# Structural, Electrical and Magnetic properties of Ce and Fe Doped $SrTiO_3$

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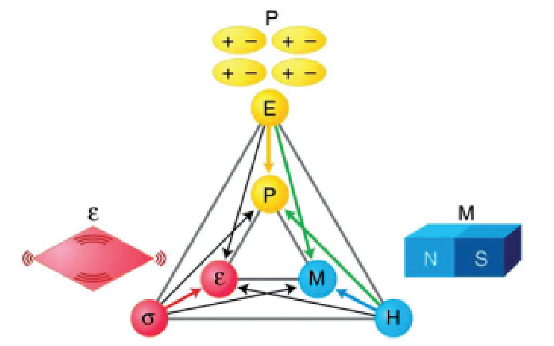
## ABSTRACT

We used solid state reaction technique to synthesize Strontium titanate $SrTiO_3$ (STO), Ce doped $Sr_{1-x}Ce_xTiO_3$ and (Ce, Fe) co-doped $Sr_{1-x}Ce_xTi_{1-y}Fe_yO_3$ samples in powder form. The crystallization temperature of the samples was estimated to be ~1080◦ from differential scanning calorimetry. The Rietveld analysis of the powder X-ray diffraction pattern confirmed the cubic Pm-3m phase of synthesized samples. We observed grain size reduction in both Ce and (Ce, Fe) co-doped samples as compared to those of undoped STO; from scanning electron microscopy measurements. Chemical component identification and their relative atomic percentage estimations were done by energy-dispersive X-ray spectroscopy. The complex impedance analysis revealed the effect of doping on frequency dependent dielectric constant and resistivity of the samples. The orders of magnitude enhancement in remnant magnetization and coercivity have been observed in (Ce, Fe) co-doped $Sr_{0.97}Ce_{0.03}Ti_{0.9}Fe_{0.1}O_3$ sample in vibrating sample magnetometer measurements. The ferromagnetic hysteresis in our (Ce, Fe) co-doped samples might have the potentials for interesting magnetic as well as multiferroic applications.

## OBJECTIVES

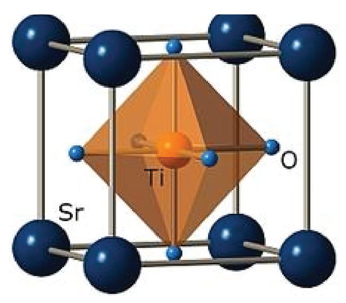
Our main objective of this project was to find a sample that has potential for multiferroic applications. Multiferroics are defined as materials that exhibit more than one of the primary ferroic properties in the same phase:



- Ferroelectricity
- Ferromagnetism
- Ferroelasticity

For that, we chose $SrTiO_3$ as our base sample and doped it with Ce and Fe respectively. Why $SrTiO_3$? That's because-

- It has stable Cubic Structure above -168ºC
- It's Melting point: 2080°C
- It's Dielectric constant is: 300



We studied the structural, electrical and magnetic properties of pure $SrTiO_3$. Then we doped it with Ce and Fe respectively and studied the changes. The reason behind choosing Ce and Fe as our doping materials was because previous studies has shown that Ce can increase the DE constant of $BaTiO_3$ ,which is also an perovskite material like $SrTiO_3$. Fe has stong magnetic properties and in previous studies, it has shown promising results in inducing magnetism in other materials when doped with.

