Surface engineering of flexible Al_2O_3 substrate by chemical solution deposition

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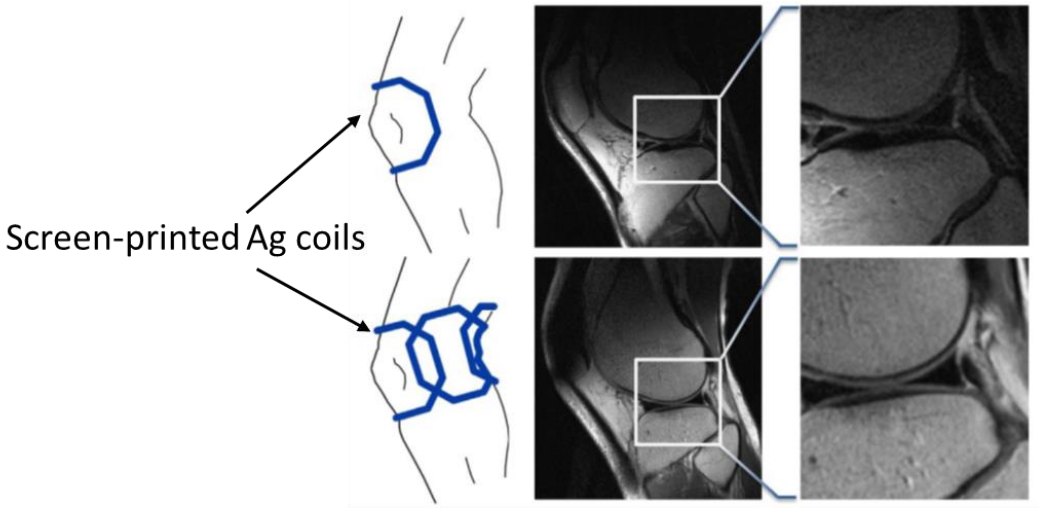
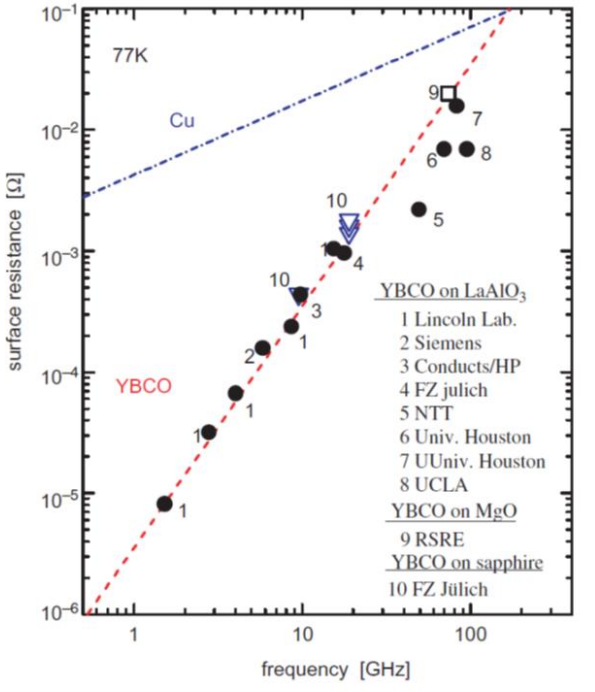
Outline

- Introduction/Motivation
- **Synthesis and precursor characterization**
- **Deposition and growth of Y_2O_3 thin films**
- **Characterization of Y_2O_3 thin films**
- Conclusions

Introduction/Motivation



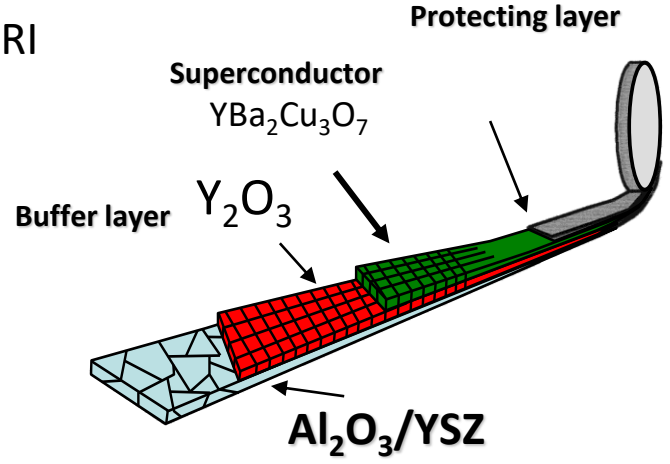
J. R. Corea, *et al.*, *Nat. Commun.* **7**, 10839 (2016)



N. Klein, *Rep. Prog. Phys.* **65**,1387 (2002)

- YBCO has ***low surface resistance*** at 77K (lower than Cu in the same conditions): ideal candidate for RF receiver coils in MRI

- YBCO deposition on flexible ceramic substrates: ***low cost*** (compared to single-crystal substrates)
  +
  flexibility (possible enhancement of SNR, coil arrays to extend the field-of-view)



Coated conductors fabrications by chemical methods

Introduction/Motivation

Why Al_2O_3/ YSZ?

- high themal conductivity;
- high stability at high temperatures;
- good mechanical strength;
- Flexible substrate;

Surface roughness required

planarization

Why Y_2O_3?

