# Experiment Proposal

Experiment number GP2023018

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**Experiment title** INSIGHT

**MRF Instrument** **High Resolution TEM**
**Days requested:** 5
**Access Route** Direct Access
**Previous GP Number:** No
**Science Areas** Energy, Materials, Physics
**DOI:** -
**Sponsored Grant** Yes
**Sponsor:** Other
**Grant Title** EUROfusion
**Grant Number:** 101052200
**Start Date** 01/03/2022
**Finish Date:** 29/02/2024
**Similar Submission?** -
**Industrial Links** -

**Non-Technical Abstract**

The samples object of this proposal are YBa2Cu3O7-x (YBCO) films with nano-engineered pinning landscapes for improving transport properties performances in the low temperature and high magnetic field regime. These nano-composite YBCO films are obtained by PLD on single crystals combining the functionalization of the substrate, with oxide nanoparticles, with the columnar growth of secondary phases in the film matrix. This growth occurs on SrTiO3 single crystal previously decorated with a uniform distribution of CeO2 nanoparticles, homogeneous in diameter and height. The samples to be investigated represent the result of a study of the defect landscape tuning through the film growth rate control. Transport critical current measurements under applied magnetic field of those films show remarkable and unique behaviours whose origin need to be investigated.

**Publications** -

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**ISIS neutron and muon source**
**IM@IT E-platform:** No

**Instruments**
**Days Requested:**
**Access Route**
**Previous RB Number:**
**Science Areas**
**DOI:**
**Sponsored Grant**
**Sponsor:**
**Grant Title**
**Grant Number:**
**Start Date**
**Finish Date:**
**Similar Submission?**
**Industrial Links**

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Science and Technology Facilities Council
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# Sample record sheet

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|---|---|---|---|
| **Principal contact** | Dr Francesco Rizzo, ENEA, ITALY | | |
| **MRF Instrument** | **High Resolution TEM** | **Days Requested:** 5 | |
| **Special requirements:** | | | |

## SAMPLE

| | | | |
|---|---|---|---|
| **Material** | $YBa_2Cu_3O_{7-x}$ on $SrTiO_3$ single crystals substrate | - | - |
| **Formula** | $YBa_2Cu_3O_{7-x}$ | - | - |
| **Forms** | Single crystal | | |
| **Volume** | 0.056 cc | | |
| **Weight** | mg | | |
| **Container or substrate** | $SrTiO_3$ single crystals substrate | - | - |
| **Storage Requirements** | - | - | - |

## SAMPLE ENVIROMENT

| | | | |
|---|---|---|---|
| **Temperature Range** | 273 - 300 K | - | - |
| **Pressure Range** | 1013 - 1013 mbar | - | - |
| **Magnetic field range** | 0 - 0 T | - | - |
| **Standard equipment** | Do Not Know | - | - |
| **Special equipment** | - | - | - |

## SAFETY

| | | | |
|---|---|---|---|
| **Prep lab needed** | Yes | - | - |
| **Sample Prep Hazards** | No | - | - |
| **Special equip. reqs** | Additional preparation of lamella from samples is required | - | - |
| **Sensitivity to air** | No | - | - |
| **Sensitivity to vapour** | Yes | - | - |
| **Experiment Hazards** | No experimental hazards | - | - |
| **Equipment Hazards** | - | - | - |
| **Biological hazards** | No biological hazards | - | - |
| **Radioactive Hazards** | No radioactive hazards | - | - |
| **Additional Hazards** | - | - | - |
| **Additional Details** | - | - | - |
| **Sample will be** | Returned to user by instrument scientist (when inactive) | - | - |

