Issues of buffer layer on IBAD-MgO template for coated conductors

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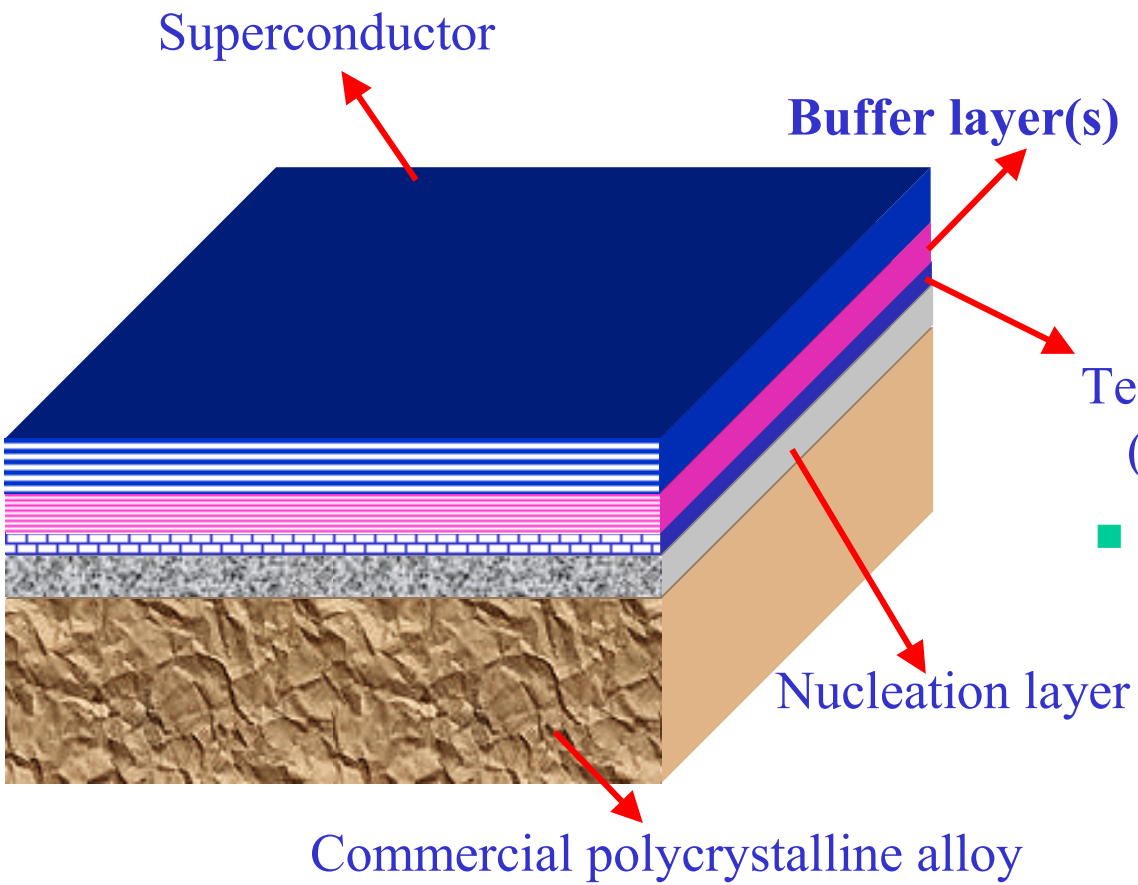
LANL uses IBAD-MgO template on commercial polycrystalline alloys to develop coated conductors



- On single crystal substrate, textured film is derived from homo- and/or hetero-epitaxial growth at elevated temperature.
- On polycrystalline substrate, a textured template must be provided before growth of desired epi-layers.

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Buffer material plays a major role in determining the performance of HTS films on metal substrates