- Perovskites type oxide;
- Thermal stability;
- Compatibility with YBCO

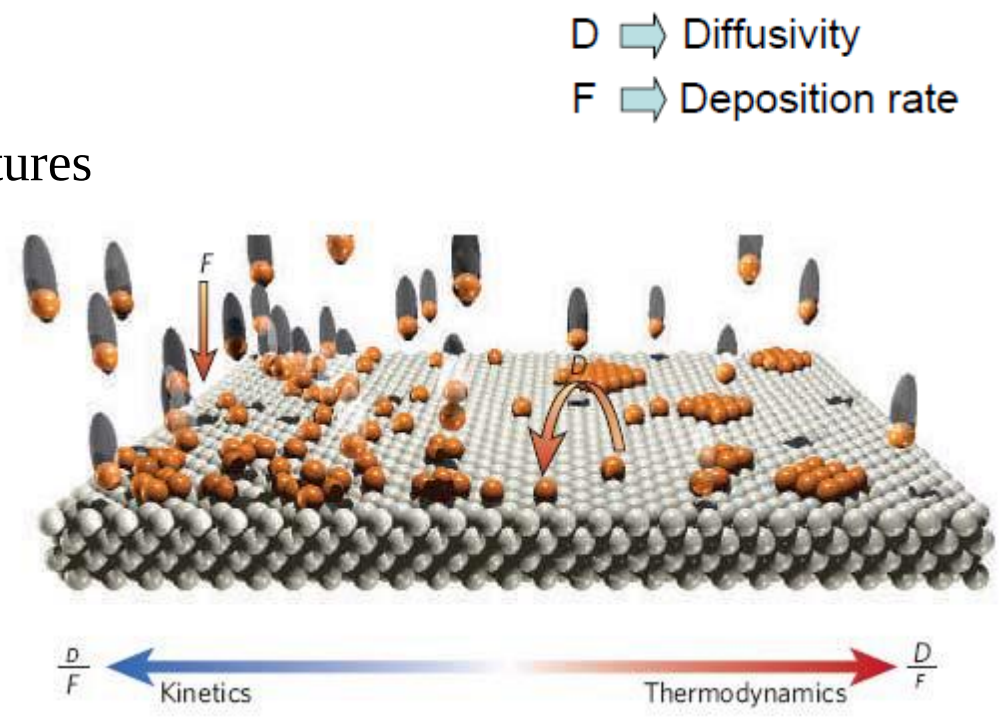
CSD

Goal: CSD Propionate-Based Solution of Y_2O_3

Chemical Solution Deposition - CSD route

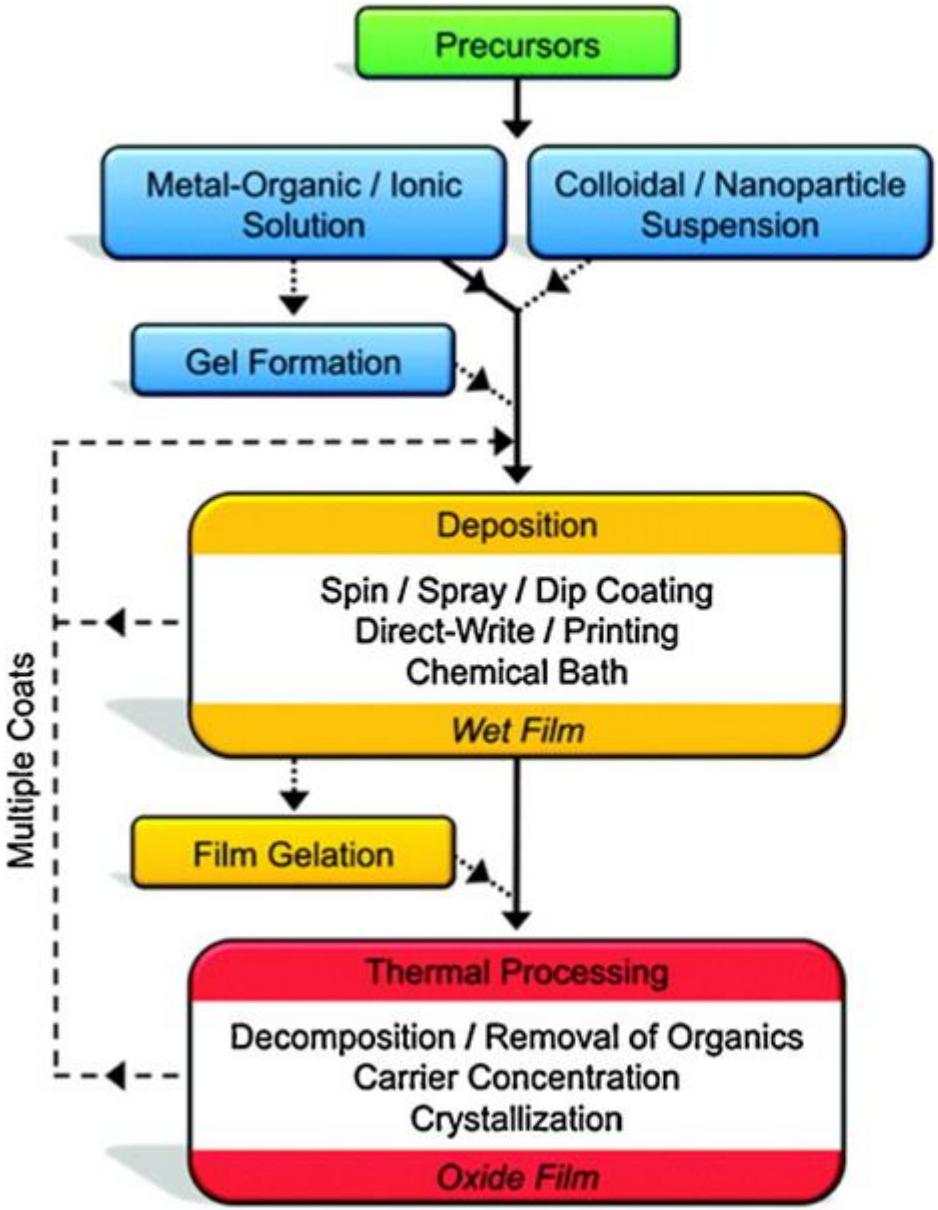
Advantages of chemical methods for deposition of thin films:

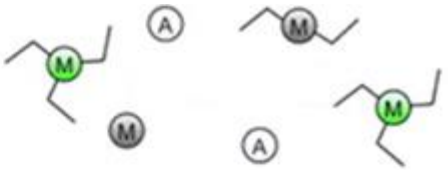
- Molecular scale homogeneity
- Lower crystallization temperatures
- Easy to scale-up
- Environmentally friendly
- Simple and versatile
- Low-cost fabrication

