Chemical solution deposition growth of low fluorine thick coated conductors of YBa$_2$Cu$_3$O$_7$ and YBa$_2$Cu$_3$O$_7$ nanocomposites with preformed BaZrO$_3$ nanoparticles

CSD methodology – ex situ growth

LOW COST, VERSATILE and SCALABLE path to grow superconductor YBCO layers

- **TFA route**
  - Precursors: \( \text{Y(TFA)}_3, \text{Ba(TFA)}_2, \text{Cu(TFA)}_2 \)
  - Decomposition
  - Conversion

- **LF route**
  - Precursors: \( \text{Y(TFA)}_3, \text{Ba(OAc)}_2, \text{Cu(OAc)}_2 \)
  - Approx. 80% Fluorine reduction !!!

Deposition by

- **Spin coating**
  - Thick films from one single deposition

- **Inkjet Printing**
  - Thick films by multidepositions
Oxide non-reactive nanoparticles were stabilized in alcoholic and ionic environment of YBCO precursor solution at high concentrations.
Nanocomposites of non-reactive preformed BaZrO$_3$ and BaHfO$_3$ nanoparticles

Flash heating: 20%M BZO

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12%M BHO

20%M BHO

High homogeneity in Np dispersion at high Np concentrations. No reactivity. Randomly oriented. $J_c = 3-5$ MA/cm$^2$ at 77 K, 200 nm
Nanocomposites w/preformed BaZrO$_3$ and BaHfO$_3$ Np

Spontaneous segregation

BZO-YBCO

Preformed Np

Higher concentration of Np without current blocking

High performance at all temperatures

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SQUID meas.

Higher concentration of Np without current blocking
success of multideposition

1,2 µm thick YBCO film by multidepositions

1,2 µm thick YBCO film by multidepositions

$J_{C(77K)} = 2 \text{ MA/cm}^2$

Growth of thick YBCO layers on LAO single crystals (LF Route)

Multideposition

By controlling the supersaturation (T, PH$_2$O and Ag) we have reached thick high performance layers of up to 1.2 µm

Further optimization is needed beyond 1.2 µm

High Reproducibility
Growth of thick YBCO layers on LAO single crystals (LF Route)

MULTIDEPOSITION

FIB

TEM

2000 nm

IJP
IJP deposition and pyrolysis of thick YBCO layers

- In situ visualization of the pyrolysis
- Thermo mechanic study
- Decomposition study
- Thickness evolution study

LF inkjet precursor solution design

- Colloidal solutions compatible with IJP
- Thick layer and CC are reachable

Robust and reproducible process in one single deposition up to ≈ 900 nm!!!
Multi deposition by inkjet printing is presented as an effective route to achieve high thicknesses in a cost effective process.

- >1µm reached with single ink jet printing deposition
  - 1.12 µm
- 1.6 µm in 2 depositions of 800 nm

IJP deposition and pyrolysis of thick YBCO layers

MO image

After pyrolysis

1950 nm

After growth

Robust single achieved for 900 nm

After growth

Single deposition

Multi deposition

2nd deposition

10 mm

10 mm
IJP thick YBCO films on LAO substrates. New supersaturation conditions

High performances YBCO thick films (600 nm - 1µm) achieved by IJP and using the supersaturation conditions for thick YBCO films growth

Pristine YBCO

600 nm

I\(_C\)(77K) = 162 A/cm\(^{\ast}\)width

Low F solution (80% reduction)

3 MA/cm\(^2\)

77K sf

IJP nanocomposites 12%

IJP pristine

Spin pristine

0 200 400 600 800 1000

0 20 40 60 80 100 120 140 160 180 200 220 240

I\(_C\) (A/cm\(^{\ast}\)width)

Thickness (nm)

0 200 400 600 800 1000

0 20 40 60 80 100 120 140 160 180 200 220 240

Low F solution (80% reduction)

Spin pristine

3 MA/cm\(^2\)

IJP pristine

I\(_C\)(77K) = 229.5 A/cm\(^{\ast}\)width

Uniformly distributed BZO NP's

YBCO + 12 %BZO

850 nm

850 nm

850 nm

850 nm
Increase of $I_c$ with thickness by IJP deposition of nanocomposites

$I_c(5K, 9T) \times 12$

$I_c(77K, 3T) \times 12$

Thickness $\uparrow \times 3$
YBCO coated conductors: solving reactivity issues

\[ J_{C(77K)} \approx 0 \text{ MA/cm}^2 \]

\[ J_{C(77K)} = 1.5 \text{ MA/cm}^2 \]

Again supersaturation conditions must be tuned in order to ensure c-axis growth of YBCO on metallic tapes.
Epitaxial growth is achieved in a 2-step process: nucleation in new supersaturation conditions and growth at 800 °C. Highly epitaxial!!! No a-b grains!!!

Thickness 1µm !!!
One single deposition

\[ J_{C(77K)} = 1 \text{ MA/cm}^2 \]
\[ I_{C(77K)} = 100 \text{ A/cm}^*\text{width} \]

Porosity still to be improved
Thick YBCO + 12 % BZO NPs coated conductors

700 - 800 nm of thickness one single deposition

\[ J_{C(77K)} = 1.4 \text{ MA/cm}^2 \]
\[ I_{C(77K)} \sim 100 \text{ A/cm}^2\text{width} \]

Similar field dependence to the thick and thin nanocomposites on single crystal for the same Np concentration
Conclusions

- The addition of non-reactive preformed nanoparticles has been proved to be a very effective pathway to achieve high performances YBCO superconducting layers.

- The inkjet printing has been enabled as an effective deposition method to achieve high quality thick superconducting layers from one single deposition (1.1 µm from one single deposition, 1.6 µm from 2 depositions).

- The studies of the pyrolysis and growth processes of thick YBCO layers generated a large amount of knowledge. We designed pyrolysis and growth processes that lead to high performances thick superconducting layers ($I_{c(77K)}^{sf} = 230$ A/cm*width for 900 nm).

- Thick YBCO coated conductors from one single deposition become a reality both for pristine YBCO and YBCO nanocomposites. These coated conductors have a lot of potential since there is room for improvement ($I_{c(77K)}^{sf} = 100$ A/cm*width).
Thank you very much for your attention!!!!