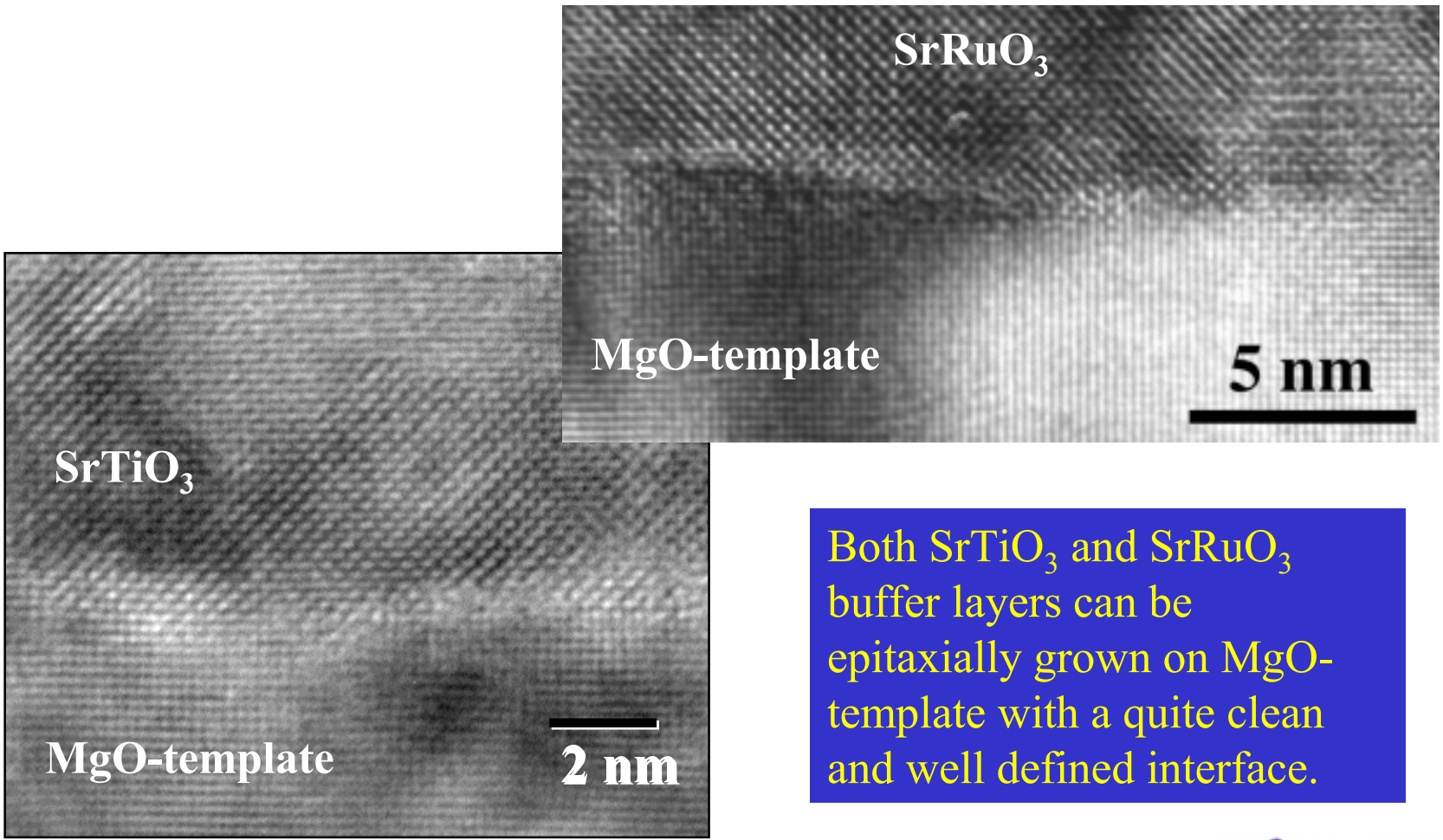
Requirements for the buffer

- Structural compatibility - crystallographic lattice match between the HTS film and the template
- Thermal stability - stable in high temperature oxidizing environment
- Chemical stability - minimal chemical interaction between the buffer and adjacent layers
- Barrier capability - provide a sufficient barrier against interdiffusion

Buffer materials on MgO

- MgO
  - ✓ $a = 4.213$ Å
- $SrTiO_3$
  - ✓ $a = 3.901$ Å
- CeO_2/YSZ
  - ✓ $a = 5.139$ Å
- $LaMnO_3$ (ORNL)
  - ✓ $a = 5.736$ Å, $b = 5.540$ Å, $c = 7.703$ Å
- $SrRuO_3$ (LANL)
  - ✓ $a = 5.573$ Å, $b = 5.538$ Å, $c = 7.856$ Å

HREM micrographs taken in $[001]_{MgO}$ show well-defined interface between the buffer layer and the MgO template



Both $SrTiO_3$ and $SrRuO_3$ buffer layers can be epitaxially grown on MgO-template with a quite clean and well defined interface.