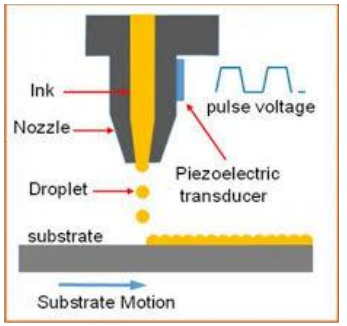


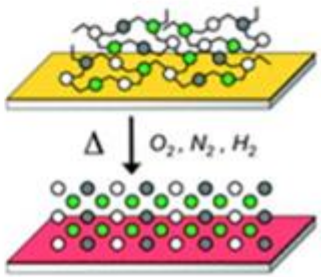
Barth et al. NATURE 2005 Vol 437 I 29

CHEMICAL SOLUTION DEPOSITION







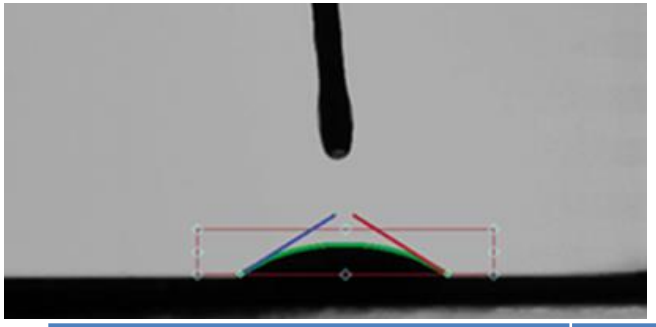


Synthesis and precursor characterization

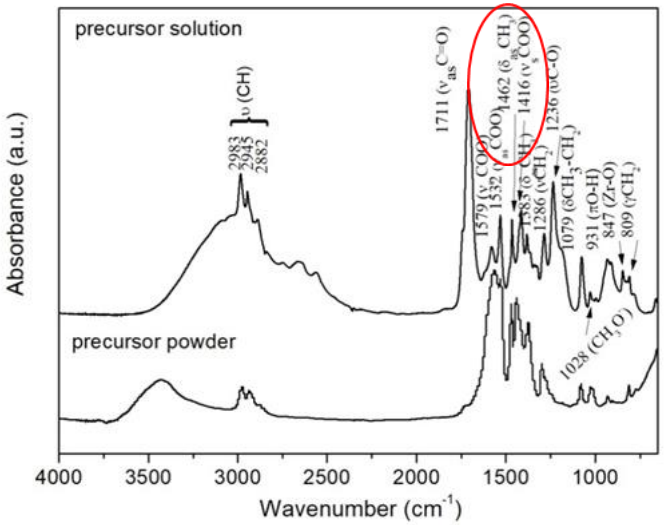
Synthesis of Y_2O_3 coating solution

$Y(CH_3COO)_3$ | CH_3-CH_2-COOH

- Final solution concentration c=1.5 M
- Propionate complex
- Contact angle ~ 95.4 ° YSZ) → bad wettability
- Long stability of the precursor solution



- FT-IR: Formation of propionate based precursor



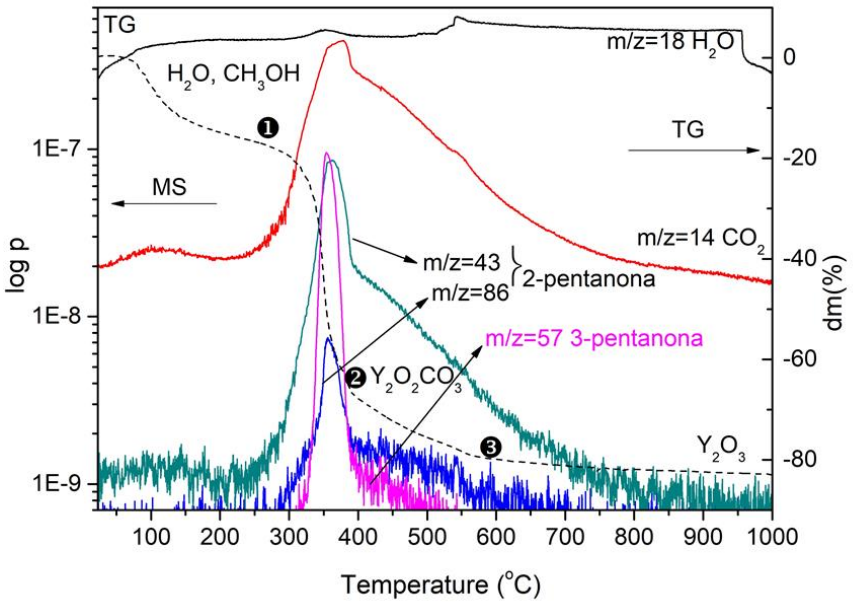
Rheologies adapated to dip-coating

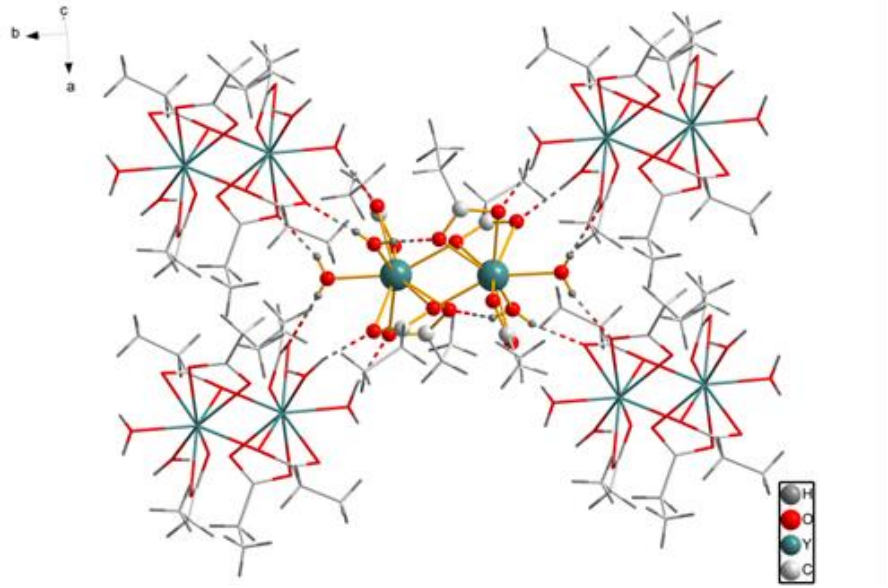
Sol.	Vascozity (cP)	Contact angle (°)	Surface tension [mN/m]
Y-Prop	19.2	95.4	25
Y-Prop@ 5%Glycerol	25.4	85.5	35.5
Y-Prop@ 10%Glycerol	28.5	65.6	40
Y-Prop@ 20%Glycerol	**33.8**	**32.7**	**55** √