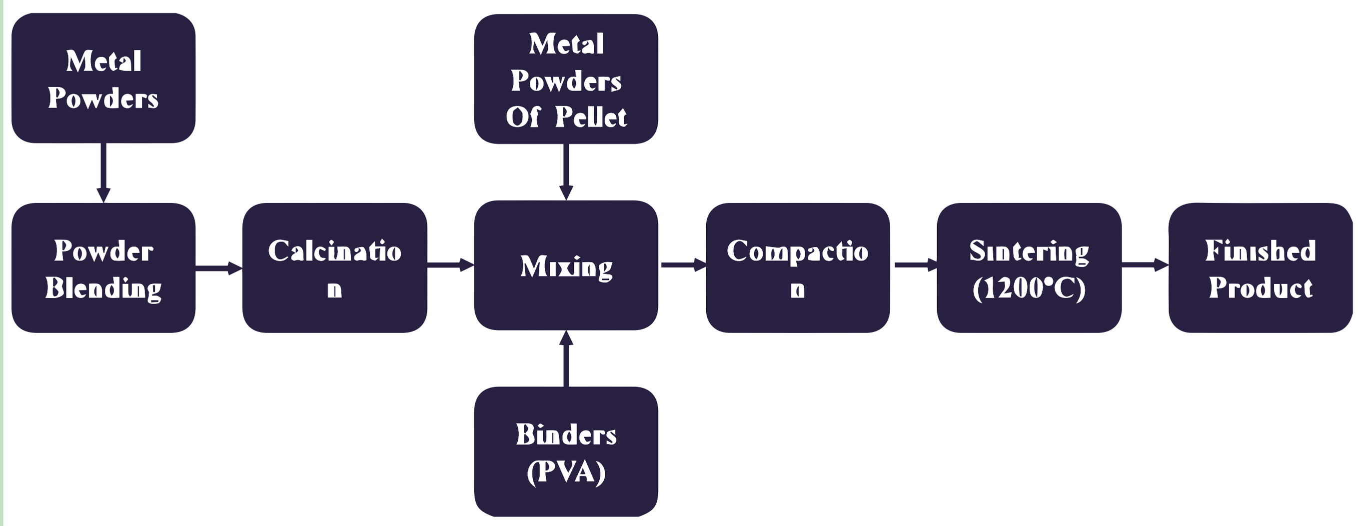
$Sr_{1-x}Ce_xTi_{1-y}Fe_yO_3$

- Inducing Ferroelectricity by Ce
- Inducing Ferromagnetism by Fe

We plan to investigate the order of ferromagnetism and ferroelectricity at different temperature. We first tried to show the effect of doping on magnetization at room temperature in this work.

## METHODOLOGY

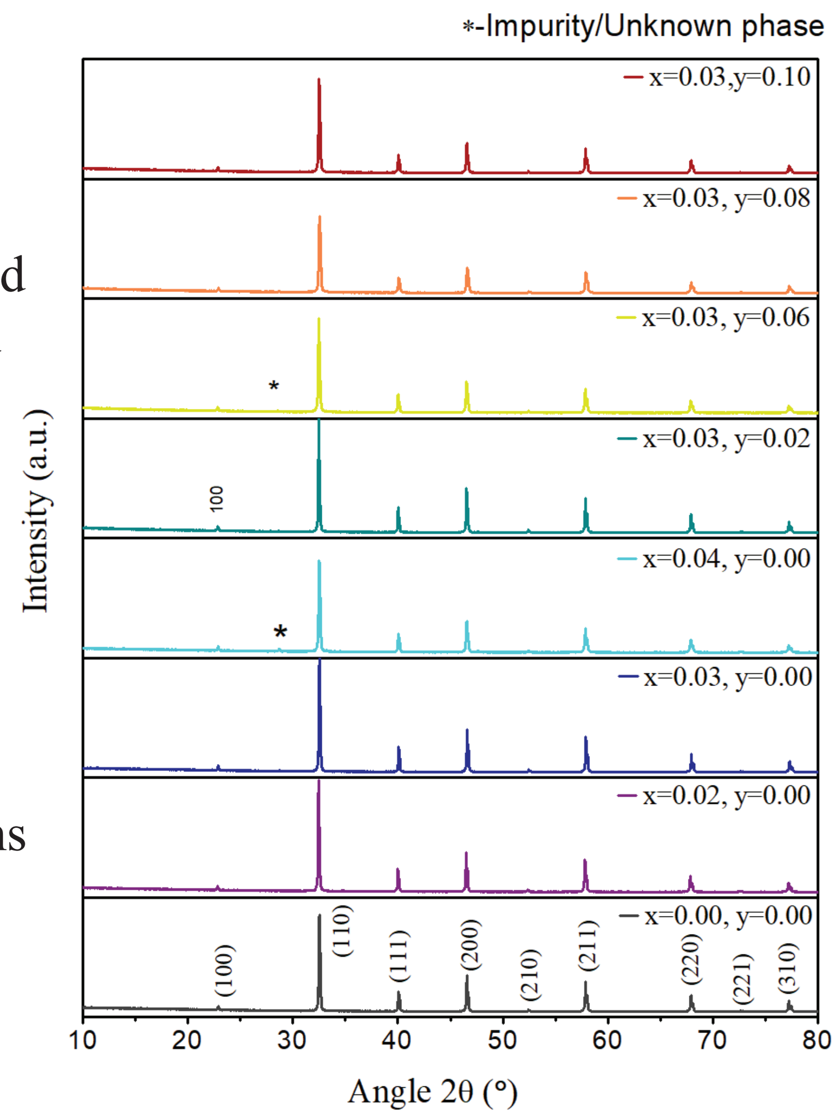
A number of different samples for undoped $SrTiO_3$, Ce-doped $SrTiO_3$ and (Ce, Fe)-doped $SrTiO_3$ have been synthesized using the standard solid state reaction method.