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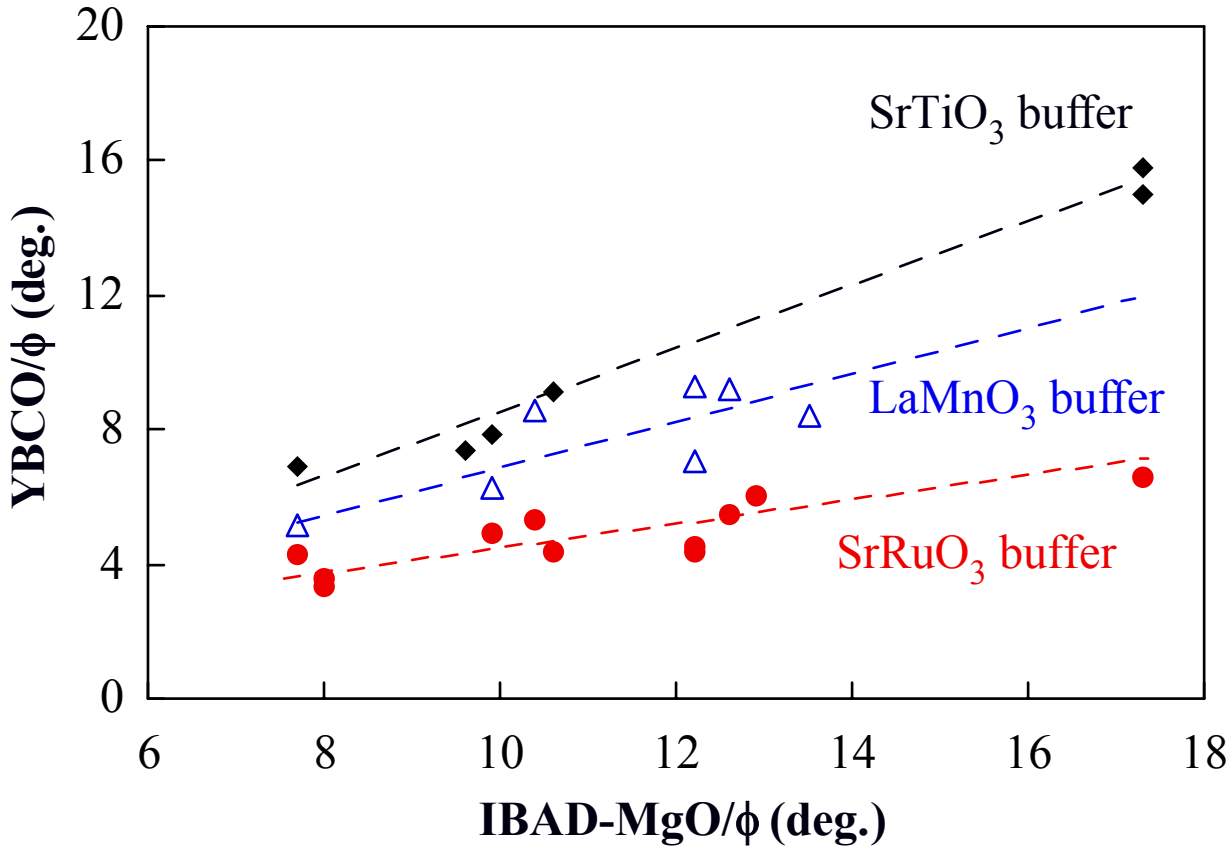
Much improved in-plane texture of YBCO on Ni-alloy while $SrRuO_3$ being used as a buffer on IBAD-MgO



Jia *et al*., Appl. Phys. Lett. **81**, 4571 (2002).