Characterization of the precursor – $[Y_2(CH_3CH_2COO)_6 \cdot (H_2O)_3]$

$Y(CH_3COO)_3$ | $CH_3\text{-}CH_2\text{-}COOH$

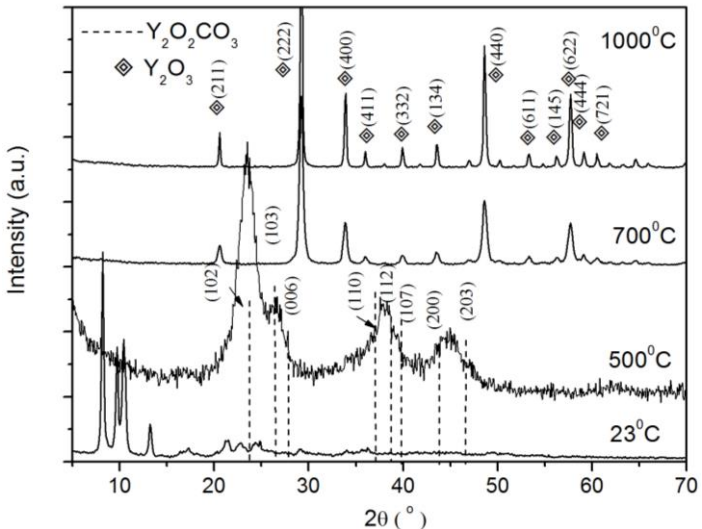
TG-MS





Cambridge Crystallographic Data Centre - CCDC 731722

XRD



The decomposition process is characterized by 3 weight loss steps:

$$[Y_2(CH_3CH_2COO)_6 \cdot H_2O] \cdot 3.5H_2O \rightarrow Y_2(CH_3CH_2COO)_6 + 4.5H_2O$$

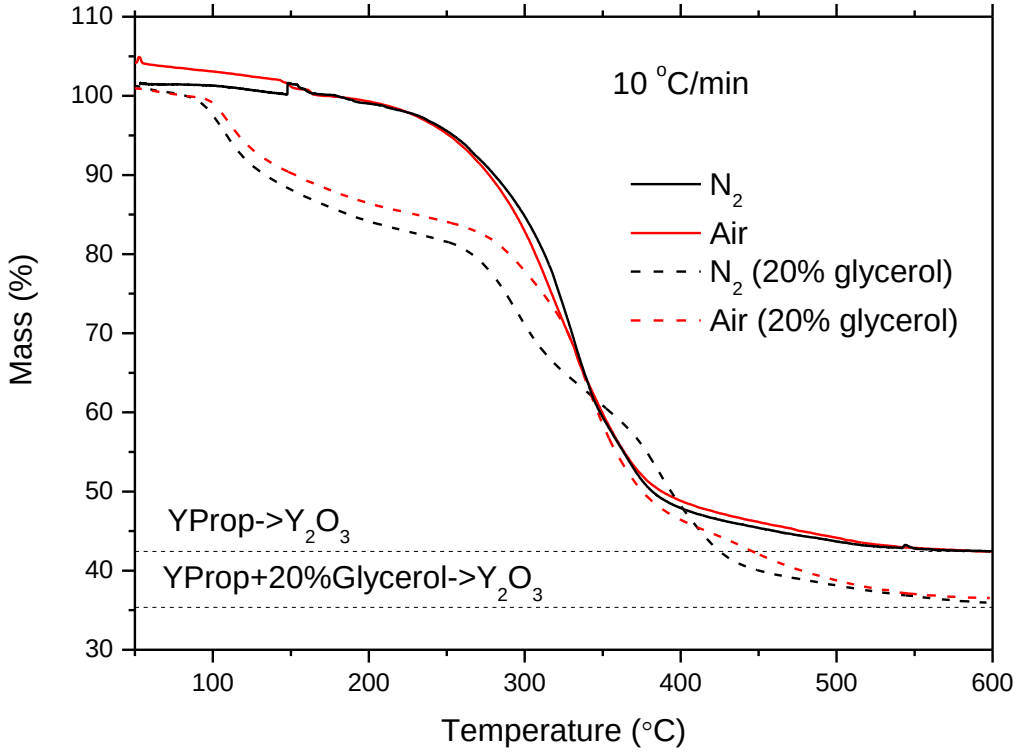
$$Y_2(CH_3CH_2COO)_6 \rightarrow Y_2O_2CO_3 + 2CH_3CH_2COCH_2CH_3 + CH_3COCH_2CH_2CH_3 + 2CO_2$$

