Structure analysis of cobalt ferrite/titania composite

Consiglio Nazionale delle Ricerche
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Structure analysis of cobalt ferrite/titania composites

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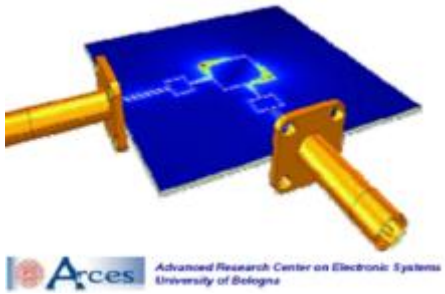
MDM's Applications

- Main Application Area:
  - **Miniaturized Microstrip Antennas**
    - for wearable and wireless applications in the **UltraHigh Frequency**

UHF → *300 MHz ÷ 3 GHz*

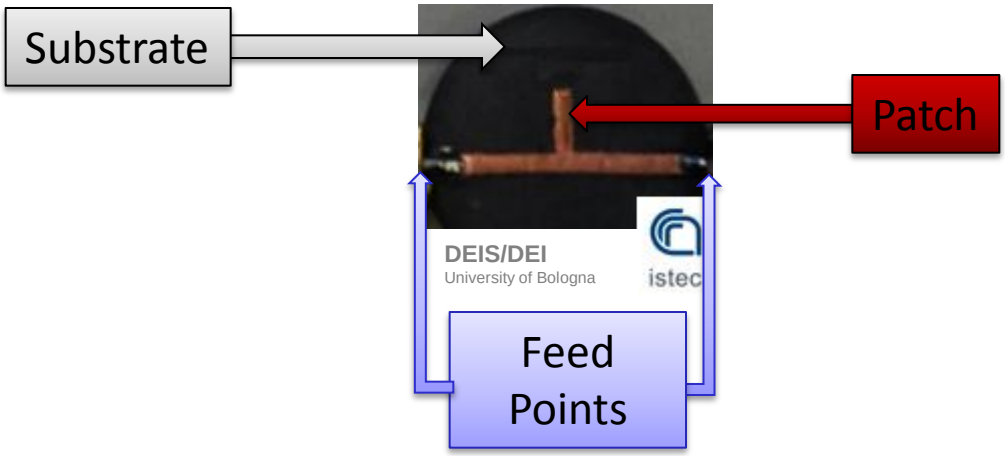


[] Martino Aldrigo, Alessandra Costanzo, Diego Masotti, Carmen Galassi. Exploitation of a novel magneto-dielectric substrate for miniaturization of wearable UHF antennas. Materials Letters. Vol. 87: 127-130, 2012

[] Martino Aldrigo, Davide Bianchini, Alessandra Costanzo, Diego Masotti, Carmen Galassi, Liliana Mitoseriu. New Broadband Button-Shaped Antenna on Innovative Magneto-Dielectric Material for Wearable Applications. Proceedings of the 9thEuropean Radar Conference. Amsterdam (the Netherlands) 31 Oct – 2 Nov 2012.

Miniaturized Microstrip Antenna

- Main Application Area:
  - **Miniaturized Microstrip Antennas**
    - for wearable and wireless applications in the UHF



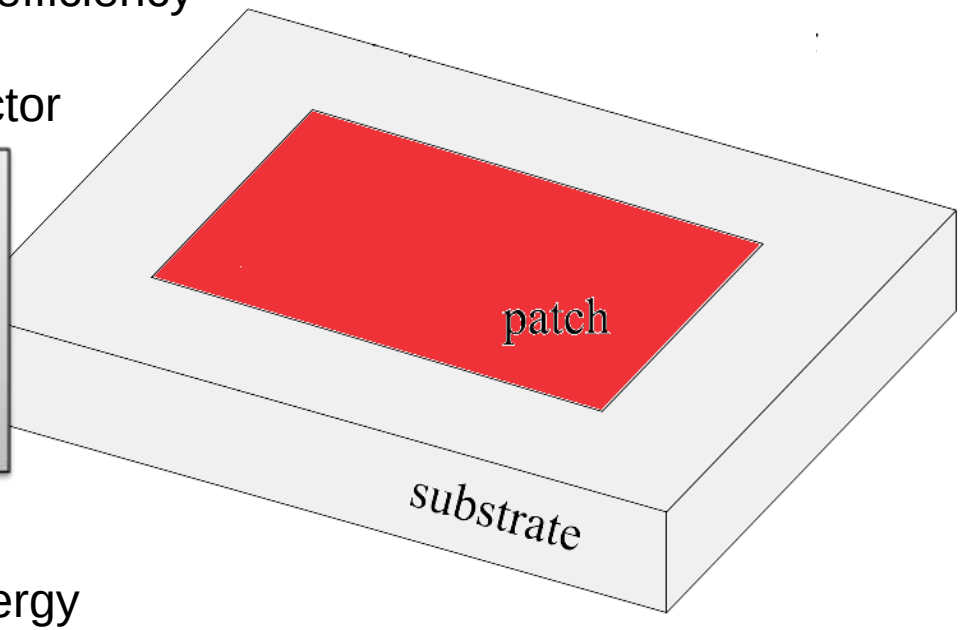
[] Howell "Microstrip Antennas," IEEE International Symposium on Antennas and Propagation, Williamsburg Virginia, 1972 pp. 177-180

Design MD substrate

Antenna performances:
- Radiation efficiency
- Bandwidth
- Quality factor

miniaturization factor

$$n = \sqrt{\frac{\mu_r}{\varepsilon_r}}$$

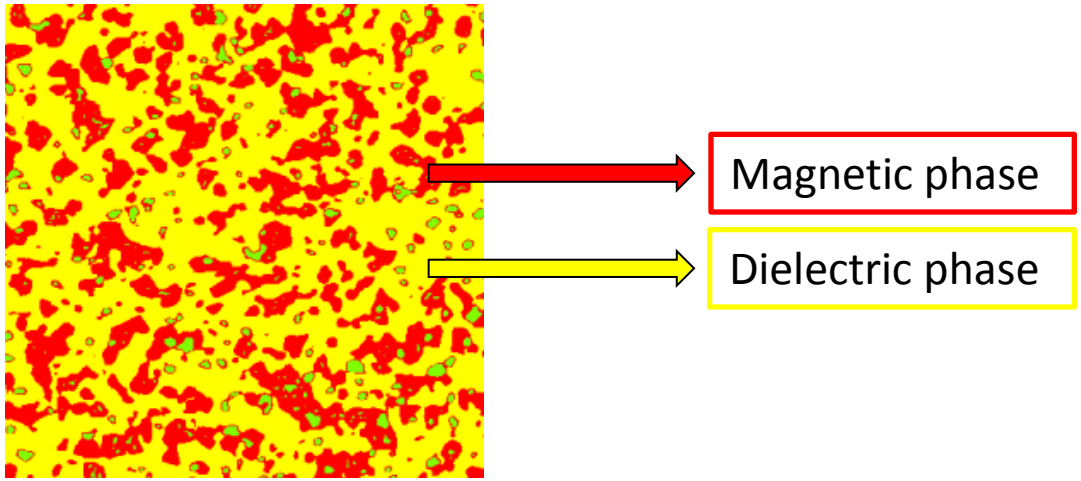


Substrate properties:
- Dielectric losses
- Magnetic losses
- Stored energy
- Radiated power

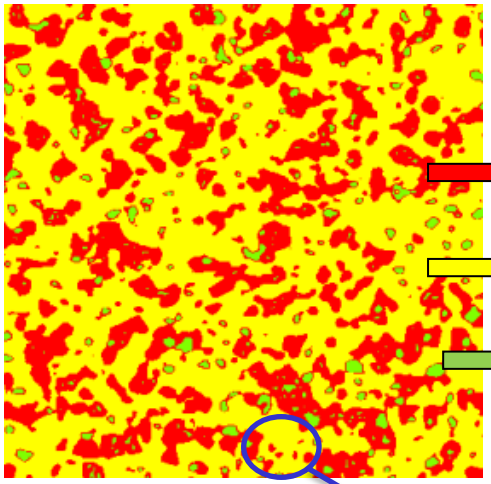
[] C. Niamien, S. Collardey and K. Mahdjoubi. *Printed antennas over lossy magneto-dielectric substrates.* European Conference on Antennas and Propagation 2010, 12-16 April 2010, Barcellona.
[] R.C. Hansen and Mary Burke. *ANTENNAS WITH MAGNETO-DIELECTRICS. Microwave and optical thecnology letters.* Vol. 26, No. 2, July 20 2000.
[] JF. Pintos, A. Louzir, P. Minard, J Perraudeau, JL. Mattei, D. Souriou, P. Queffelc. Ultra-Miniature UHF Antenna using Magneto dielectric Material.

