Superconducting $YBa_2Cu_3O_{7-\delta}$ nanocomposites using ZrO_2 nanoparticles obtained by polyol route

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OUTLINE

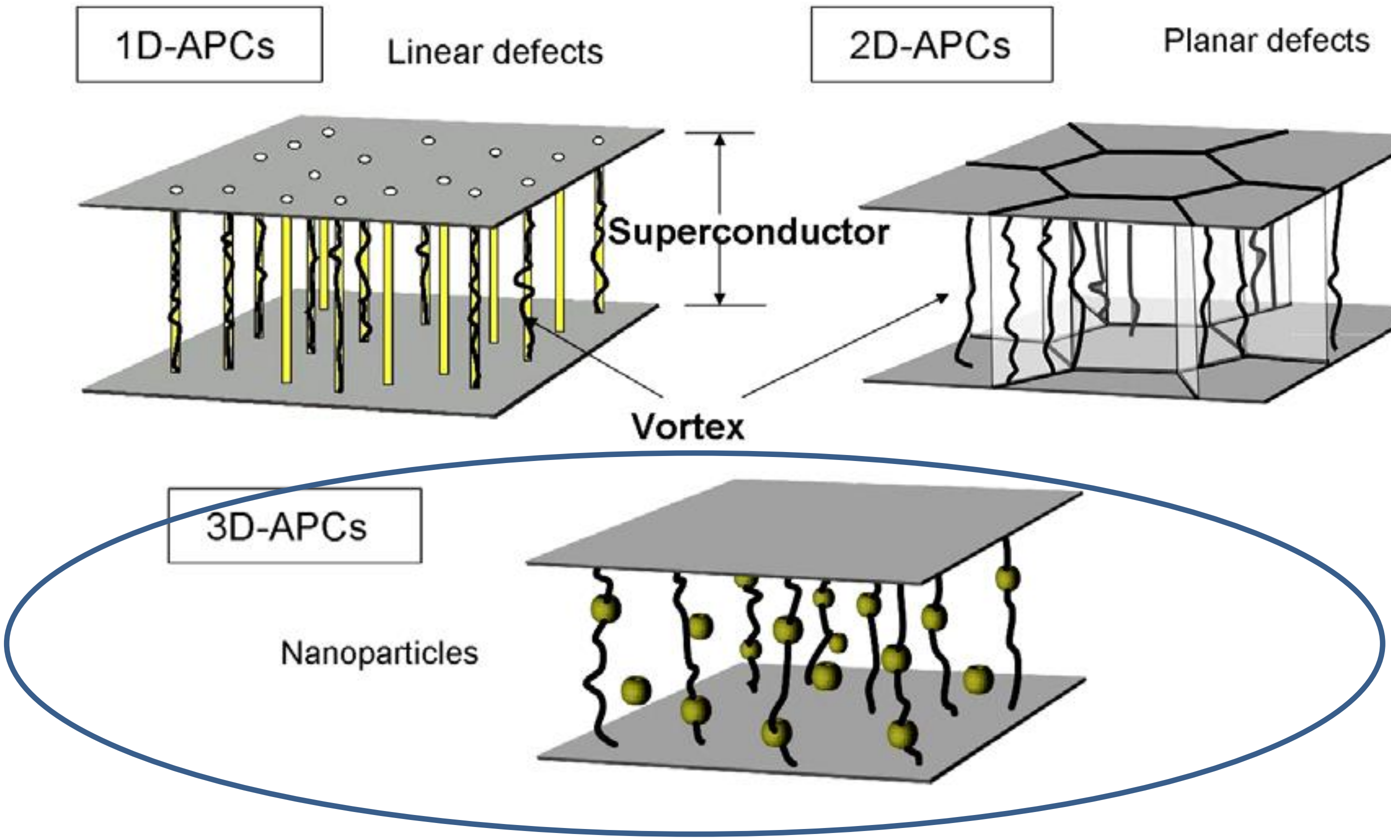
New approaches for Chemical Solution Deposition (CSD) of $YBa_2Cu_3O_{7-\delta}$ (YBCO) nanocomposites superconducting films.

- The **wet-chemical synthesis** of well-dispersed, ultra-small and homogeneous **ZrO_2 nanoparticles**.

- The growth of **YBCO nanocomposite** films by **CSD** employing **ZrO_2 nanoparticles** stabilized in alcoholic media.

Conclusions and perspectives.