$$Y_2O_2CO_3 \rightarrow Y_2O_3 + CO_2$$

Characterization of the precursor

$Y(CH_3COO)_3$ | CH_3-CH_2-COOH | glycerol

Overlapped TG

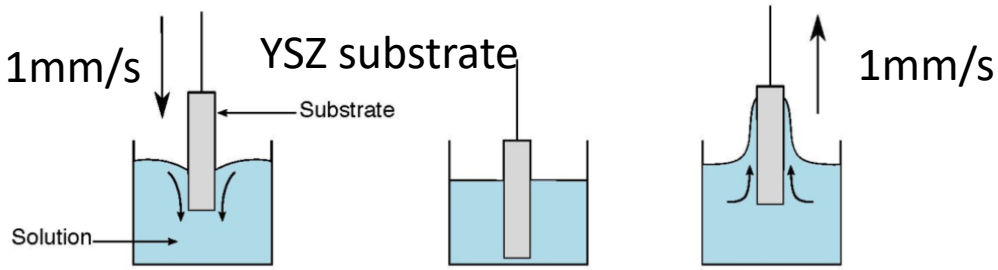


decomposition kinetics changes due to the presence of glycerol

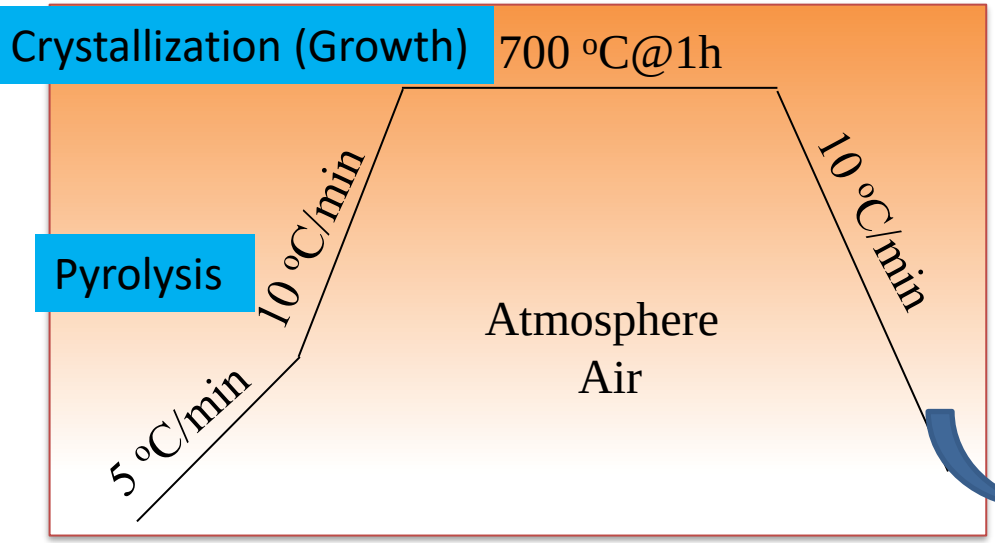
- The use of chelating agents (Glycerol) avoid polymerization of YProp stabilizing the solution;
- The TG curves of the Y-Prop with glycerol have the same shape as Y-Prop, but all the transformations occur at lower temperature;
- Decomposition process is strongly modified accordingly;

Deposition and growth of Y_2O_3 thin films

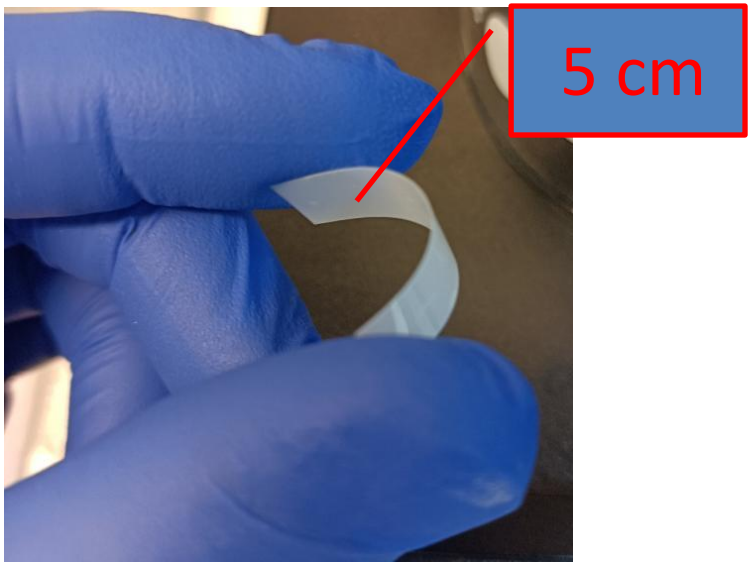
Dip- coating



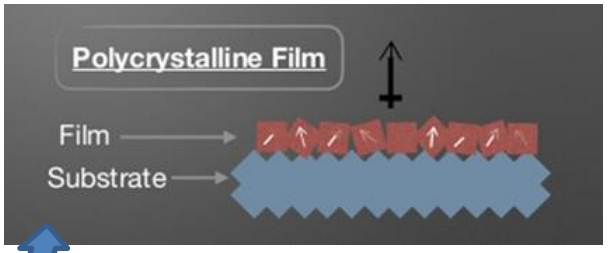
Single step - Heat treatment of the Y_2O_3 thin films



Optical imagine/YSZ



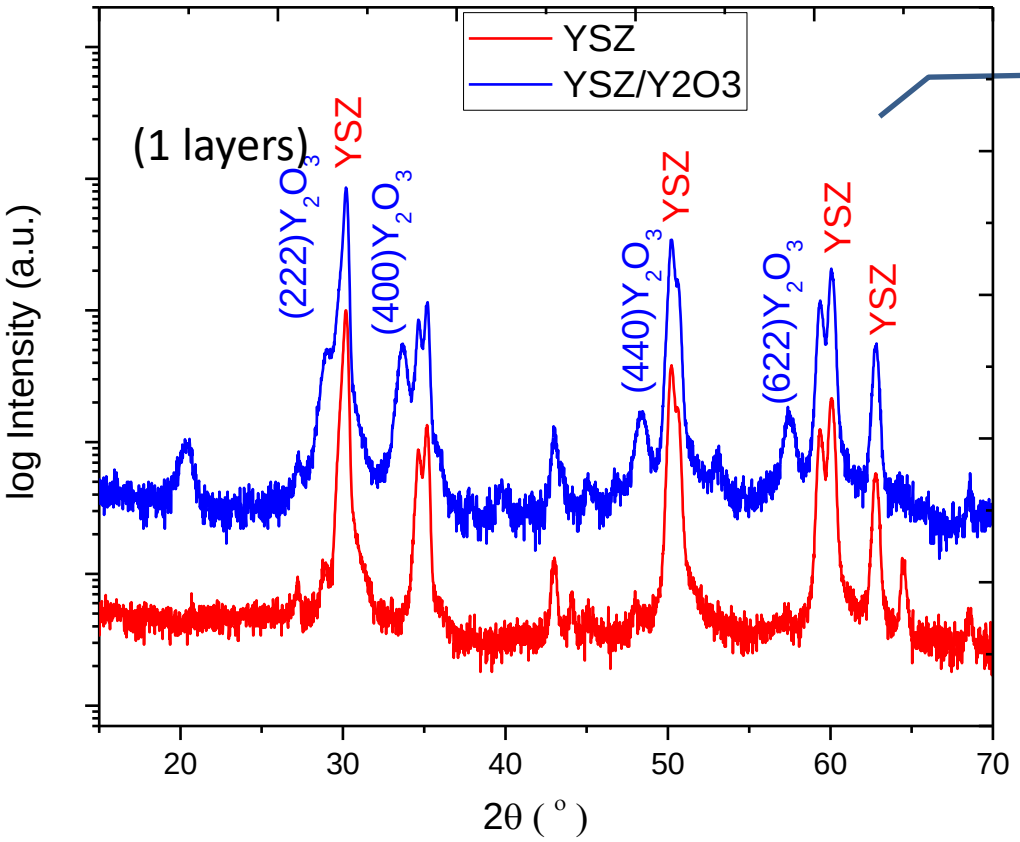
11 mm in width and 40 μm thickness



ENrG Inc., for providing flexible YSZ samples.