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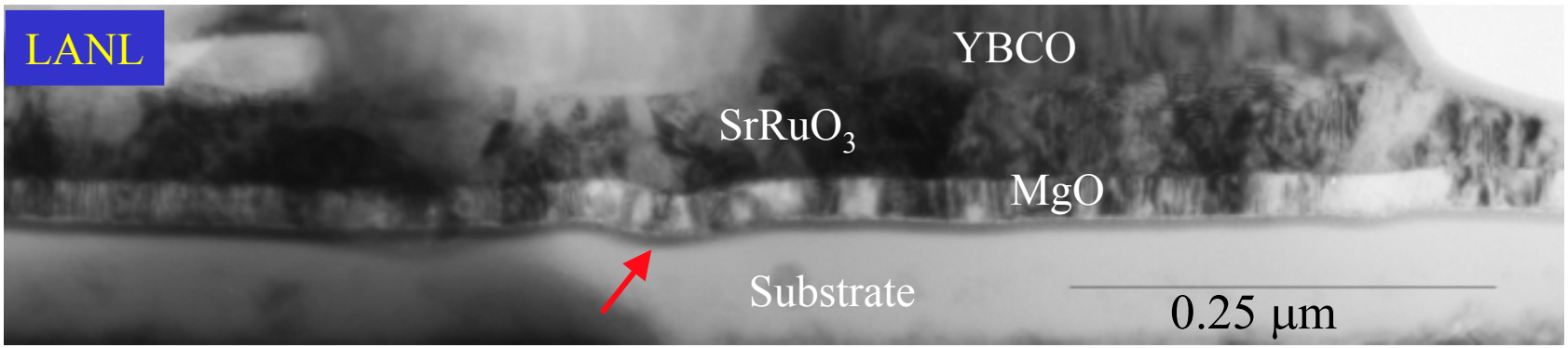
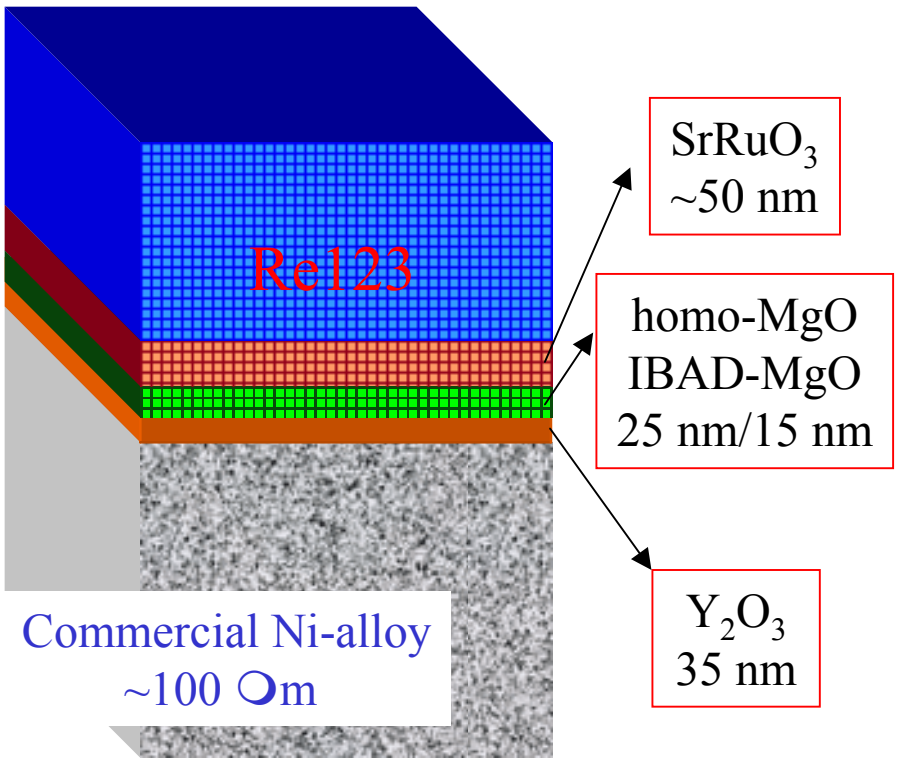
Other factors need to be considered in choosing buffer layer materials



Buffer can also serve as a healing layer to terminate the structural defects and/or stop the propagation of defects from penetrating into the top region of the multilayers.

High quality Re123 films have been deposited using IBAD-MgO template and $SrRuO_3$ buffer layer



- PLD Y123
  - t = 1.4 μm
  - FWHM = 2.2 deg.
  - J_c = 2.3 MA/cm^2
  - $I_c^{eq.}$ = 320 A/cm-width
- PLD Eu123/Y123
  - t = 0.47 Om
  - FWHM = 3.9 deg.
  - J_c = 4.9 MA/cm^2
  - $I_c^{eq.}$ = 230 A/cm-width