The vortex pinning control using the Artificial Pinning Centers (APC)



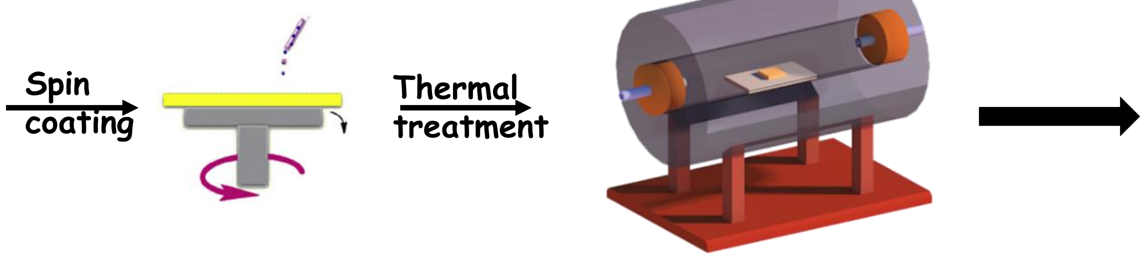
The improvement of the critical current density, *Jc*, under magnetic fields is strongly desired for producing efficient, low-cost HTS coated conductors.

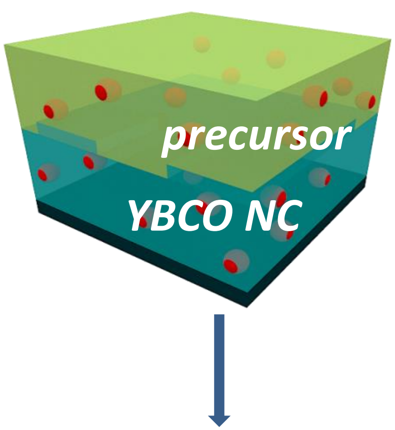
Nanocomposites with preformed nanoparticles are promising for Coated Conductors fabrication.

Chemical Solution Deposition (CSD)

- low investment costs and scalability compared to vacuum techniques;
- the growth mechanisms are deeply modified.

In-situ approach





(Y,Ba,Cu) - precursor solution
+
M-salt (M=Zr,Ta,Hf,Ce)

Thermal decomposition and conversion:

- Pyrolysis
- Growth
- Oxygenation

- Nanoparticles formation
  - epitaxial structure or randomly oriented.
- YBCO conversion and trapping of nanoparticles

Chemical Solution Deposition (CSD)

Ex-situ approach

Nanoparticles synthesis

Wet chemical methods !!!

Solvothermal synthesis –

(Thermal, MW, Autoclave, Hot injection)

Requirements:

- Small size (< 10 nm range)
- Narrow size dispersion
- Highly crystalline
- Highly dispersive
- Stable in alcoholic media
- Stable in YBCO ionic environment

(Y,Ba,Cu) - precursor solution

\+

Metal oxide nps stabilized in polar media (Metal = Zr,Ta,Hf,Ce)

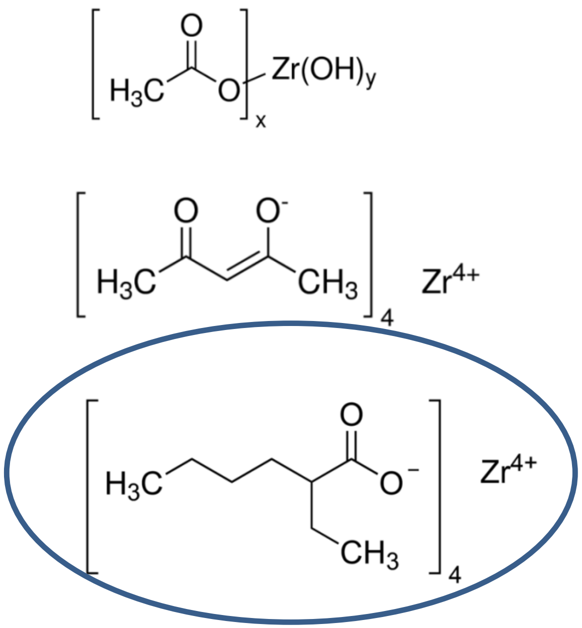
Thermal decomposition and conversion:

Pyrolysis

Growth

Oxygenation

ZrO_2 nanoparticles synthesis solvothermal decomposition



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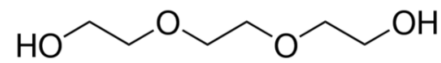


