Sandia All-Solution Deposition Method

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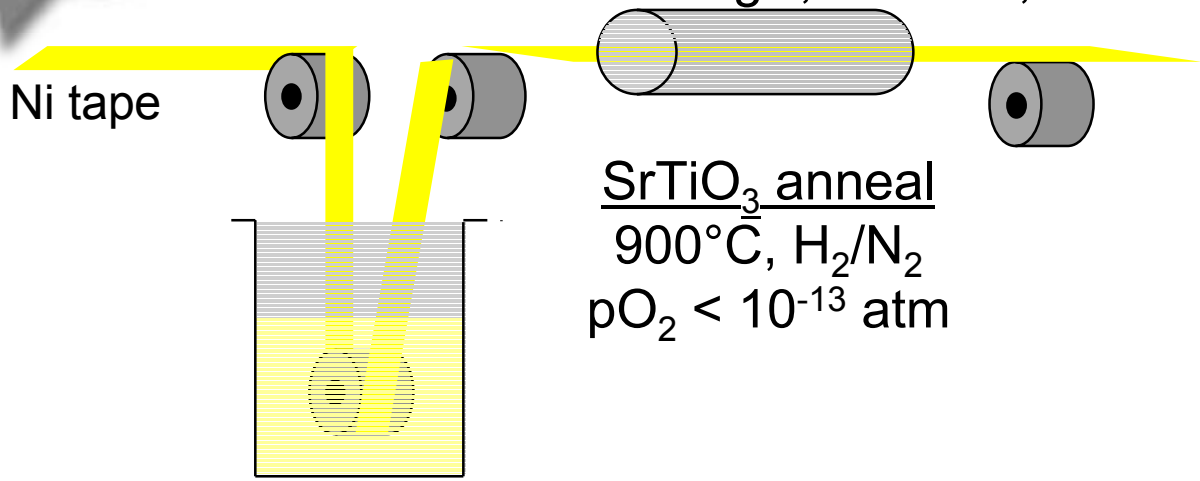
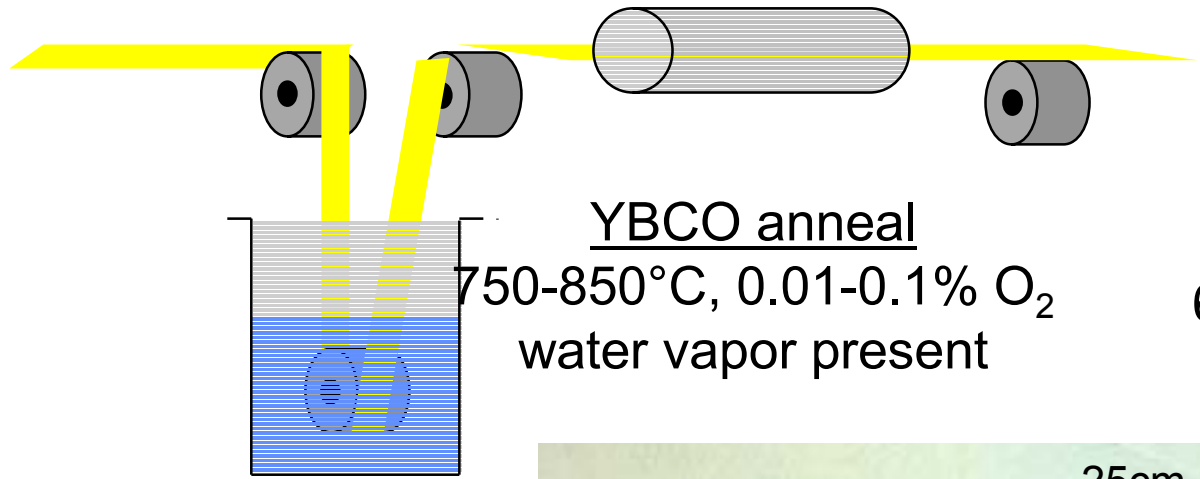