Magnetodielectric Materilas - MDM's

MDM's are composites with magnetic fillers in a dielectric matrix



The dielectric permittivity (ε) and magnetic permeability (μ) of MDM's can be tailored choosing the kind of magnetic and dielectric phases and theirs volume percentage in order to achieve **new electromagnetic properties**.

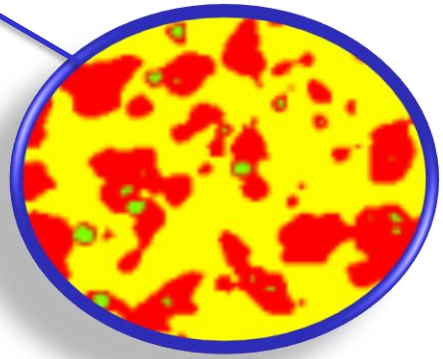


Vol. % Magnetic phase (**μ**)

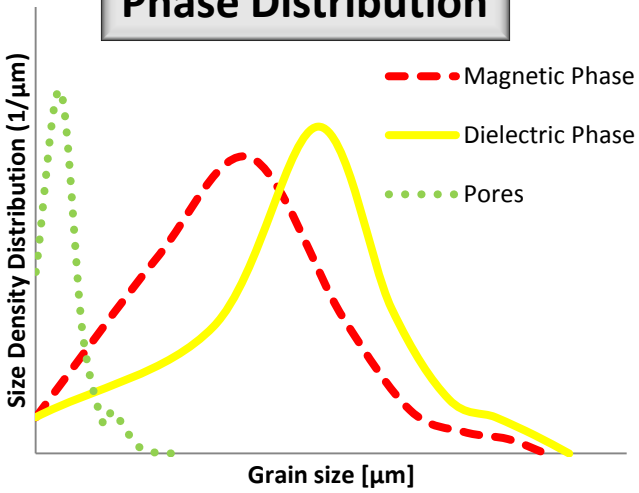
Vol. % Dielectric phase (**ε**)

Vol. % Pores

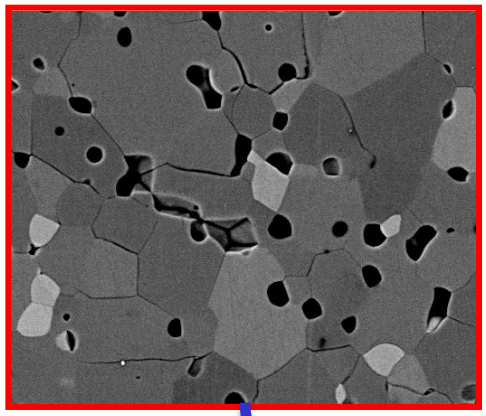
Phase Dispersion



Phase Distribution



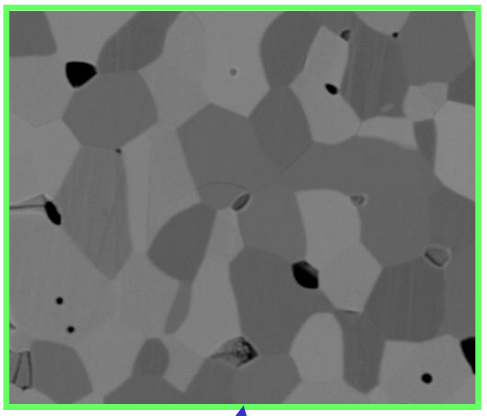
Cobalt ferrite/titania composites as MD substrate



Grain Boundaries Adhesion

Interface: Kind & Thickness

Pores



Reduction
Dielectric Losses

Cobalt ferrite/titania composites as MD substrate

Dielectric phase

Titania TiO_2

TO

Magnetic phase

Cobalt ferrite $CoFe_2O_4$

CFO

TO properties:

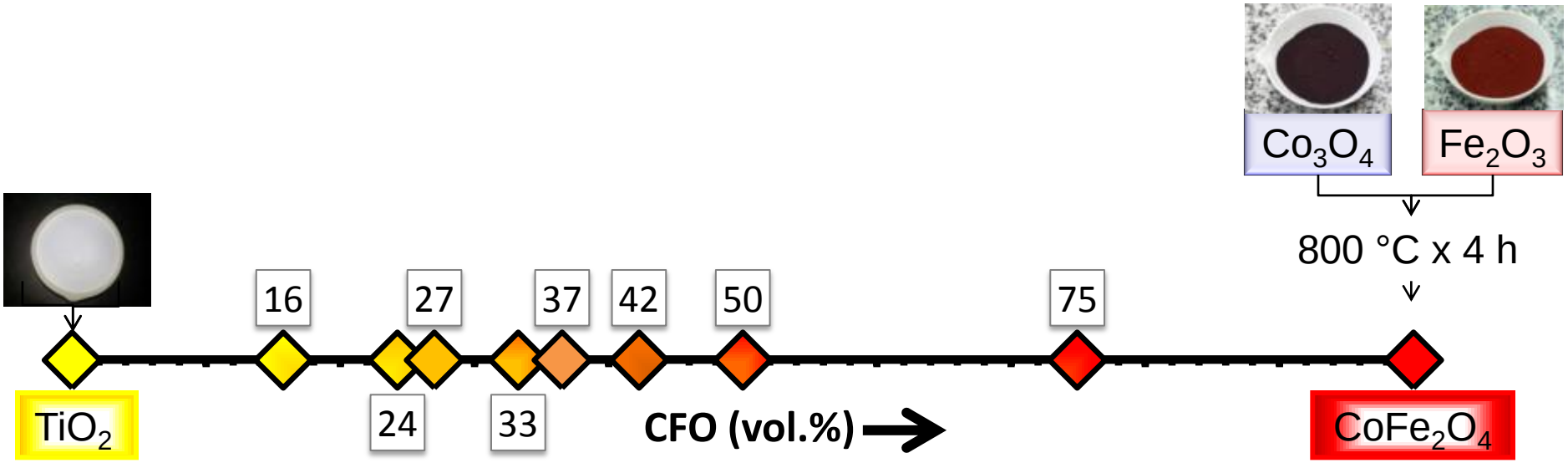
- low dielectric constant @UHF
- good process behaviour compared to others materials with low dielectric constant

CFO properties @RT:

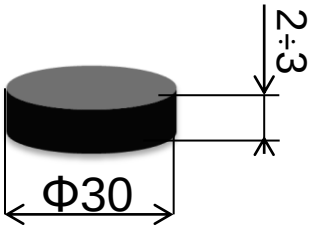
- high coercivity
- large magnetic anisotropy
- moderate saturation magnetization
- high resistivity
- good mechanical and chemical stabilities

Experimental

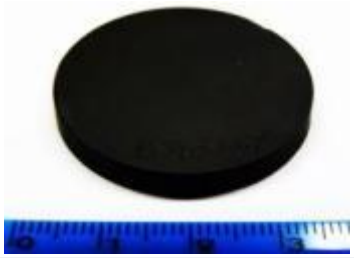
The samples were prepared by **solid state reaction** starting from commercial powders:



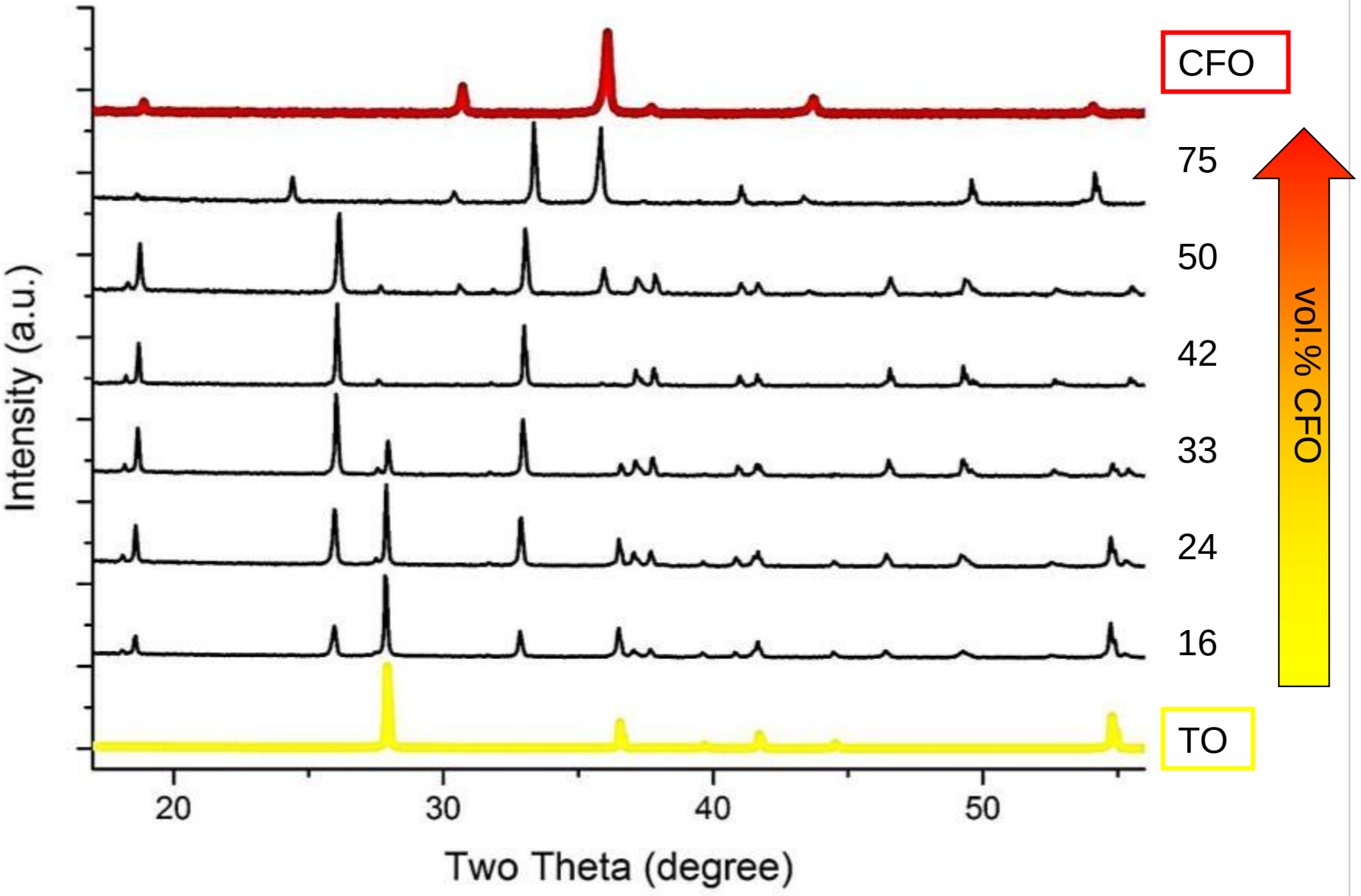
- mixing
- cold linear pressing at 70 MPa



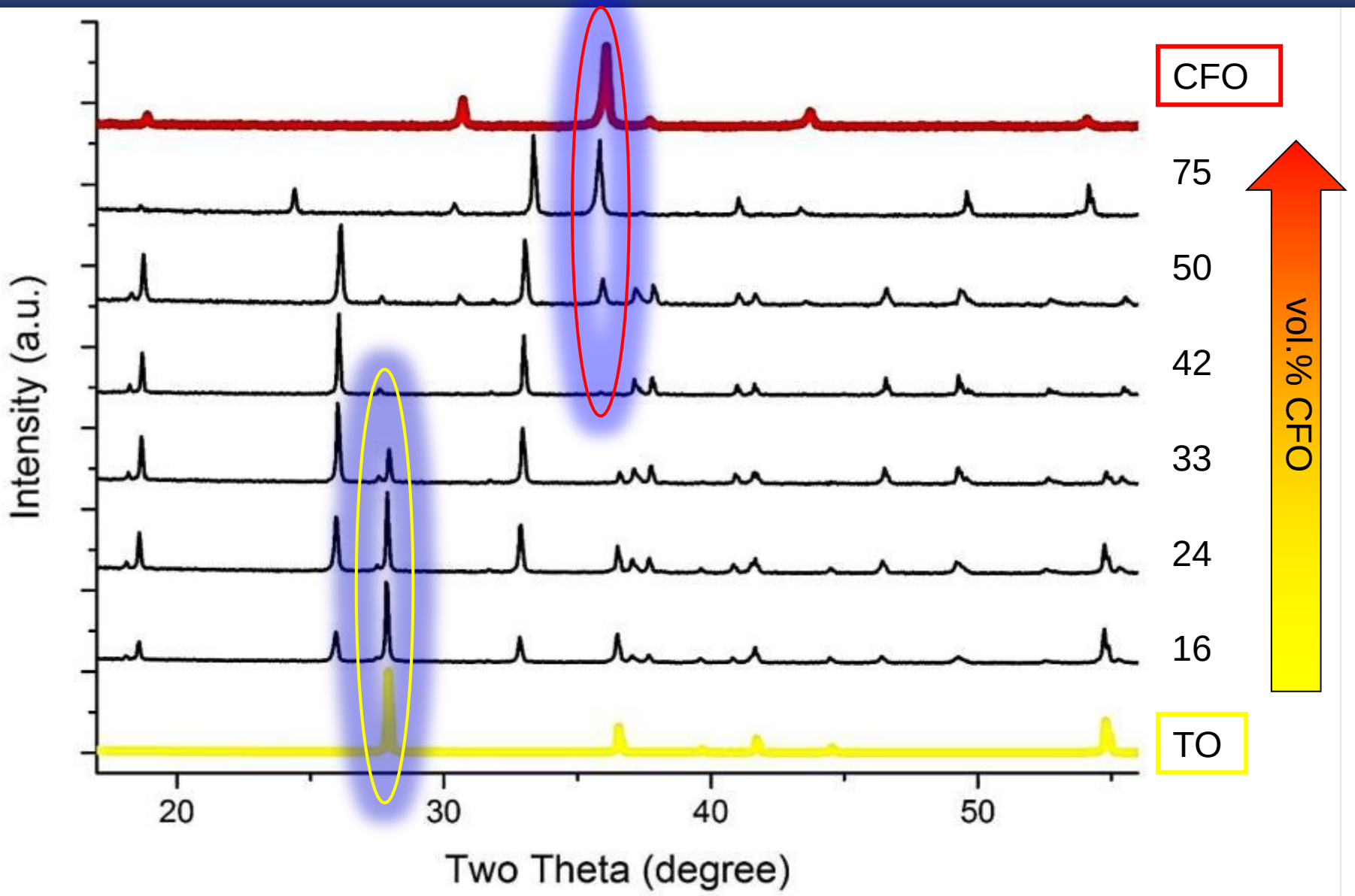
- Isostatic pressing at 250 MPa
- sintered in air at 1200 °C for 2 h



XRD


CFO
75
50
42
33
24
16
TO
vol.% CFO
Intensity (a.u.)
20
30
40
50
Two Theta (degree)

XRD


CFO
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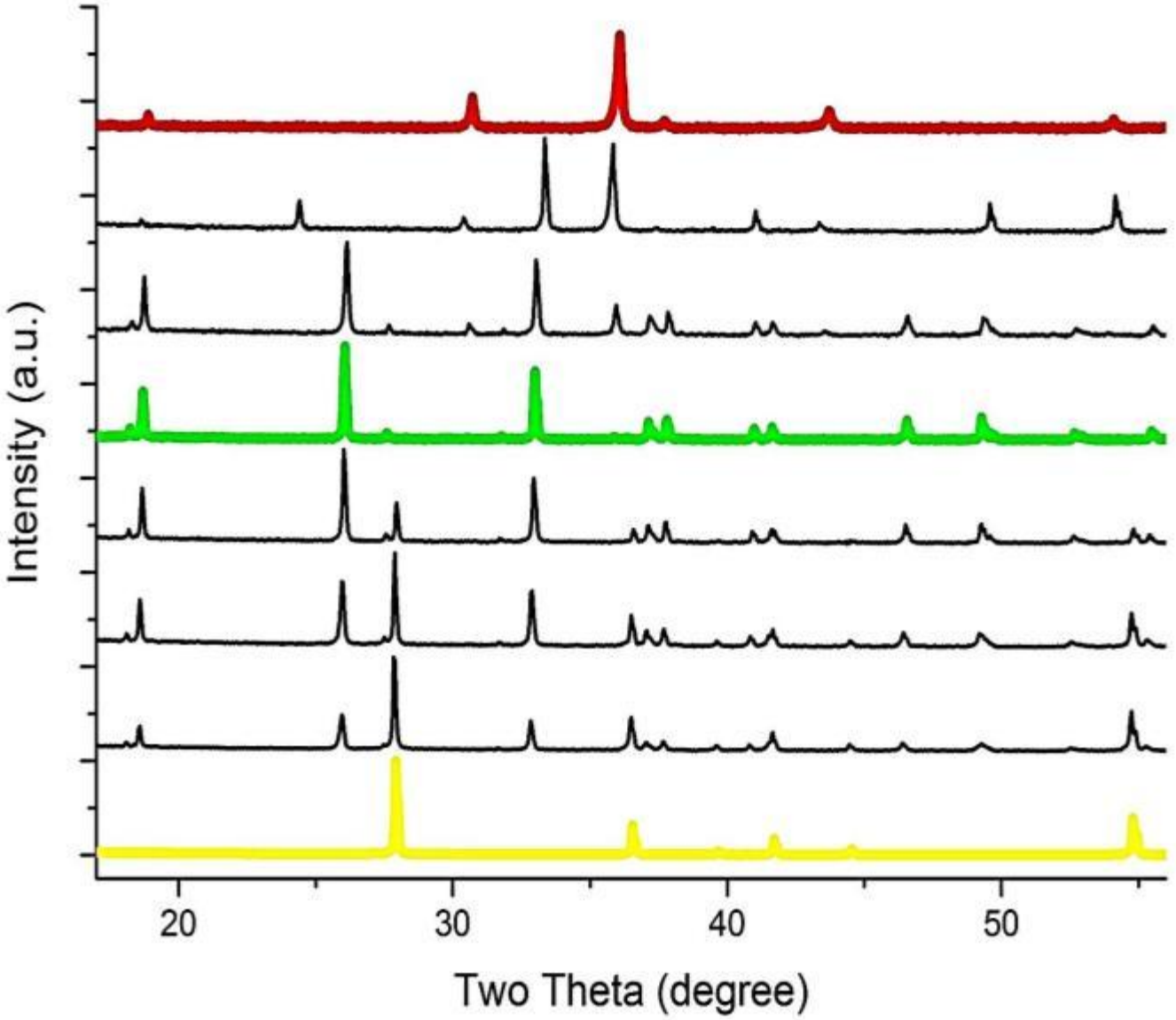
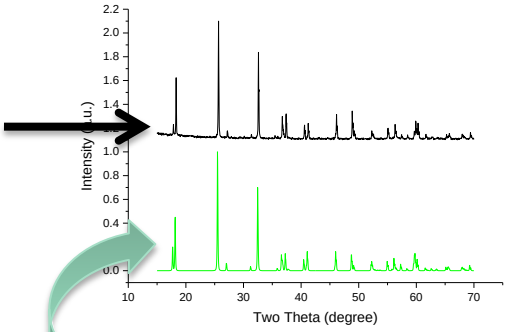
XRD