Solvent/ stabilizing agent

ZrO_2 nps stabilized in EtOH **4.7 mM**

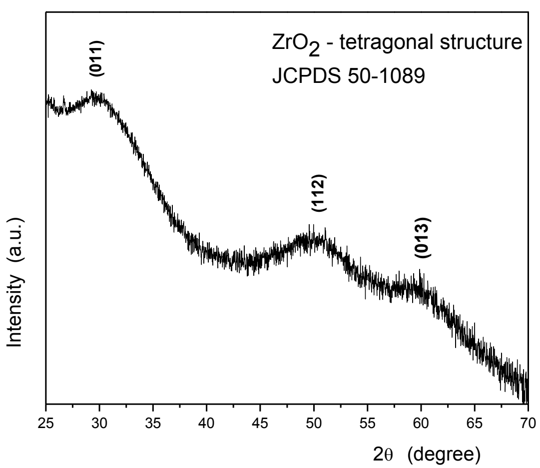
Reaction conditions:

Thermal Process:

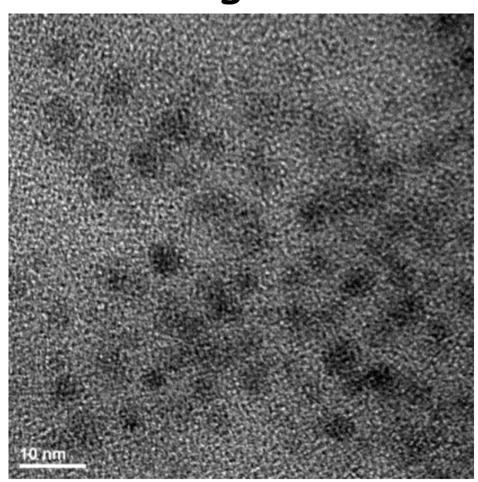
1°C/min heating rate to 280°C / 2 h reflux

Washing procedure: $C_4H_8O_2$ + C_2H_5OH (EtOH)