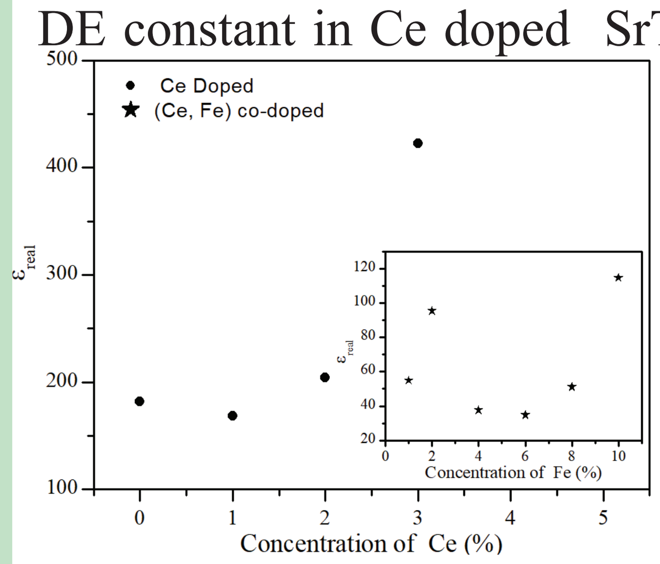

For the Ce-doped samples, x = 0.01, 0.02, 0.03, 0.04, 0.06, 0.08 and 0.1 were prepared with the chemical formula $Sr_{1-x}Ce_xTiO_3$. In case of (Ce, Fe)-double doped samples with chemical formula $Sr_{1-x}Ce_xTi_{1-y}Fe_yO_3$, a series of combinations with y = 0.01, 0.02, 0.04, 0.06, 08 and 0.1 for fixed x = 0.03 have been synthesized. The crystallization temperatures of the undoped, Ce and (Ce, Fe) doped samples are measured to be ~1080◦ using a differential scanning calorimetry. The samples were shaped into circular disk-shaped pellets and toroid rings. Then the pellets and rings are loaded into the high temperature furnace (Nabertherm Muffle Furnace LT 5/14) for sintering at 1250◦ C for 4 hours.

## RESULTS

XRD pattern shows presence of secondary phase and impurity peaks for more than 3% Ce dopant concentration. First dopant (Ce) concentration was fixed to be 3% and Samples with various concentrations of second dopant (Fe) along with 3% Ce dopant were prepared. Except for 6% Fe doped sample, all synthesized compositions showed incorporation of both dopants on STO. Synthesized STO, 3% Ce doped and 3% Ce and 10% Fe co-doped samples were used for further characterizations to investigate the properties of Ce and Ce-Fe doped STO.