**Title of the proposal: Innovative strategies for Improving the pinning efficiency of YBCO thin films**

**Acronym of the proposal: INSIGHT**

## Background and Context

For the last quarter century, the study of pinning centres in $YBa_2Cu_3O_{7-x}$ (YBCO) has been a fundamental topic in material science[1–4], with the aim of producing high quality coated-conductors by enhancing the critical current density ($J_c$) of the superconductor when a magnetic field is applied~~,~~ $J_c$ is ultimately related to the dissipation due to the onset of magnetic flux vortex motion. In YBCO films, artificially formed columnar nano-sized structural defects can act as effective pinning centers for magnetic flux vortices in a wide range of temperature and magnetic field[5] The effect on $J_c$ provided by mixed addition of secondary phases using PLD is well known[5–8] : the interaction between the dopant phases during the film growth stage dramatically changes the final film microstructure with significant effects on $J_c$. In particular, this effect has been investigated with Ta- and Nb-based double perovskites, $Ba_2Y(Nb/Ta)O_6$ (BYNTO), showing that a variety of defects can be generated and controlled in YBCO nanocomposites depending on the film growth conditions (Fig.1). On the other hand, substrate functionalization has also been recently studied for both pld and CSD YBCO[9–11]. In both cases, a large amount of defects was generated in the films, as an effect of the interference of the oxide nanoparticles with the growth process (Fig.2). These defects were able to boost the material properties acting as pinning centres for magnetic flux vortexes. Thus, the combination of these two strategies could open up new microstructural scenarios in YBCO films grown by PLD, possibly achieving a superior vortex pinning capability, especially in the low *T* high field regimes.The emerging interest in high temperature superconductor materials for nuclear fusion and high energy physics applications has motivated new research activities on YBCO aimed at the development of YBCO coated conductor for high field applications[2,7,12–14]. In perspective of a commercial exploitation of the nuclear fusion energy, YBCO based magnet technology offers a realistic vision for a more compact (higher field) and more efficient (higher temperature) fusion devices if compared to the currently available low temperature superconductor Nb-based technology limited to 4.2 K and 13 T. Similarly, YBCO would offer a suitable and feasible opportunity for the development of very high field magnets (> 20 T) for future high energy particle accelerators. However, at low temperature conditions REBCO has yet to be sistematically investigated so and thus there is insufficient understanding of the most suitable defect landscape, neither of the required optimum pinning centres nor of the materials engineering needed to create them.

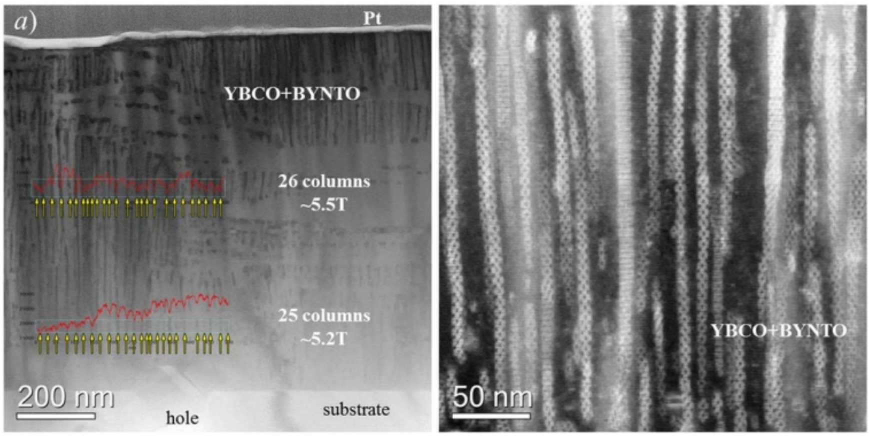


Fig.1 ABF STEM overview of the film showing the BYNTO columnar structures developed across the entire film thickness. Yellow arrows identify BYNTO columns in three different regions[4]

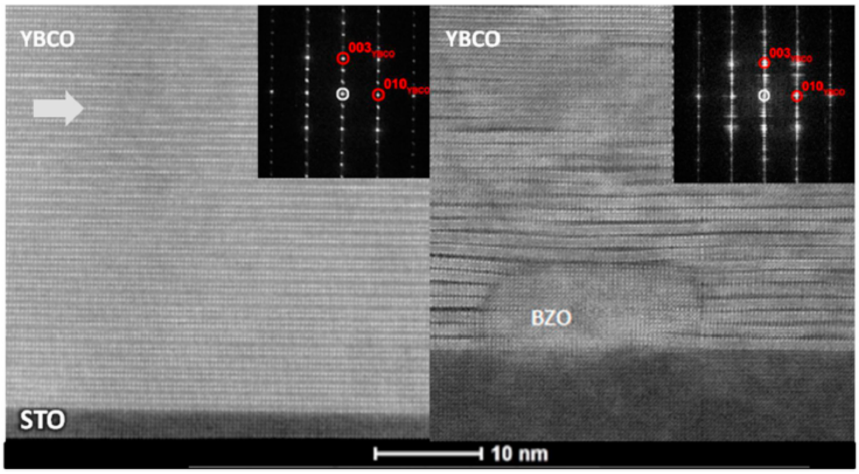


Fig.2 HAADF images of a YBCO films grown on a BaZrO3 (BZO) decorated template, showing the high density of defects generated around the oxide nanoparticle[8].

## Proposed Experiment

Detailed investigation of the microstructure of the nanocomposite films deposited by PLD on decorated substrates. The obtained microstructural information will be coupled with the transport properties, measured as a function of the applied magnetic field intensity and direction and of the temperature, to find the structural origin of the observed enhancement of the pinning capabilities and an explaination for the observed in field/temperature behaviour. In particular, the samples object of this proposal have already been fully characterized in terms of $J_c$ properties in order to be able to clarify the mechanisms of segregation and self-assembly of secondary phases in the presence of the decorated substrate, and to assess the relationship between structural defect landscape and vortex pinning at low temperature and high field conditions. Moreover, the effects of growth rate on the generated defect landscape within the nanocomposite film matrix will be investigated.