Characterization of Y_2O_3 thin films

Y_2O_3 thin films on YSZ



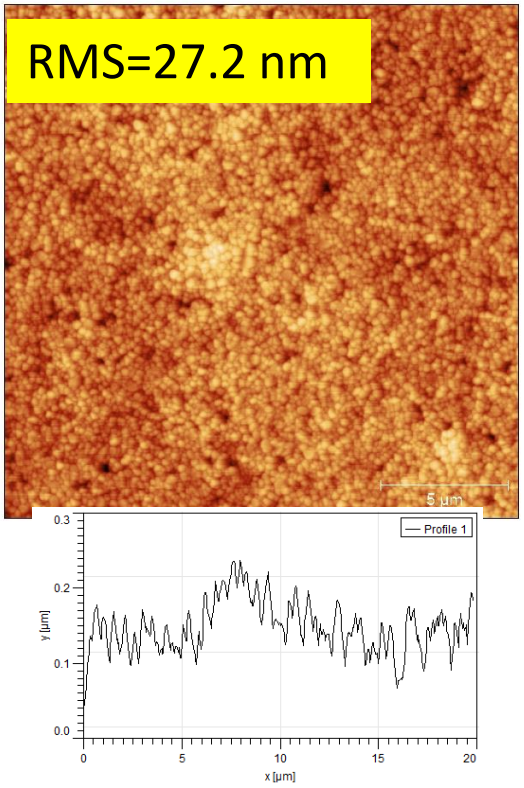
XRD θ-2θ scans for the thin films exhibit only Y_2O_3 reflections;

Thermal treatments in the range 700 ºC in air are suitable;