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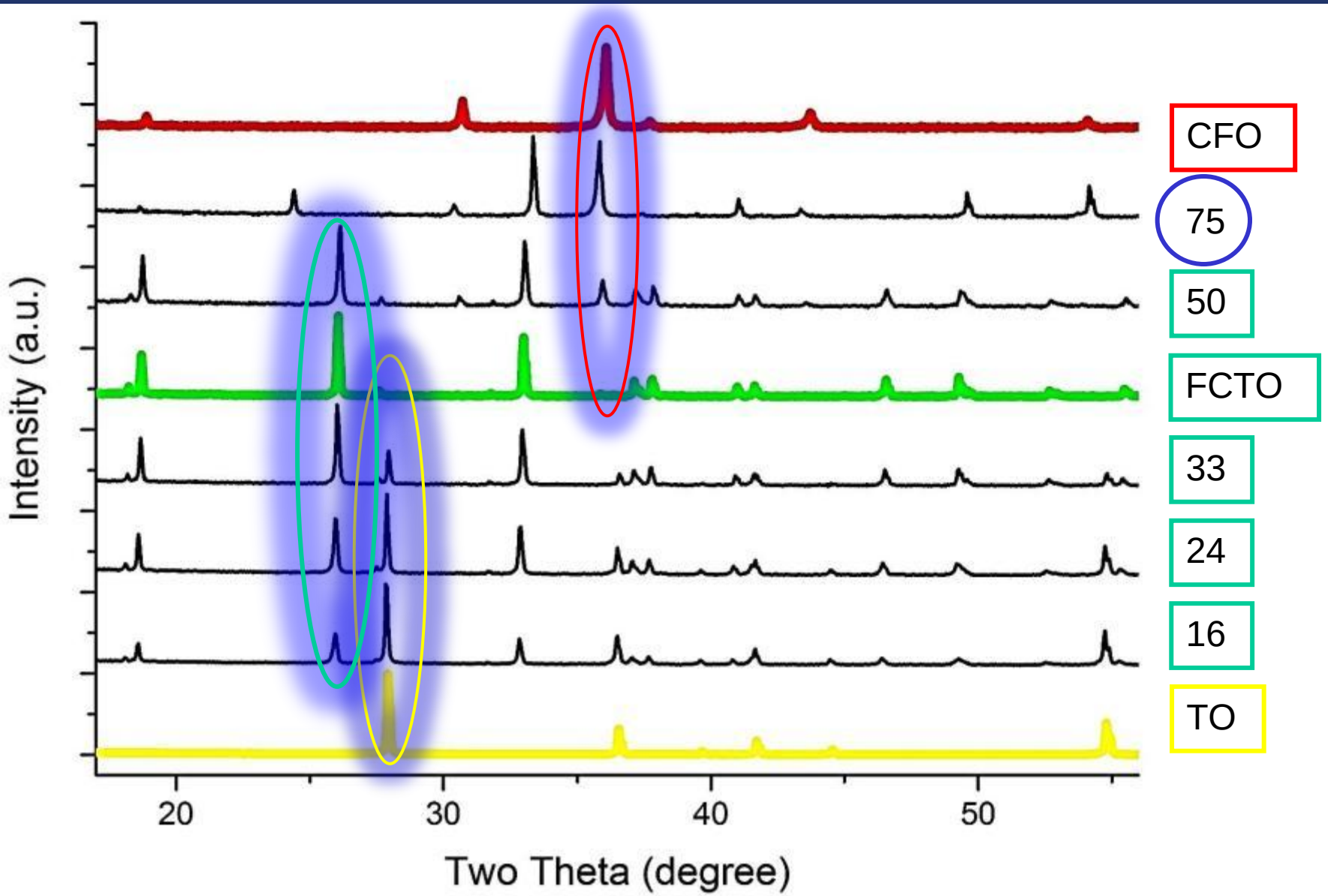
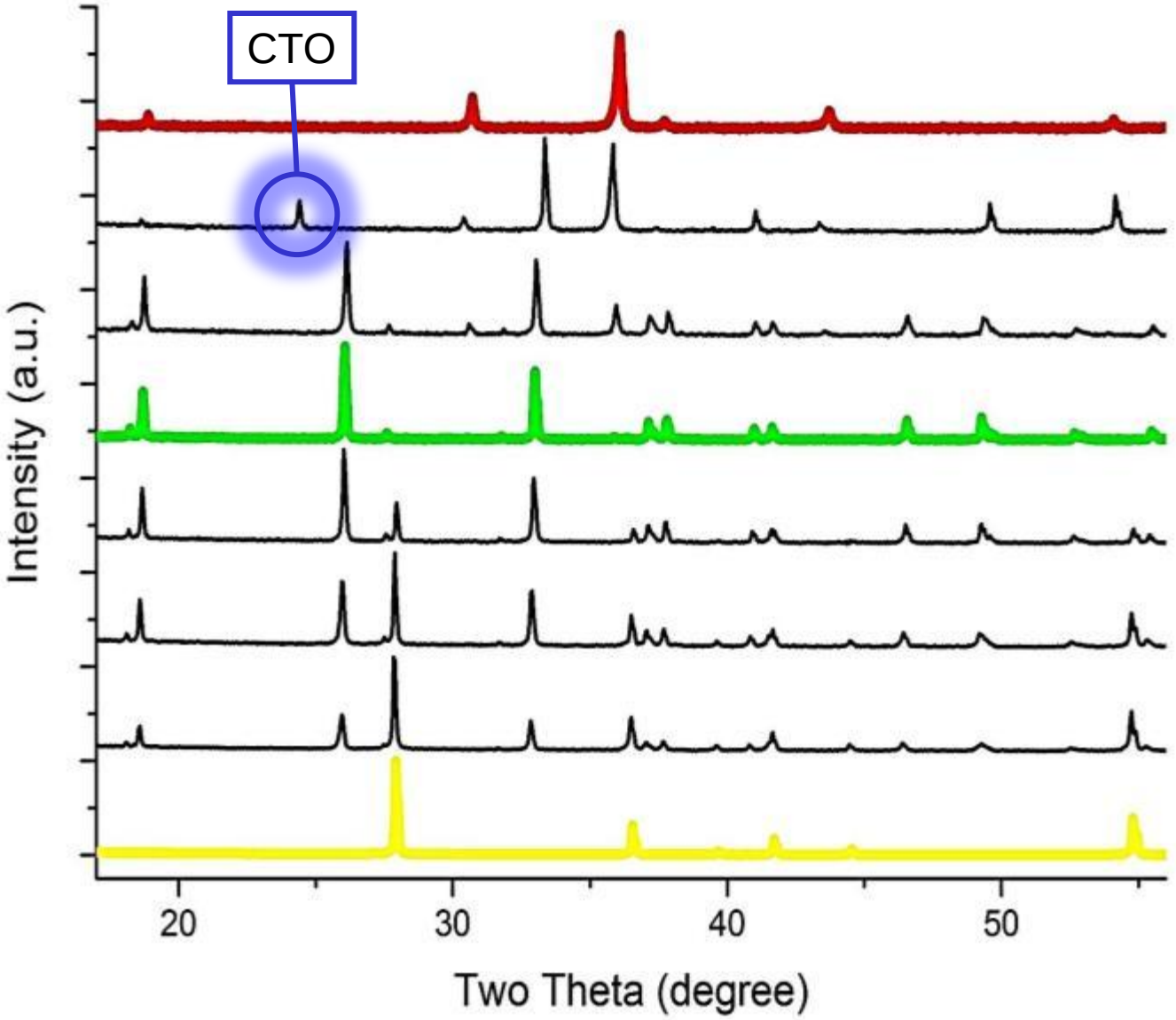
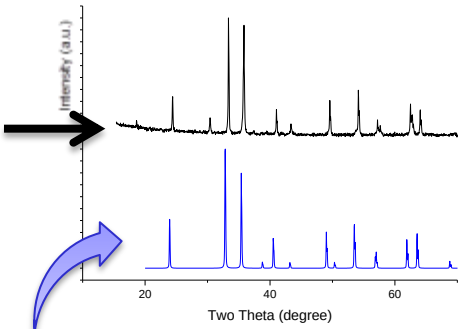
$Fe_2CoTi_3O_{10}$ (FCTO)