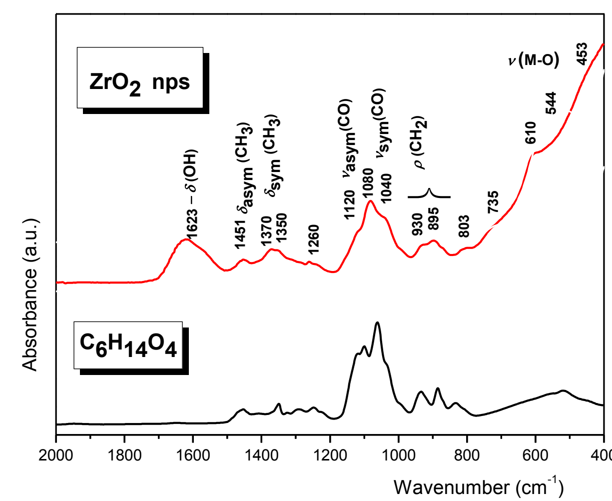
XRD pattern



TEM image

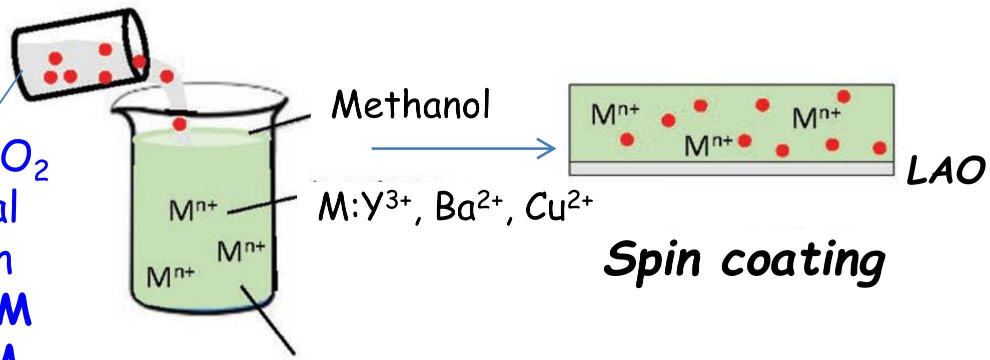


FTIR spectrum

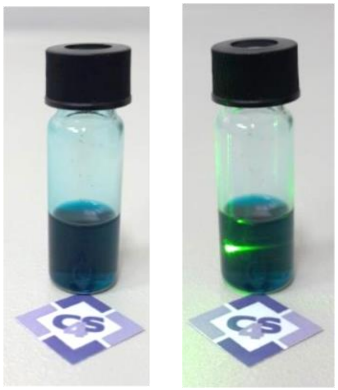


Growth of YBCO-ZrO_2 nanocomposites

1 ml ZrO_2 colloidal solution
4.7 mM
36 mM

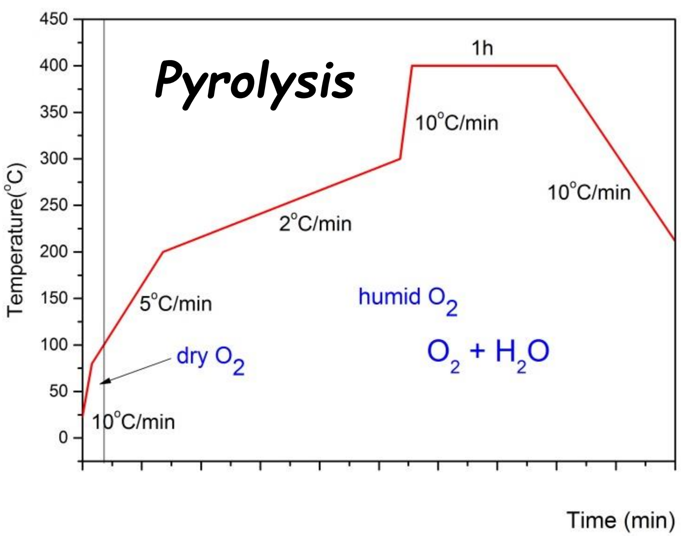


1 ml **YBCO**-Propionate, **1.5 M**
[0.25 M Y, 0.5 M Ba, 0.75 M Cu]