Characterization of Y_2O_3 thin films

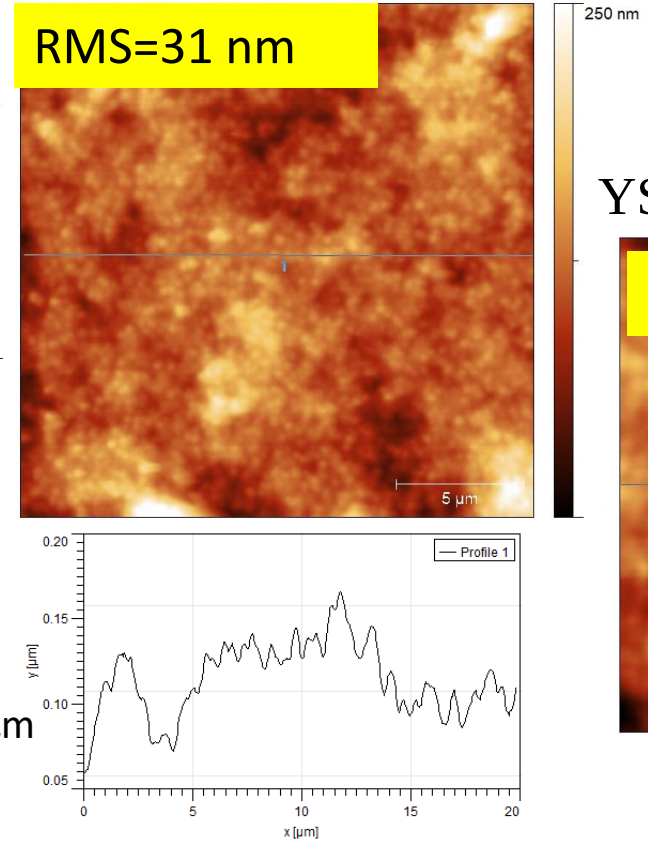
Y_2O_3 thin films on YSZ

YSZ

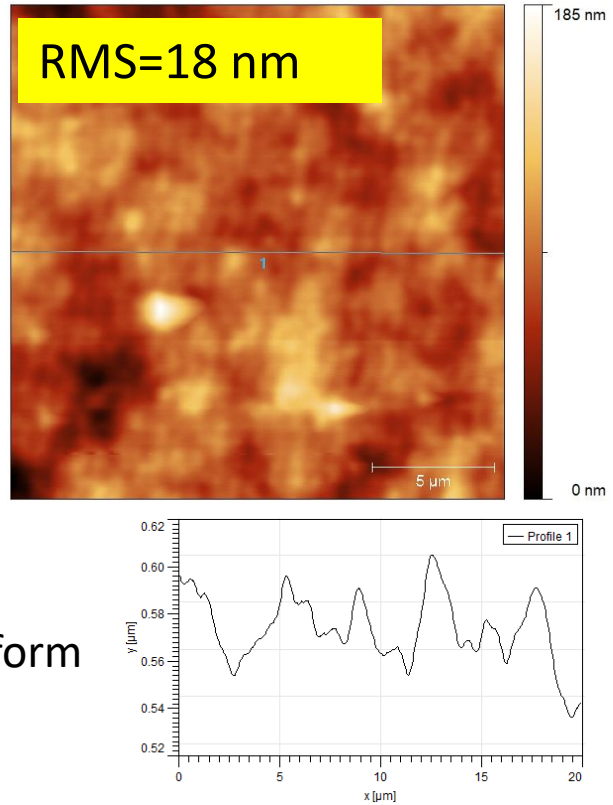


- surface consisting of high hills
- hills are 260 nm high and 2–6 µm wide

YSZ/Y_2O_3 – 1 layer



YSZ/Y_2O_3 – 2 layers



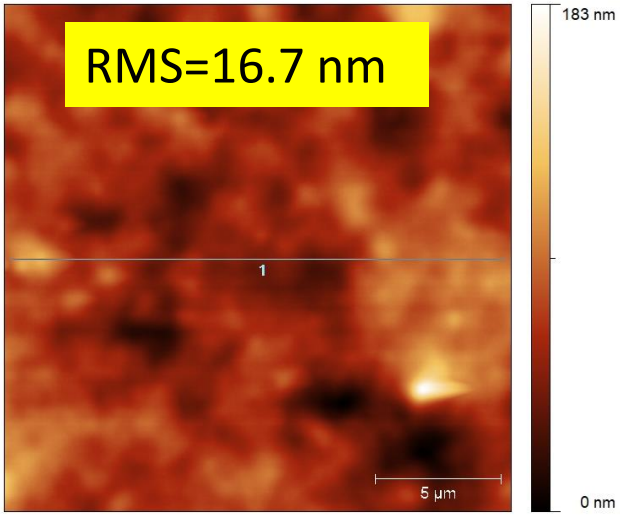
AFM imagine evidenced a uniform and highly dense morphology

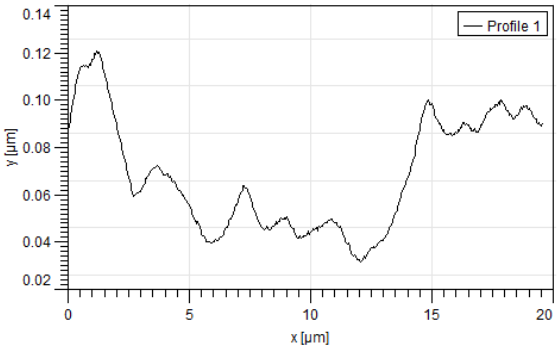
❖ In both cases, two different morphologies were observed:
- smaller/round grains and
- larger/planar grains

Characterization of Y_2O_3 thin films

Y_2O_3 thin films on YSZ

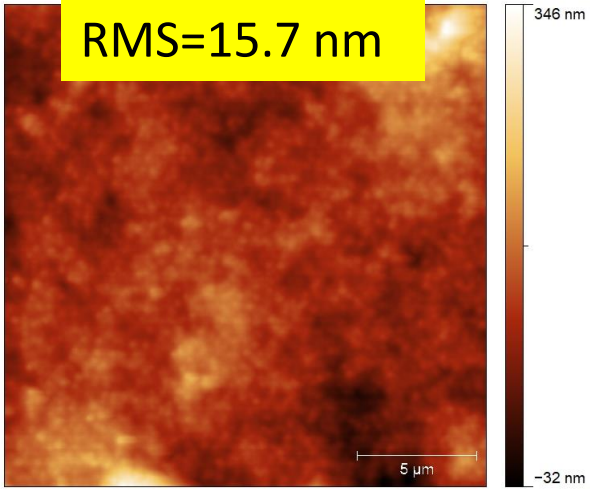
YSZ/Y_2O_3 – 3 layers

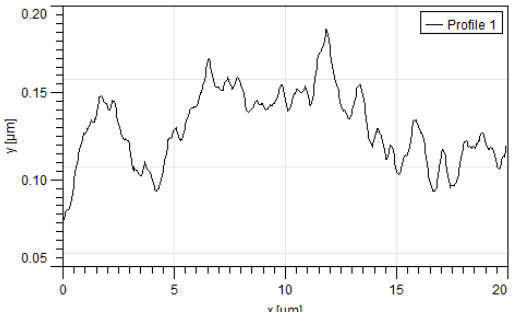




Good wetability and oxide adherence to Y_2O_3 has been proven in all cases

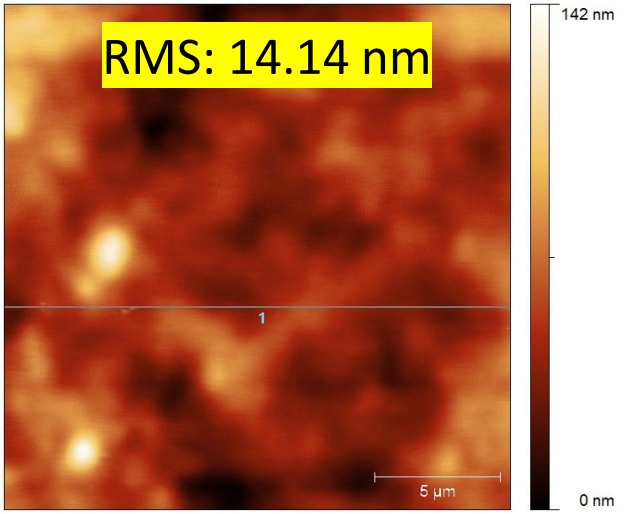
YSZ/Y_2O_3 – 4 layers

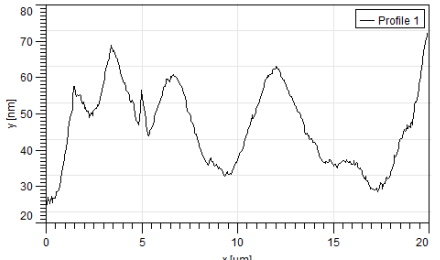




Delamination on the borders only.