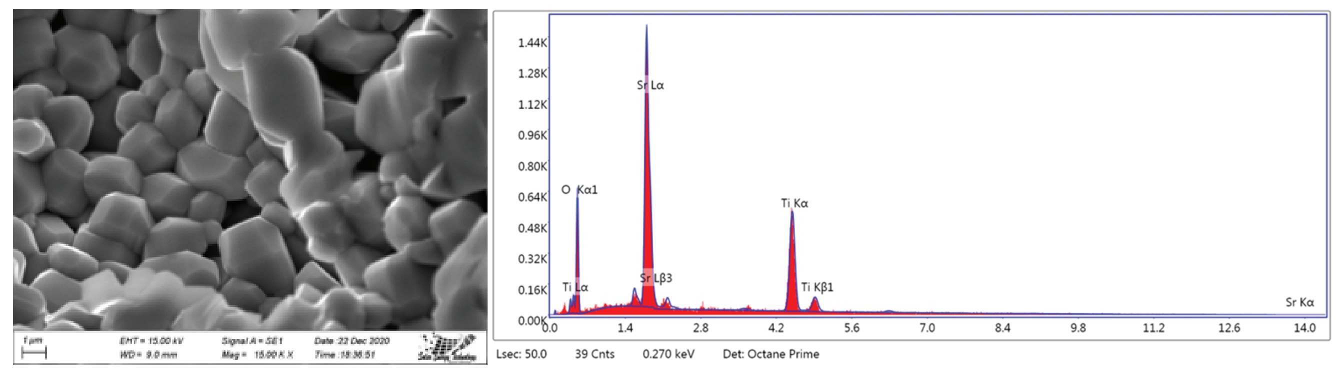



From the Complex Impedance Analysis, we found increase in DE constant in Ce doped $SrTiO_3$. But after we doped $SrTiO_3$ both Ce and Fe, the DE constant decreaesd. The DE constant was measured with a frequency range of 100-100kHz. Here the DE constant of different samples at 1kHz is shown.

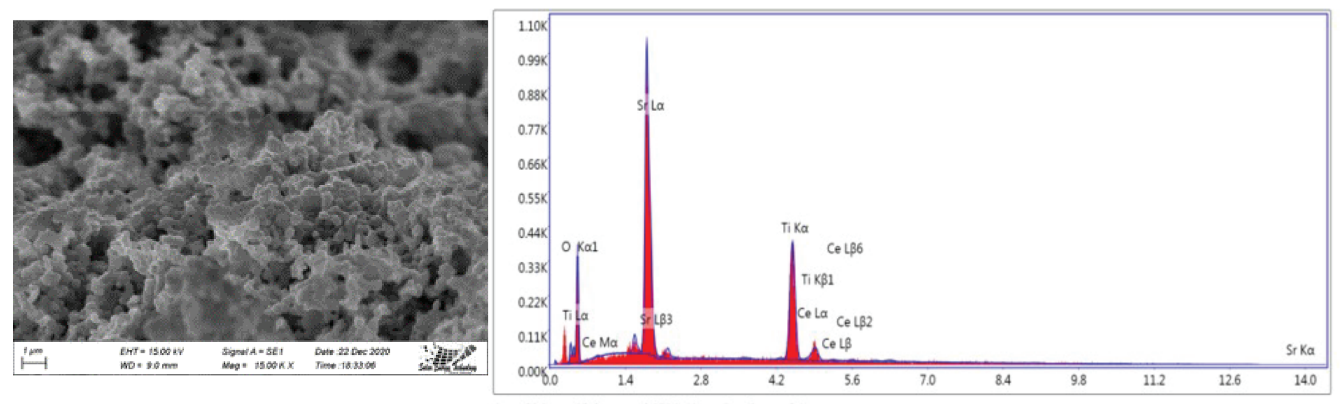



From Scanning Electron Microscope, we found that the grain size of $SrTiO_3$ was reduced when doped with Ce and Fe ($Sr_{0.97}Ce_{0.03}Ti_{0.9}Fe_{0.1}O_3$ ).