XRD


Intensity (a.u.)
20
30
40
50
Two Theta (degree)
CFO
75
50
FCTO
33
24
16
TO

XRD





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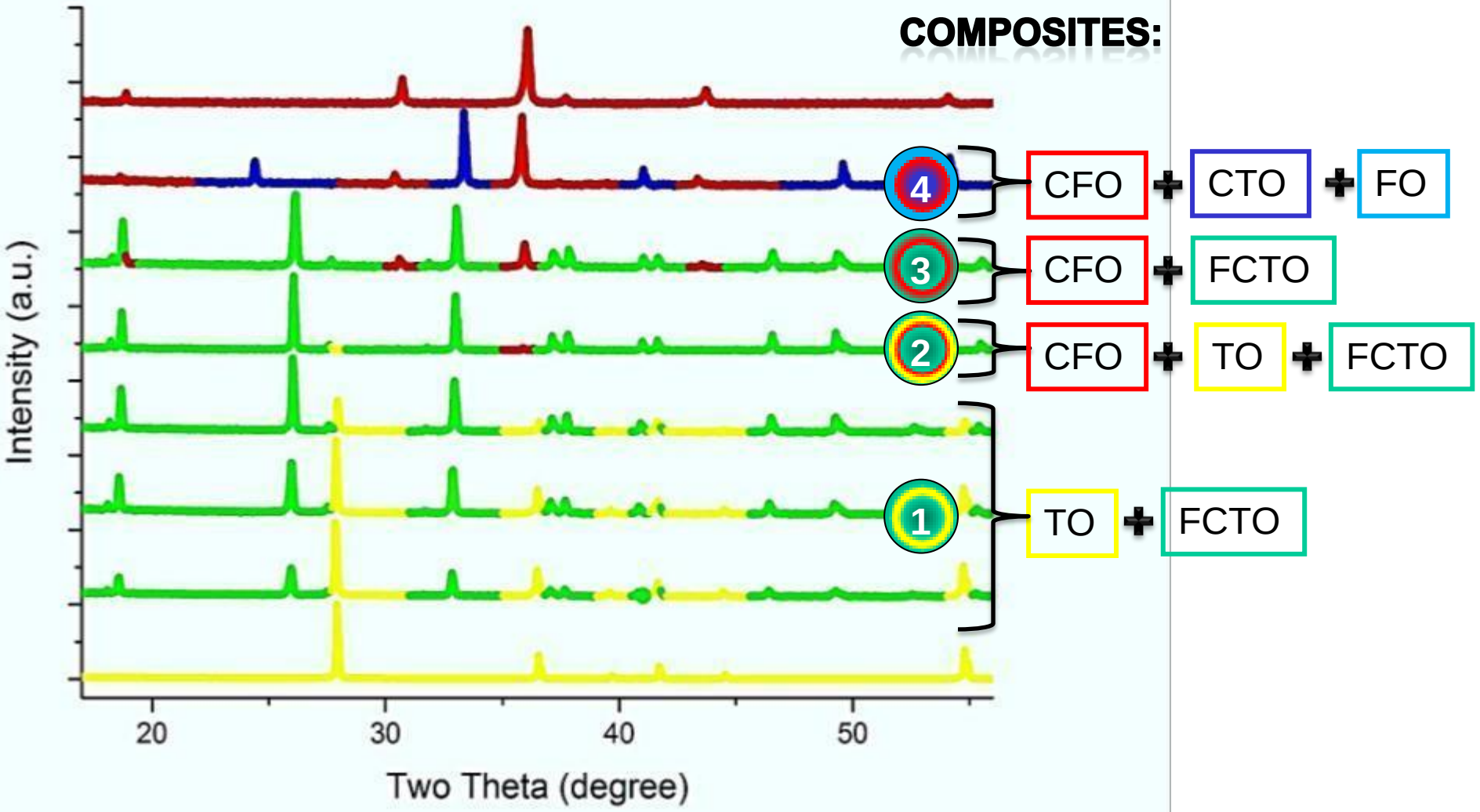
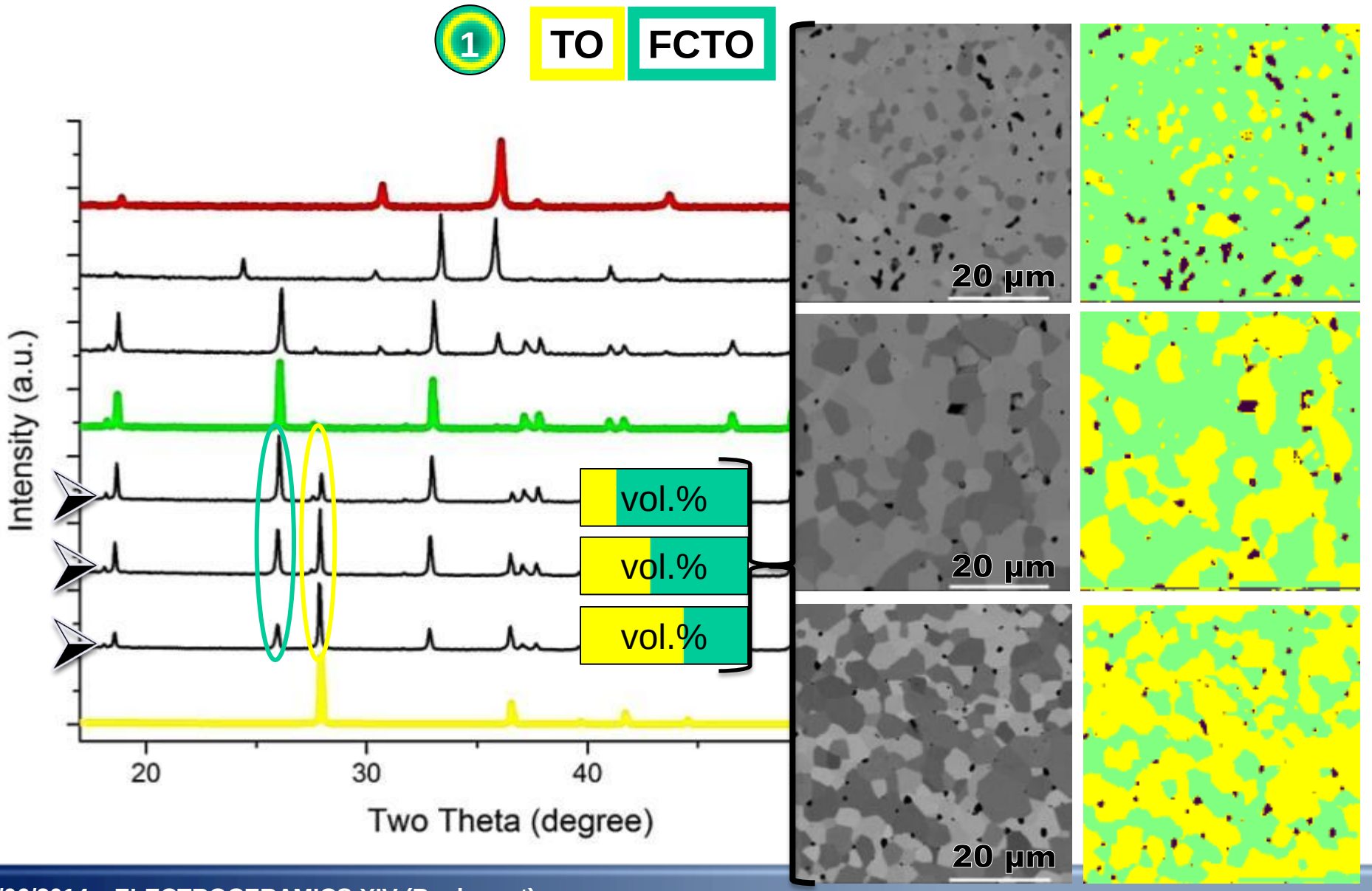
$CoTiO_3$ (CTO)