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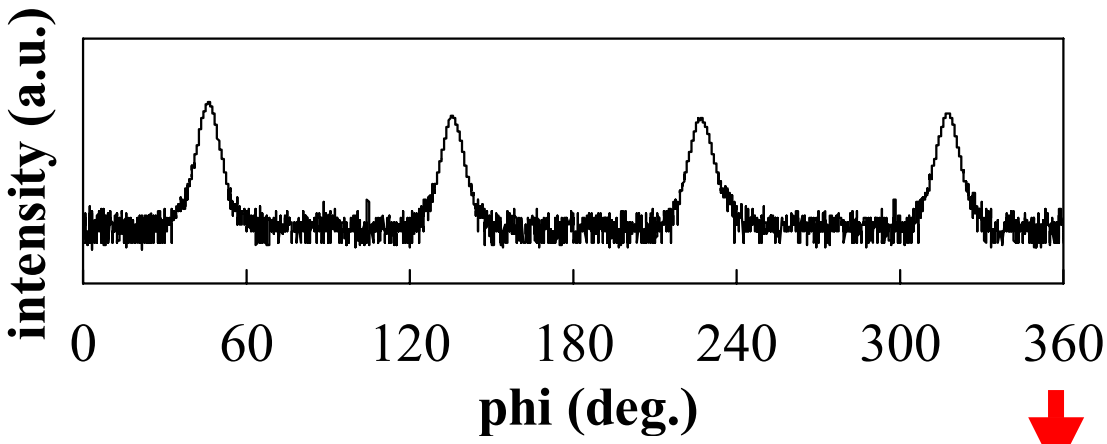
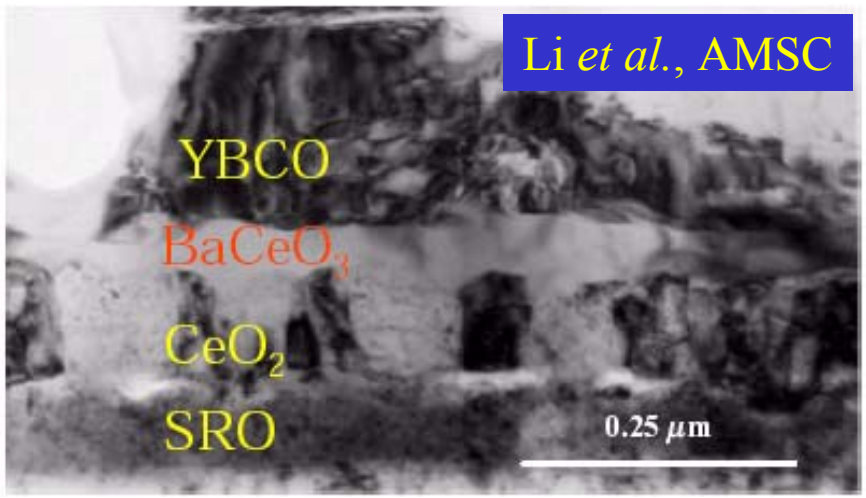
Different processing technologies lead to different microstructure of the materials





Y123 by PLD on SRO
Epi-growth, high quality

Y123 by MOD on SRO
Random oriented.
CeO_2 needed for
high quality Y123

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Interplay of the processing conditions on the properties of the buffer layer materials

- Processing temperature
  - Thermal stability of the materials (processing conditions used for superconductor coatings needed to be considered)
- Environment
  - Reducing atmosphere can lead to the change of the physical properties of the buffer materials
    - $SrRuO_3 + 2H_2 \rightarrow SrO + Ru + 2H_2O$
- Processing compatibility
  - Physical vapor deposition
  - Chemical vapor deposition
  - Ex-situ process
  - In-situ & Ex-situ processes

Cost and performance needs to be balanced in choosing buffer materials

- Cost of the materials ($/kg)
  - Sr: 180 Ti: 220 Y: 2,650
    Zr: 150 Ce: 150 La: 5,000 Ru: 30,000
- Buffer layer thickness
  - Thin buffer layer requires less materials and labor
- How many layers being used
  - Single buffer layer is preferred in terms of both materials, capital, and labor
- Controllability and reproducibility
- How easily the process can be adapted by others
- Scalability of the process
- Windows for the optimized performance

Summary: buffer plays a critical role in determining the performance and the cost of coated conductors

- Materials
  - Structural and chemical compatibility
  - Thermal stability
  - Barrier property
- Architecture
  - Single layer
  - As thin as possible
- Process
  - Wide process window
  - Stable under different processing environment
  - Processing compatibility