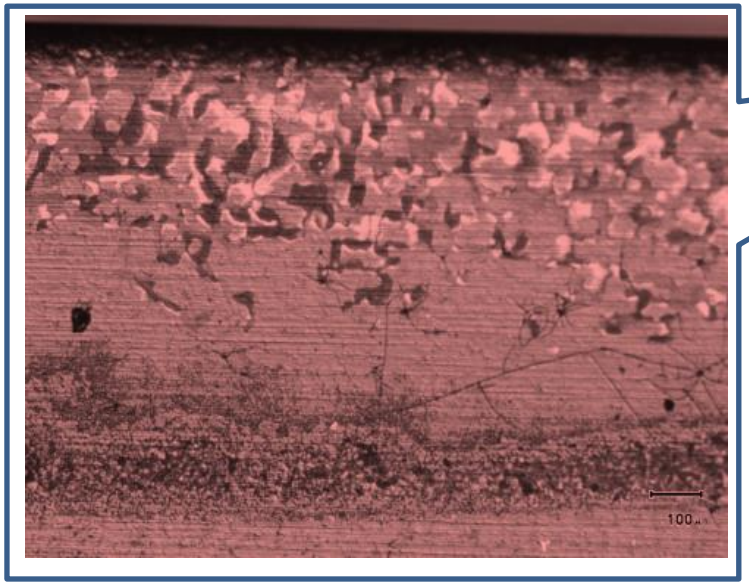
YSZ/Y_2O_3 – 5 layers



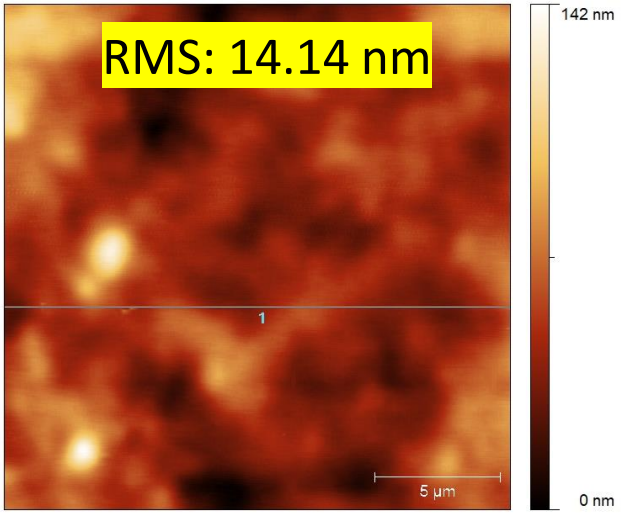


Characterization of Y_2O_3 thin films

After thermal treatment



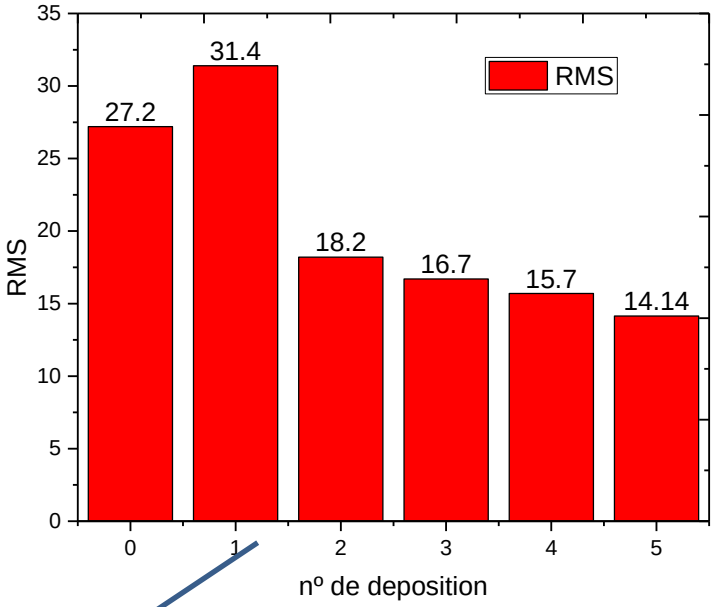
YSZ/Y_2O_3 – 5 layers



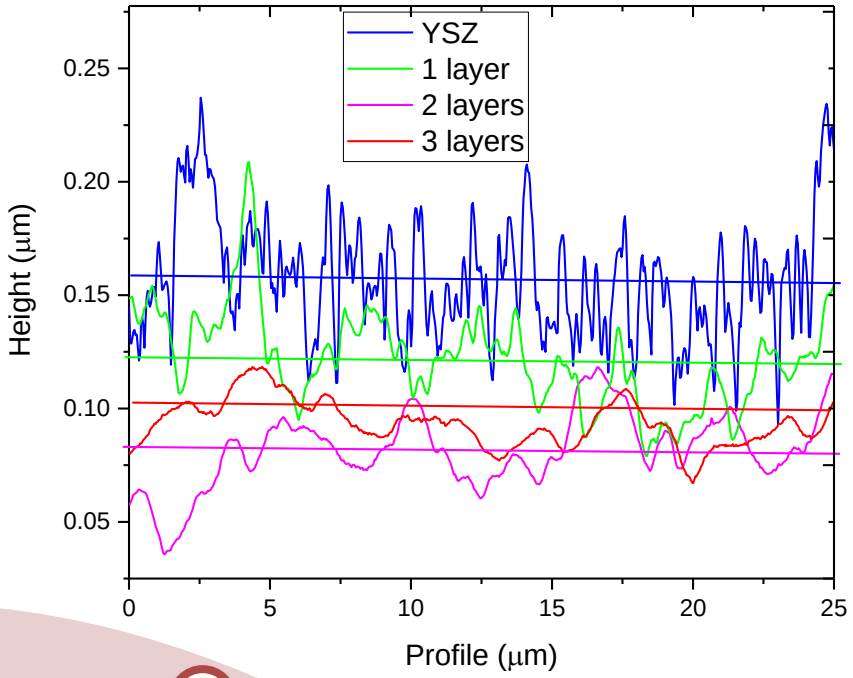
Delamination on the borders only.

Characterization of Y_2O_3 thin films

Y_2O_3 thin films on YSZ



Peak-to-valley vs. no.layer



Roughness down to 15 nm are stabilized above 4 layer with a 1.5M solution of Y2O3

YSZ 260 nm

1 layer 278 nm

2 layer 156 nm

3 layer 145 nm

4 layer 114 nm

5 layers 80 nm

Summary

- The thermal decomposition mechanism of precursor has been elucidated;
- Y_2O_3 thin films deposited on YSZ substrates have been grown by chemical solution deposition starting from metal acetate as reagents;
- We have successfully demonstrated good-quality Y_2O_3 films on flexible polycrystalline YSZ substrate using a chemical method;
- A high degree of crystallinity of the Y_2O_3 films with suitable morphology has been shown;

Future work

- Increasing the thickness of the Y_2O_3 films (conc.,)
- Integrating the Y_2O_3 layers in superconducting architecture;

Acknowledgments

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Thank you for your attention!