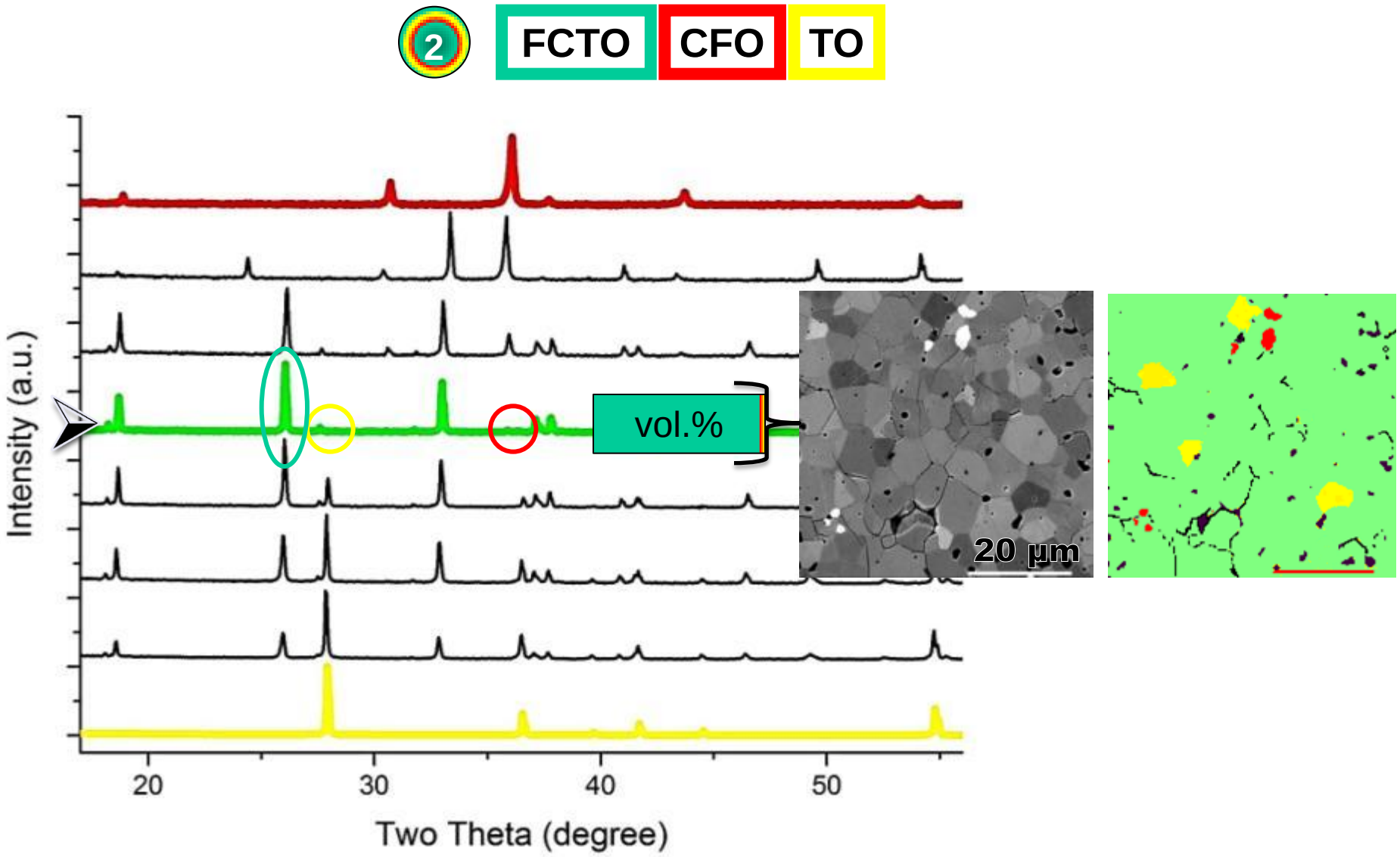
Fe_2O_3 (FO)

XRD


COMPOSITES:
4
CFO + CTO + FO
3
CFO + FCTO
2
CFO + TO + FCTO
1
TO + FCTO
Intensity (a.u.)
20
30
40
50
Two Theta (degree)