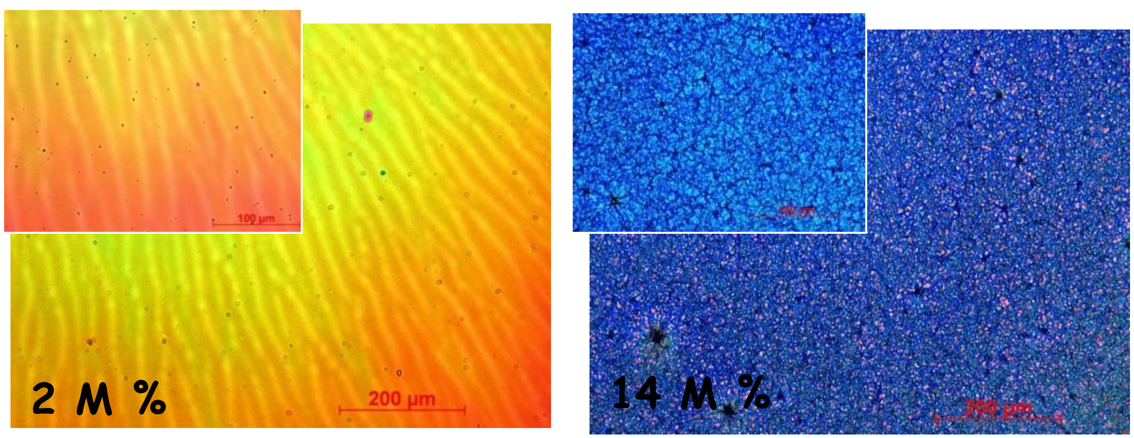


2 M % of ZrO_2 nps

Thermal treatment

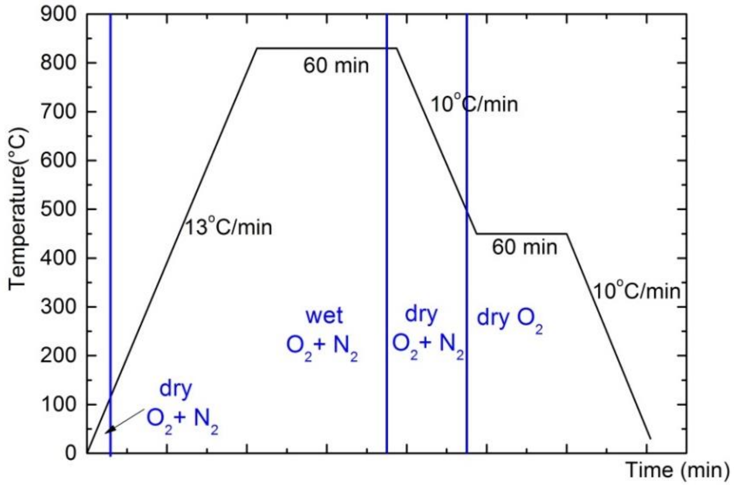


Optical images of the pyrolized films containing 2M% and 14M % ZrO_2 nps

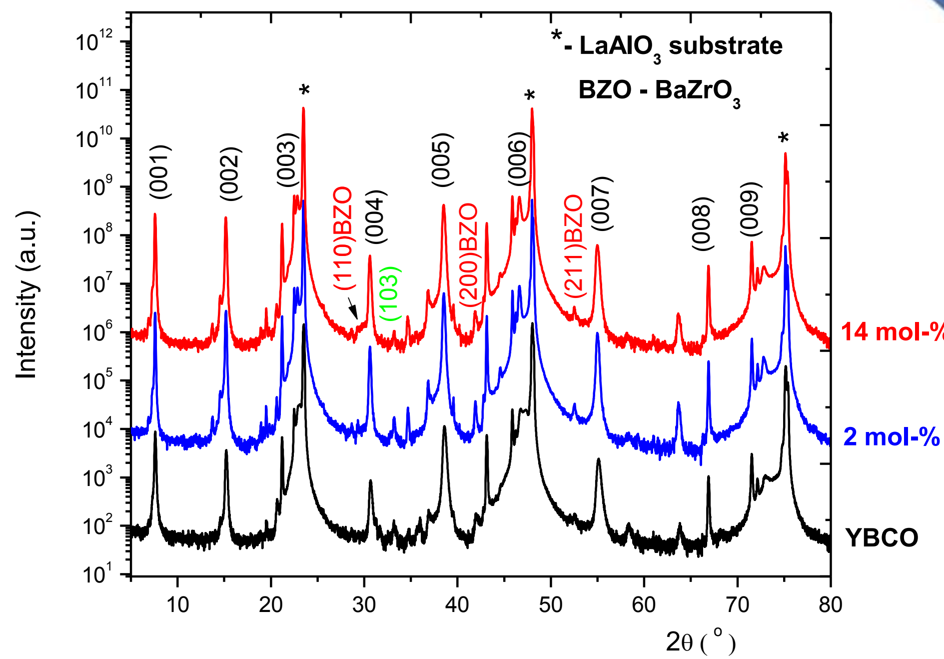


Very smooth and homogeneous layers, without any cracks.

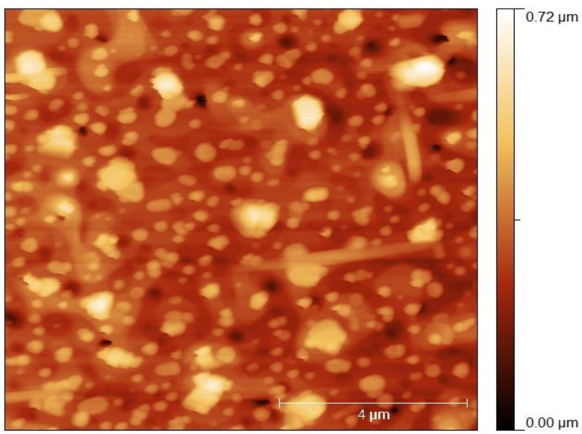
Crystallization



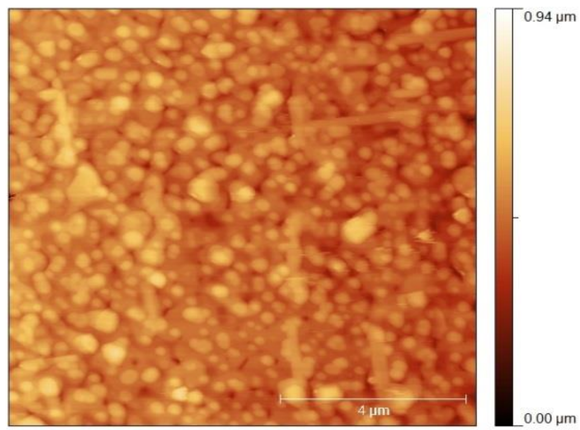
XRD patterns of YBCO and $YBCO-ZrO_2$ nanocomposite films