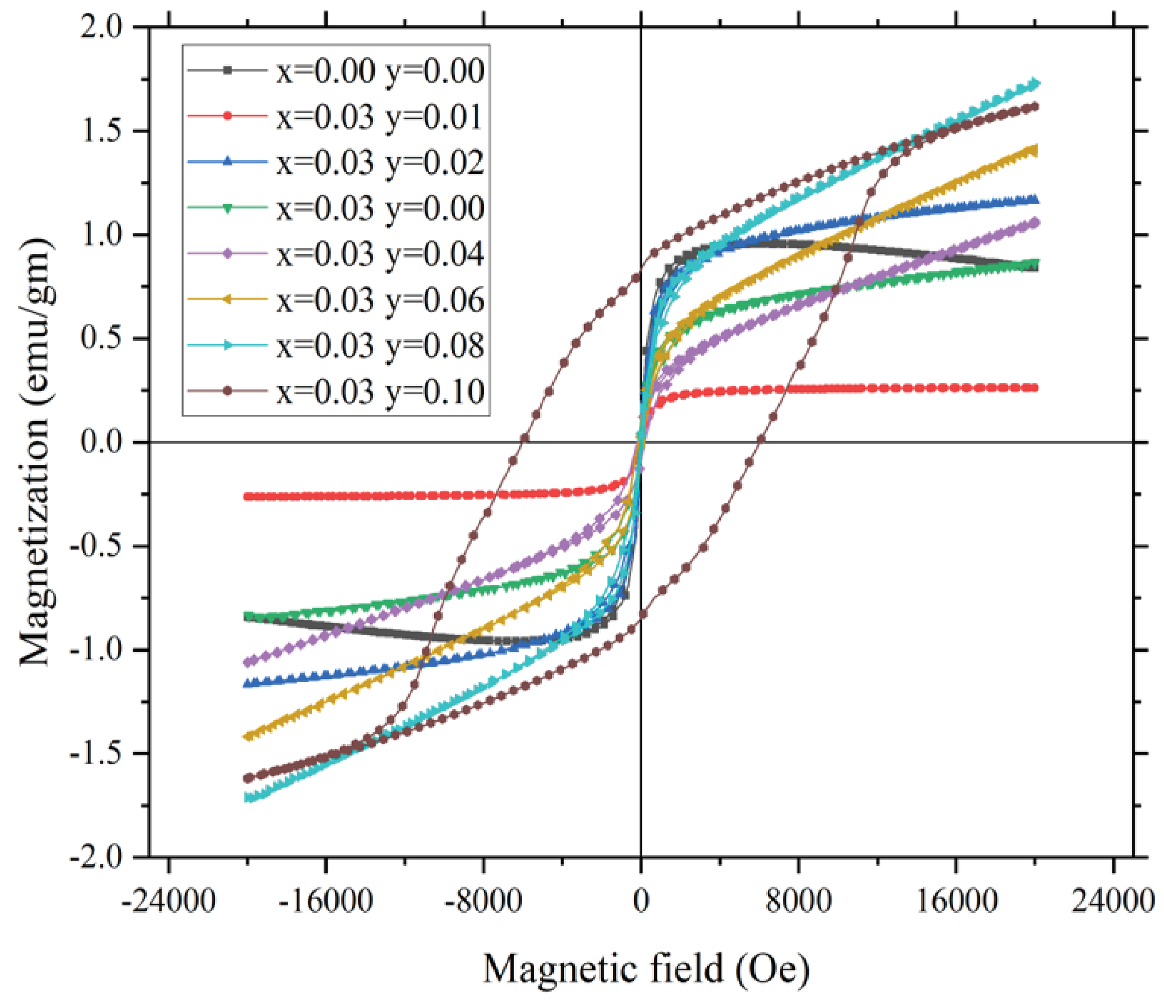
$SrTiO_3$



$Sr_{0.97}Ce_{0.03}Ti_{0.9}Fe_{0.1}O_3$



Then using Vibrating Sample Magnetometer, we measured the magnetic response of our samples with magnetic field. $Sr_{0.97}Ce_{0.03}Ti_{0.9}Fe_{0.1}O_3$ exhibited promising magnetization and remanence. Where $SrTiO_3$ showed paramagnetic behavior, $Sr_{0.97}Ce_{0.03}Ti_{0.9}Fe_{0.1}O_3$ showed ferromagnetic behavior.




## CONCLUSION

This is still an ongoing work. We tried to show the effect of doping on structural parameters , magnetization and dielectric properties. Xrd shows very little change in structural parameters and desired formation of our composition. Grain size of the samples is reduced with doping concentration. Dielectric constant vary randomly with both dopant concentration and becomes smaller than our pure STO sample. Remnant Magnetization and coercivity are enhanced greatly due to co-doping.