Microstructure

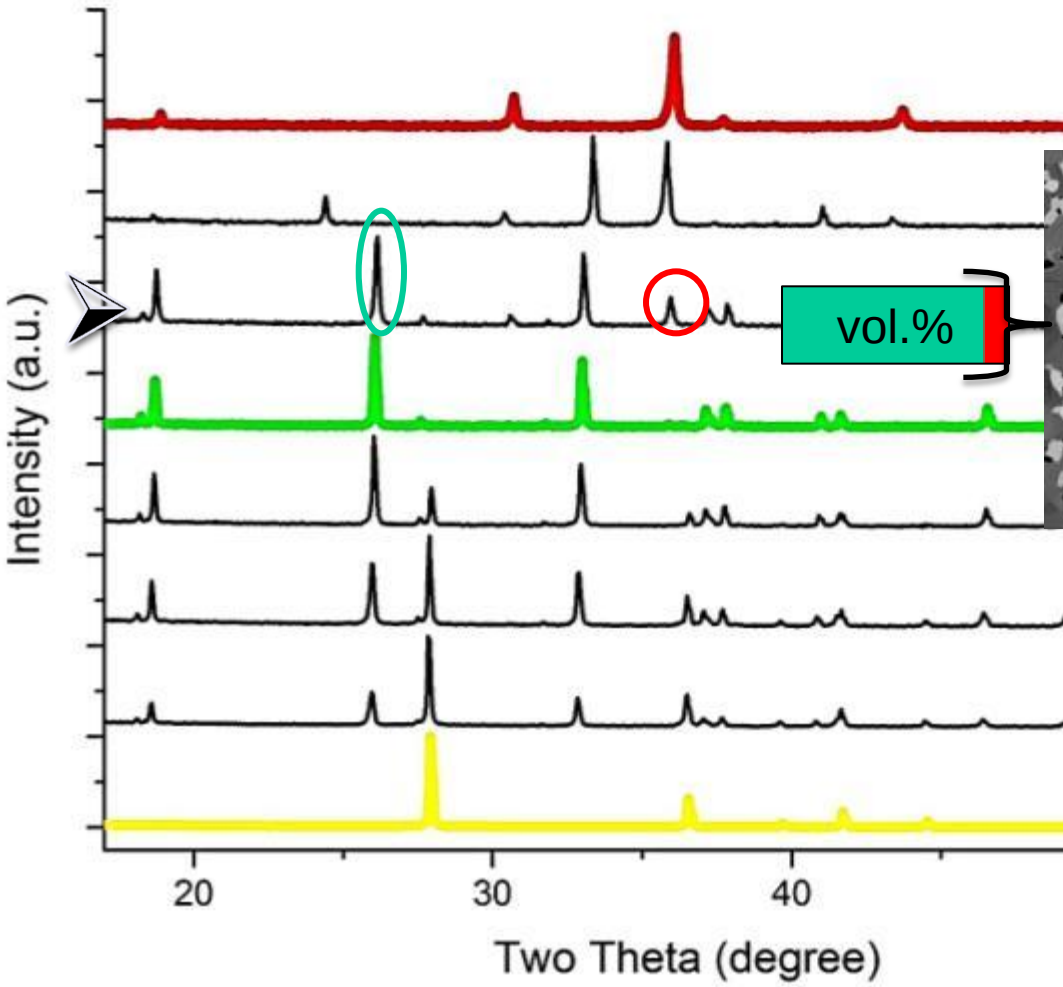



2
FCTO
CFO
TO
Intensity (a.u.)
20
30
40
50
Two Theta (degree)
vol.%
20 µm

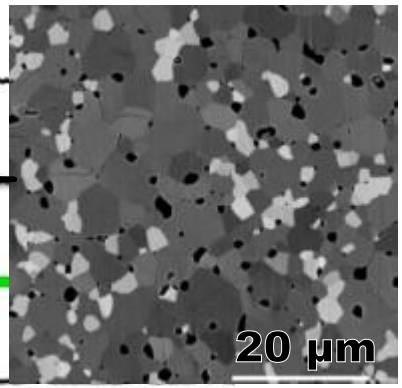
Microstructure

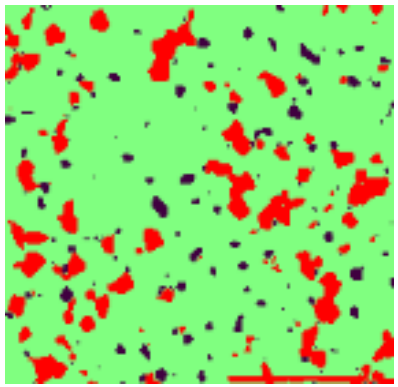
3

FCTO CFO

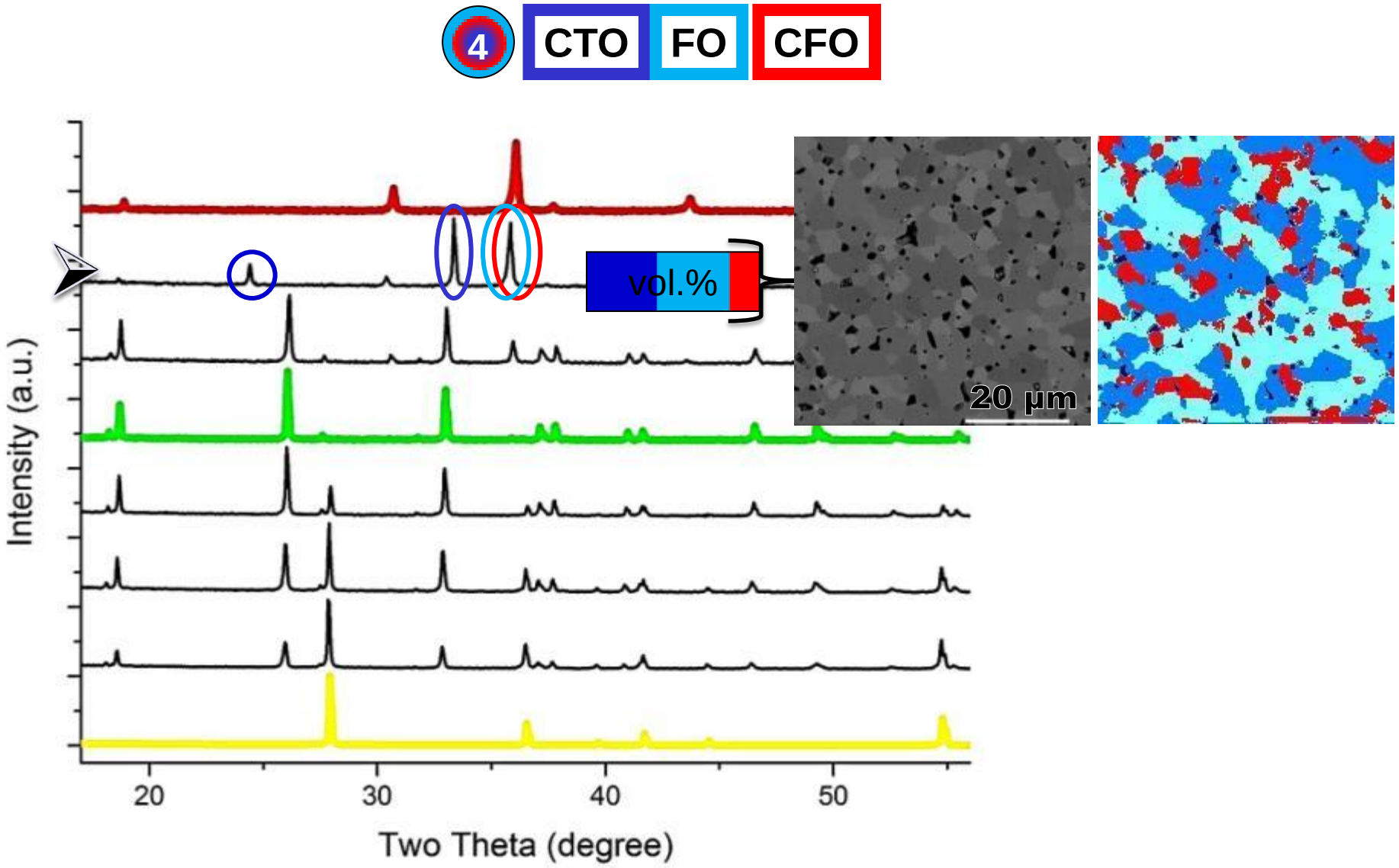


vol.%

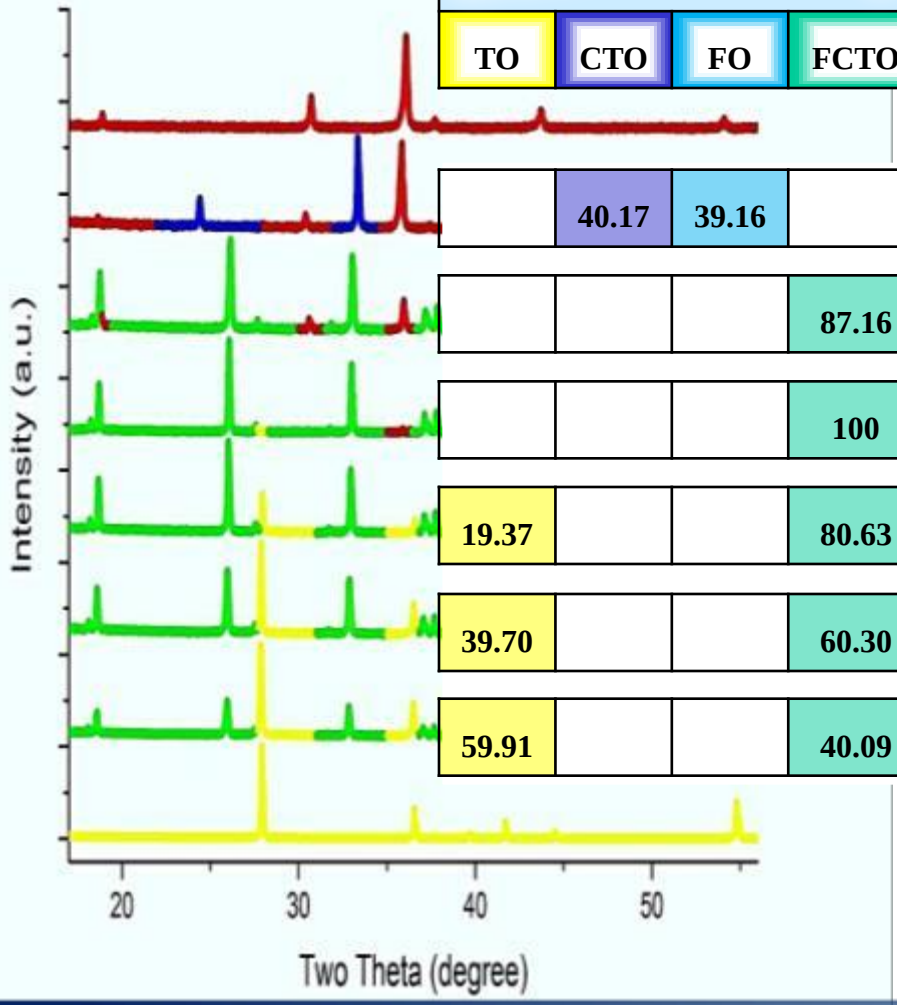




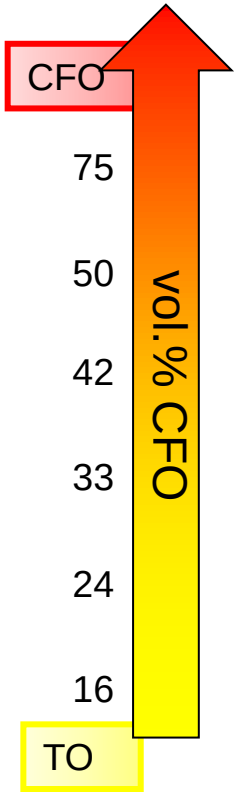
Microstructure



Results

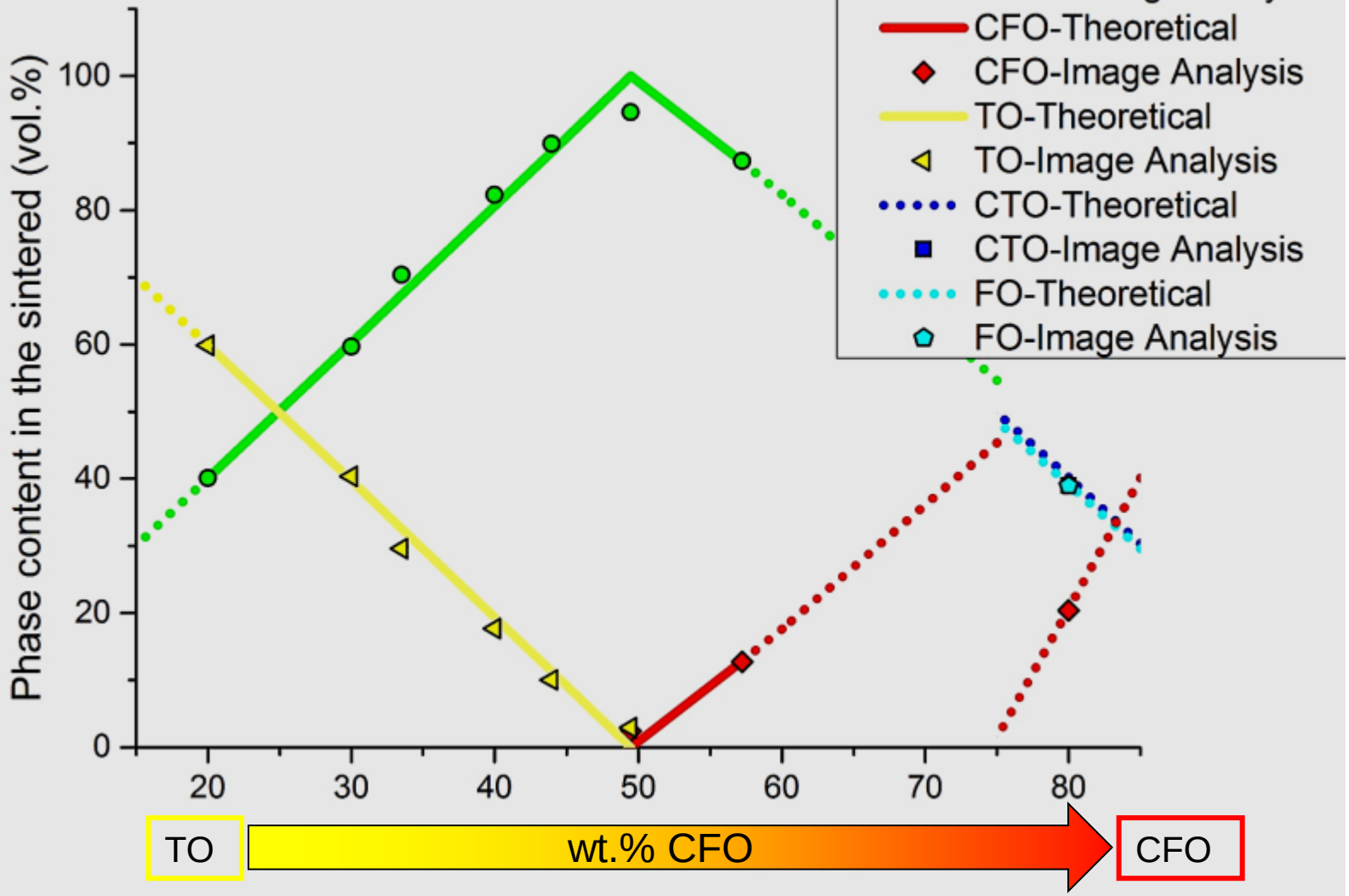


Theoretical (vol.%)					Image Analysis (vol.%)				
TO	CTO	FO	FCTO	CFO	TO	CTO	FO	FCTO	CFO
	40.17	39.16		20.67		39	40.6		20.4
			87.16	12.84				87.3	12.7
			100		2.9			94.6	2.5
19.37			80.63		17.7			82.3	
39.70			60.30		40.3			59.7	
59.91			40.09		59.9			40.1	

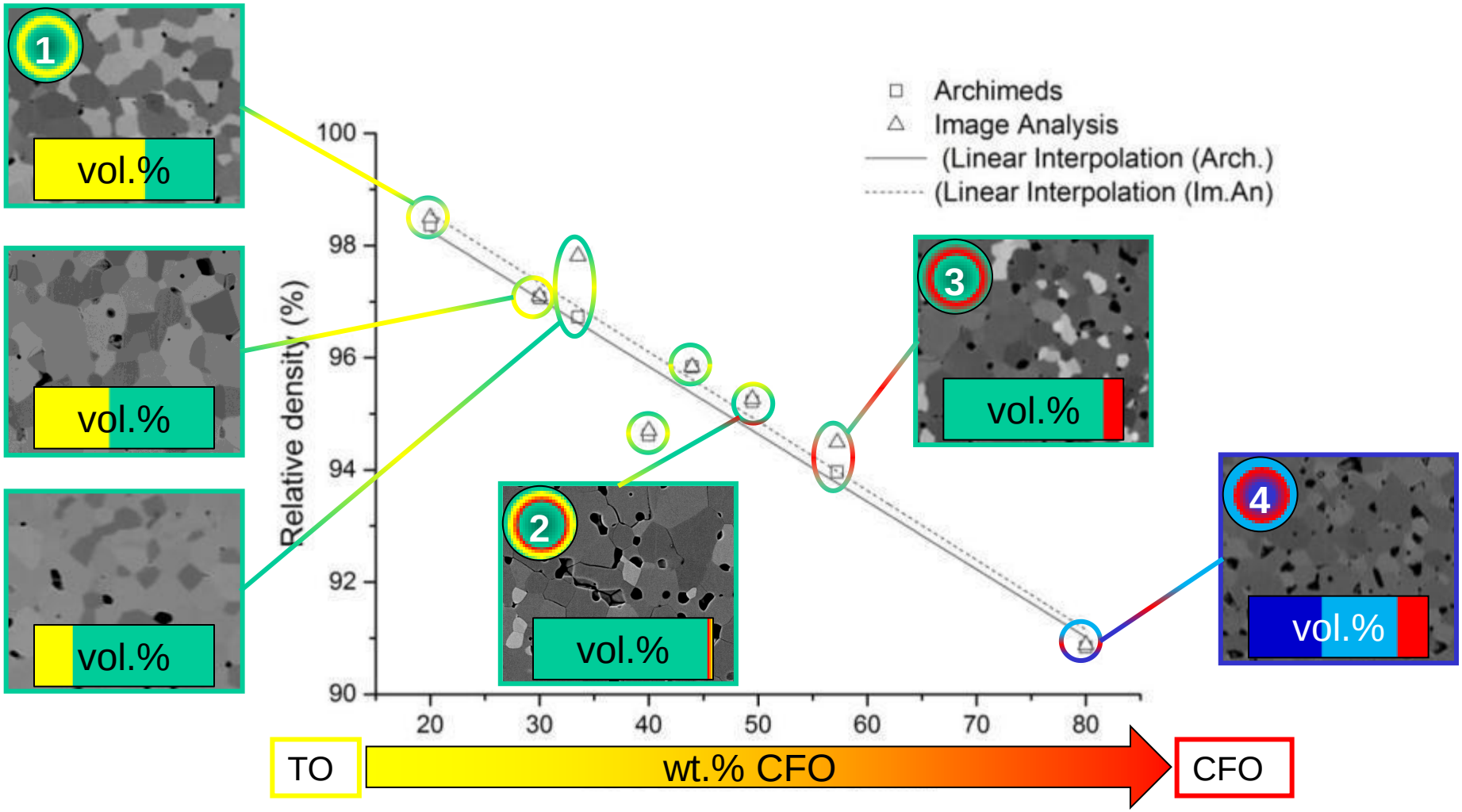


Results

Achievement of new electromagnetic properties tailoring magnetic and dielectric phases



Results


1
vol.%
vol.%
vol.%
Archimeds
Image Analysis
(Linear Interpolation (Arch.)
(Linear Interpolation (Im.An)
Relative density (%)
100
98
96
94
92
90
20
30
40
50
60
70
80
2
vol.%
3
vol.%
4
vol.%
TO
wt.% CFO
CFO

Conclusions

1. New composite ceramic materials were produced by combining a magnetic and a dielectric phases in order to investigate the possibility to tailor their magneto-dielectric properties

2. The microstructural characterization of the several compositions investigated evidenced that new phases are formed during the heat treatments.

3. The results show that it is possible to design the final composition by controlling the ratio of the dielectric to the magnetic starting phases.

4. The study of the magnetic and dielectric properties is now still in progress.

5. Further investigations will be performed to better control the residual porosity after sintering.

Thank you for your kind attention