AFM investigation



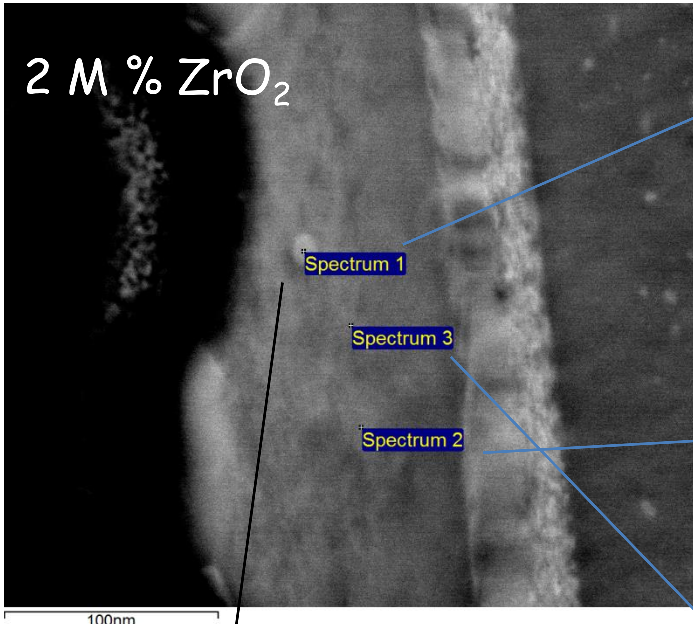
YBCO

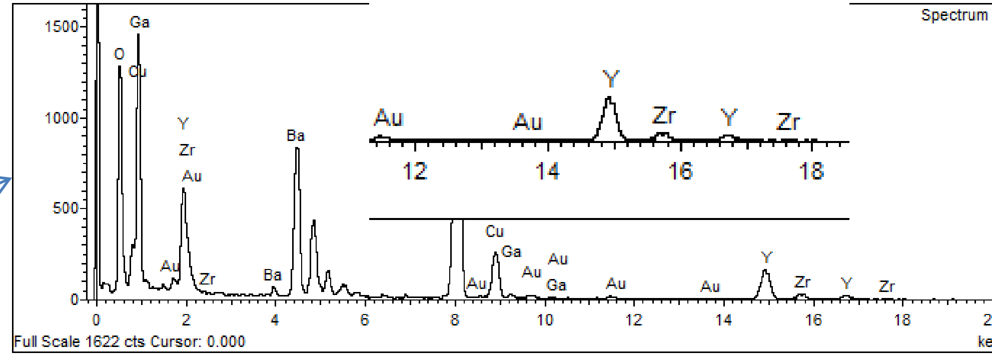


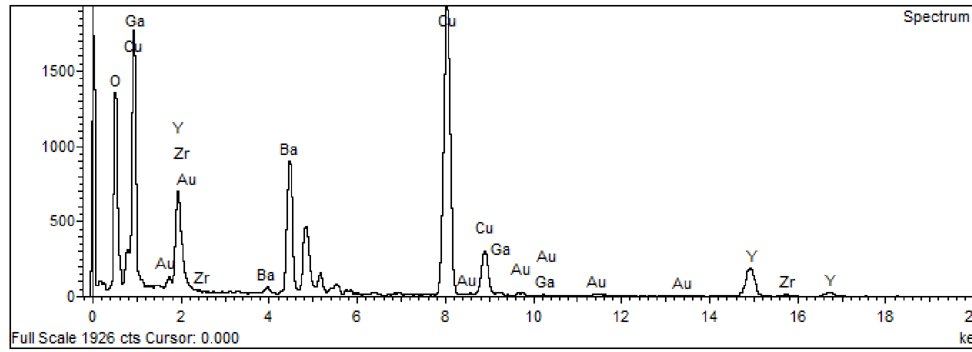
YBCO- 2 mol% ZrO2

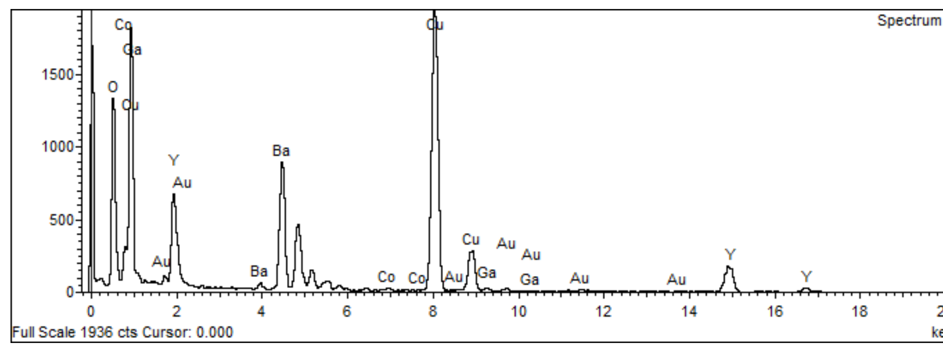
Dense film with homogeneous surface morphology.

