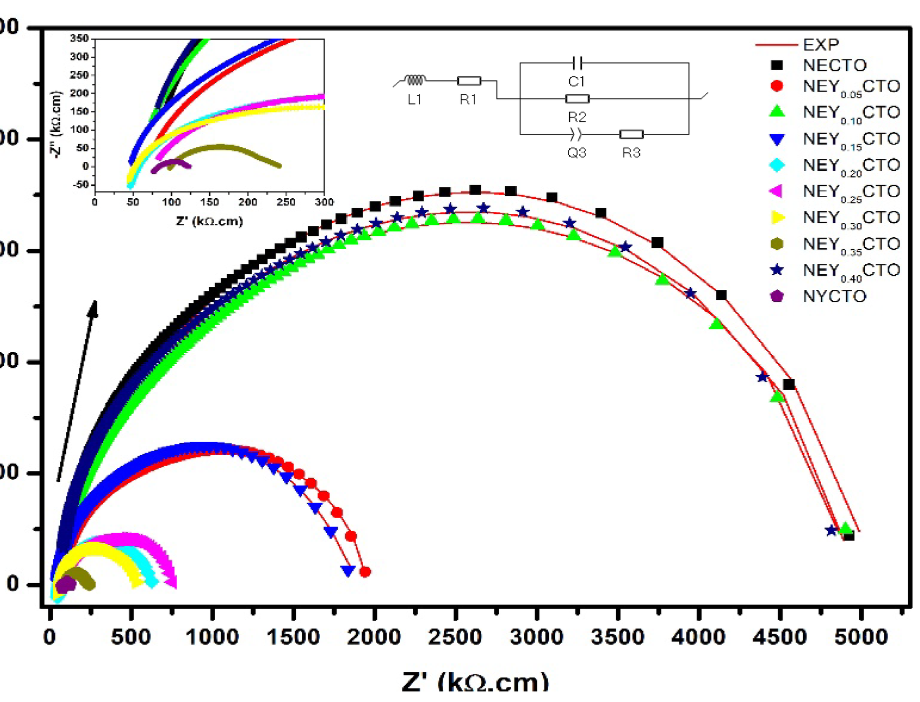

Fig.6 : The complex impedance spectroscopy of $Na_{0.5}Er_{(0.5-x)}Y_xCu_3Ti_4O_{12}$

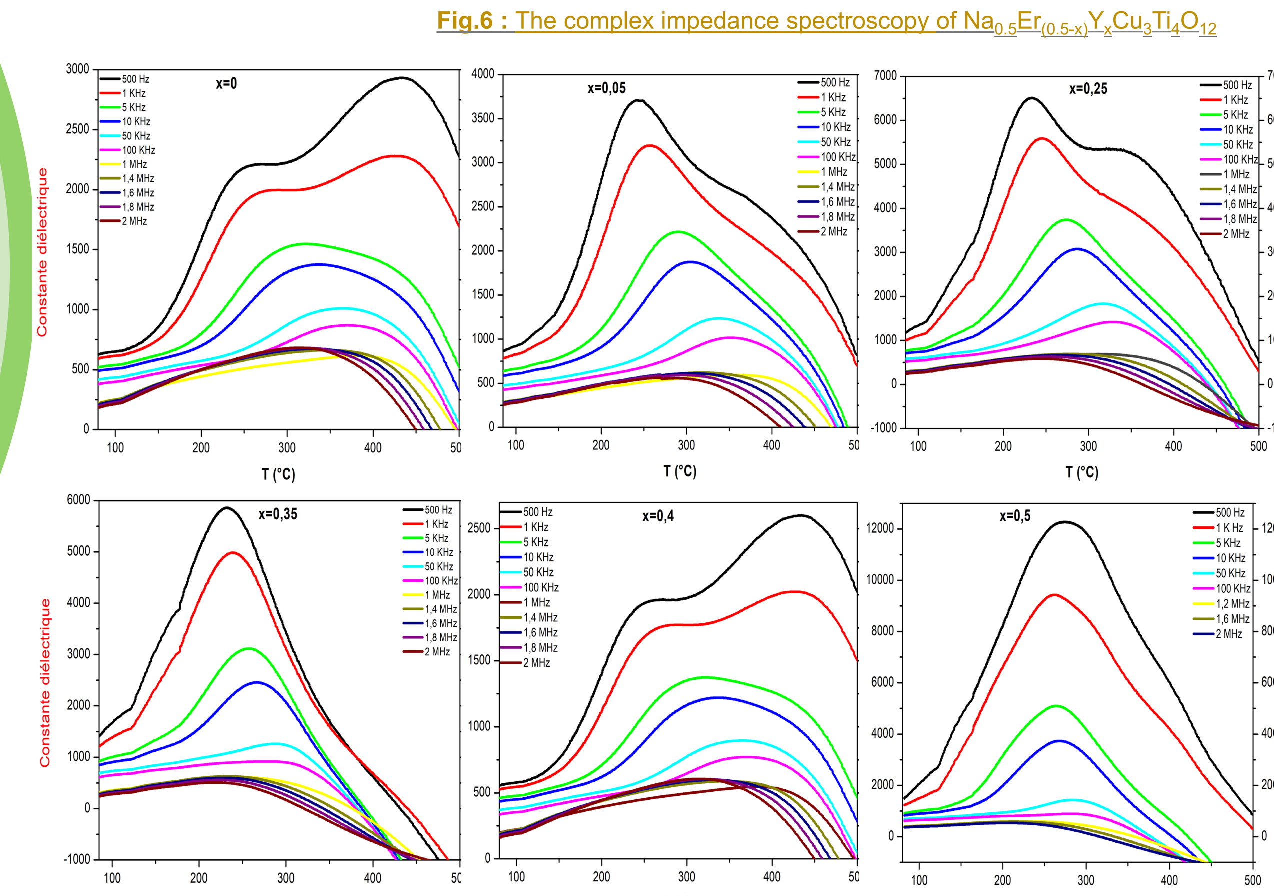

Fig.7 : : Evolution of the dielectric constant, at different frequencies, as a function of temperature for $Na_{0.5}Er_{(0.5-x)}Y_xCu_3Ti_4O_{12}$ (x=0 à 0.5)

- The value of the dielectric constant of all samples, for all frequencies, increases with increasing temperature and passes through two maximums and then decreases. The peak of these two anomalies widens more and more as the temperature increases, which highlights the diffuse nature of these ceramics.
- The T_1 peak shifts towards higher temperatures as the frequency increases up to 100 KHz, reflecting the relaxation phenomenon and from 1 MHz this peak moves towards low temperatures indicating the presence of the resonance phenomenon [4].

IV. CONCLUSIONS AND PERSPECTIVES

- NEYCTO ceramics crystallize in the cubic perovskite phase.
- Yttrium doping did not affect grain morphology and size.
- The improved properties of NECTO with an increasing in ε_r and simultaneously reducing in tanδ can be achieved by suitable doping content of Y^{3+} ions, such as x=0.15.
- The presence of two dielectric anomalies with a large diffuse nature as well as the relaxation and resonance phenomena were observed in those materials.
- In the future work, we will study the effect of preparation processes and treatment conditions on the dielectric properties of NEYCTO ceramics.
- Moreover, we will examine the photocatalytic properties of our materials.

V. REFERENCES

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