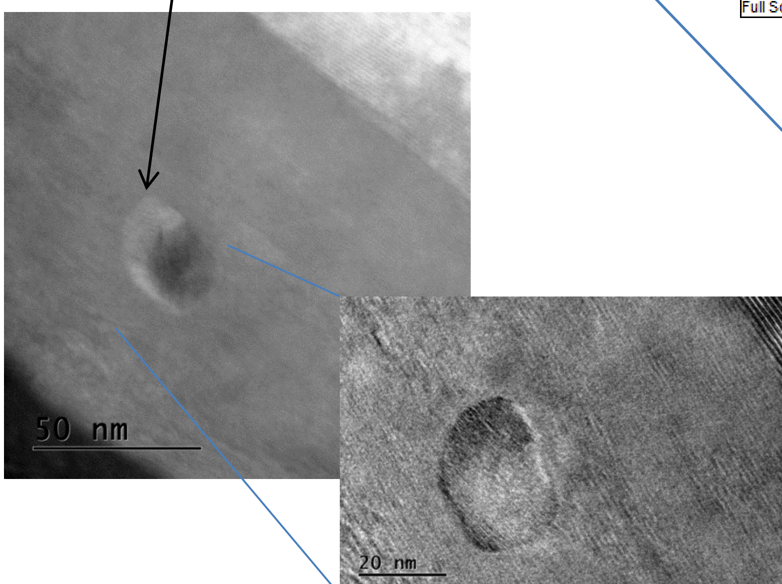
TEM measurements





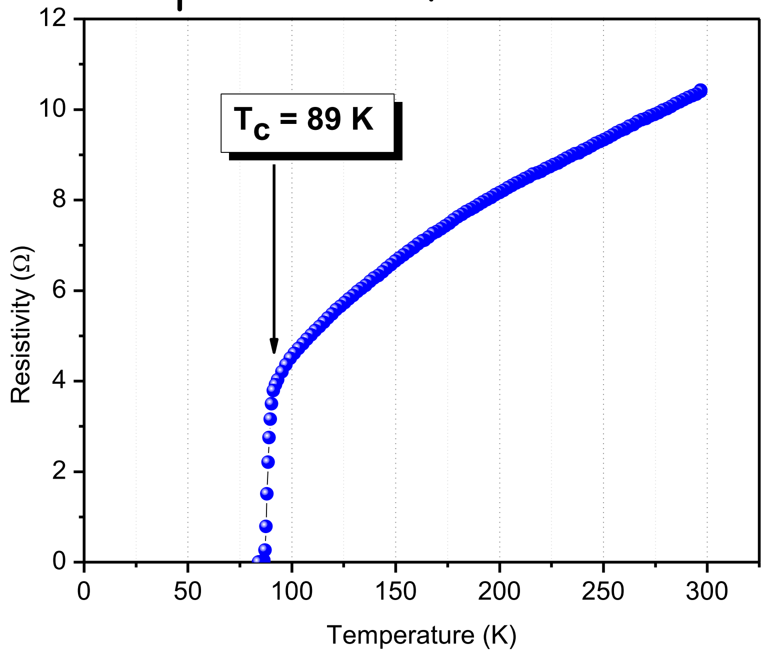


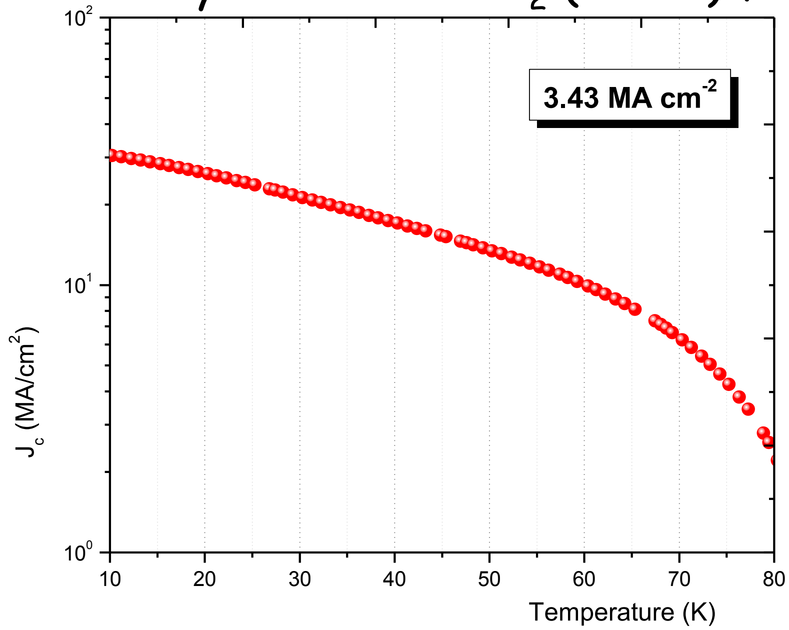




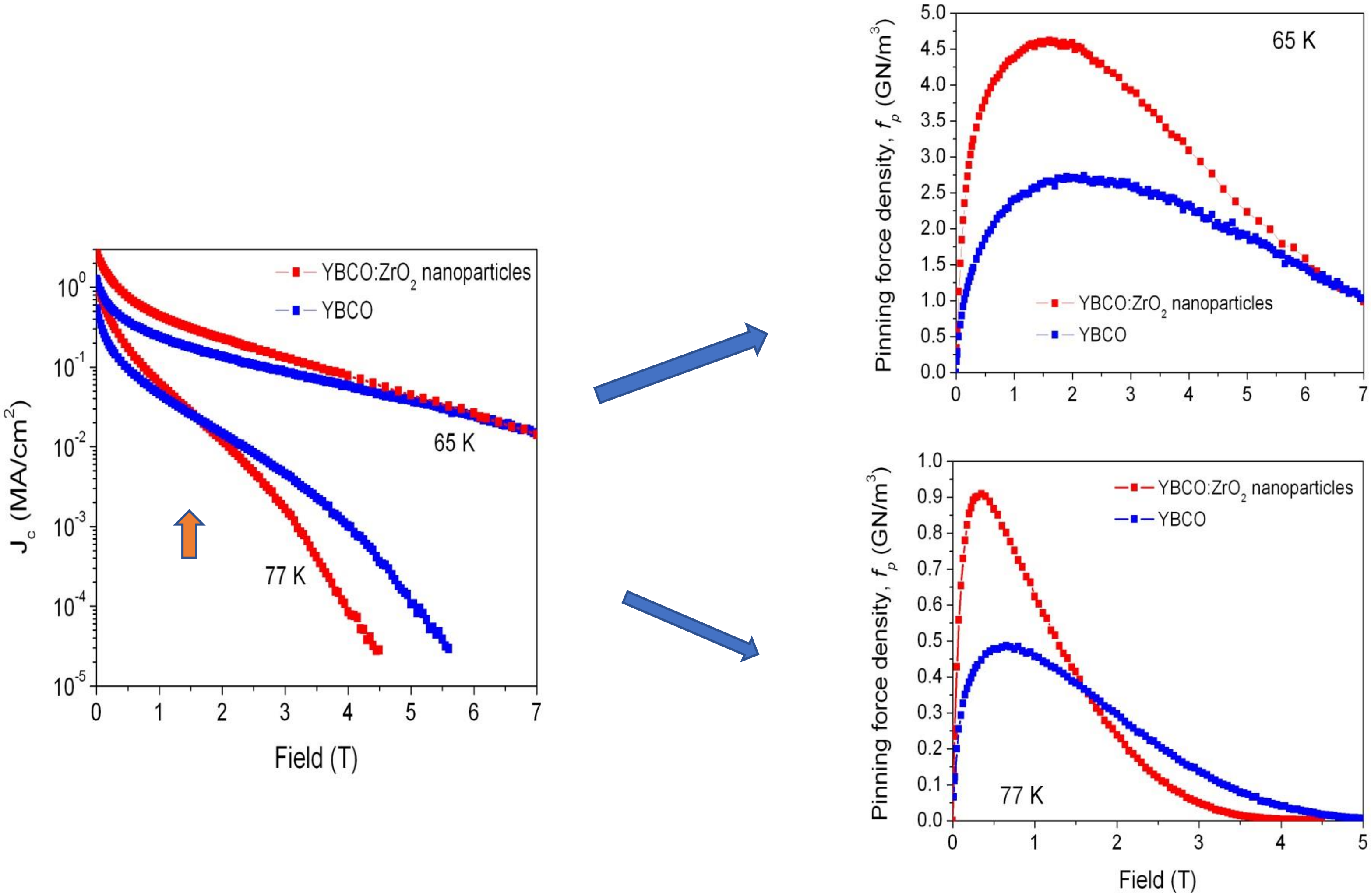
Superconducting properties

Temperature dependence of the resistivity and temperature dependence of the critical current density in YBCO-ZrO_2 (2 M%) film





% mol ZrO_2	Tc (K)	Jc (MA/cm^2)
0 (YBCO)	90	1.5
2	89	3.43
14	85	0.08



- at 77 K ZrO_2 additions increase the J_c value at low fields, below a cross-over field of approx. 1.6 T;
- at 65 K the ZrO_2 nano-particles prove to be effective pinning centres over a wide field range (up to 7 T);
- the maximum pinning force is almost doubled when ZrO_2 nano-particles are added to the YBCO film;

Conclusions and perspectives

The potential of the ex-situ approach to the growth of superconducting YBCO-ZrO_2 nanocomposites has been proven.

ZrO_2 nps present a low-crystallinity, but a narrow size distribution and good dispersity.

YBCO-ZrO_2 (2 M%) nanocomposite films present better morphology and superconducting properties than pure YBCO. The presence of $BaZrO_3$ phase have been evidence by XRD and TEM.

Supplementary investigations are required to achieve a full understanding of the correlation of the synthesis and processing methodologies with the final morphology and structure of nanocomposite films and with their superconducting properties.

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Acknowledgements

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