$SrTiO_3$ anneal
900°C, H_2/N_2
$pO_2 < 10^{-13}$ atm



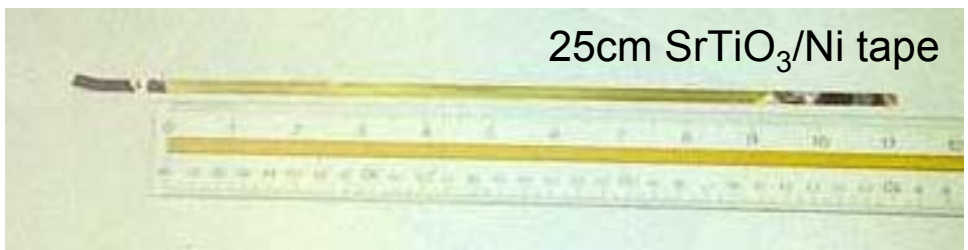
YBCO anneal
750-850°C, 0.01-0.1% O_2
water vapor present

Solutions are:
metal acetates
metal alkoxides
trifluoroacetic acid
solvents

Coating parameters:
1-5 cm/s pull speed
0.1-0.4 μm/coating

3 cm/s = 947 km/yr
(single width)

60 sec hot zone = 1.8 m



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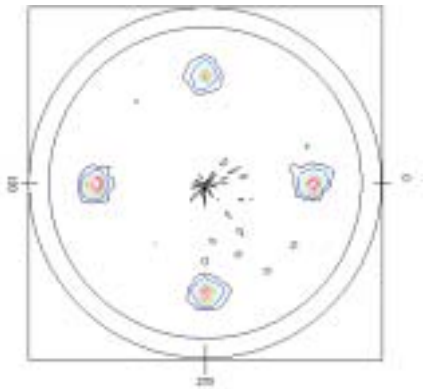
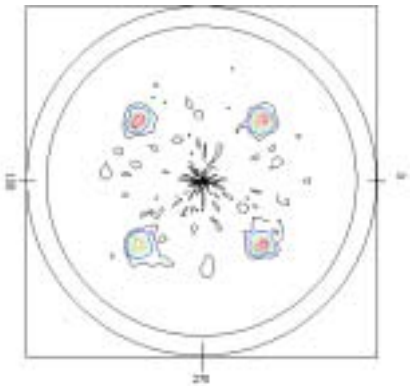
Current status

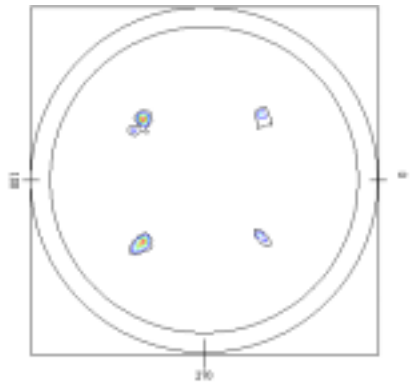
YBCO (113)



STO (220)



Ni (220)



short length (2.5-25 cm)

YBCO thickness	Jc	Ic	substrate
0.25 um	4 MA/cm^2	100 A/cm	$LaAlO_3$
1.3 um (6 layers)	0.7 MA/cm^2	91 A/cm	$LaAlO_3$
0.12um	1.3 MA/cm^2	16 A/cm	STO/Ni
0.25, 0.5, 1.0 um	*- in progress FY2003 -*		STO/Ni

long length (1 m)

- in progress FY 2003 -

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Scale-up considerations

- Both STO and YBCO may be coated at 3 cm/s = 950 km/yr
- Very low capital cost (conductor material cost ~$ 0.39-0.78/kA-m)

- Limitation of TFA-YBCO: thick film conversion, time

dip coating → pyrolysis → crystallization → oxygenation

3-10 cm/s 15s (was 3h) 0.5-1 h 0.5 h

1-1.5 hours

- Approaches:
  - Spontaneous pyrolysis: organic burnout (was 3+ hours, now 20 sec)
  - Thicker YBCO layers: increased to 0.6-1.0 μm/coating
  - Thick film conversion by P_{O_2}, P_{H_2O} changes (with ORNL)
  - Cima vacuum TFA-YBCO conversion (2 mins. for 0.9 micron film)

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Obstacles to scale-up

Thickness of YBCO layers: single coat to 1 micron needed

- Need to control film tensile stress to avoid cracking
- If limited to < 1μm, can (i) multi-pyrolyze or (ii) multi-crystallize
  - Demonstrated limited success using both methods

Thick film conversion should/must be faster than 1 hour

- Same issues as BaF_2-YBCO conversion

Ability to single-coat buffer layer, with rapid thermal annealing

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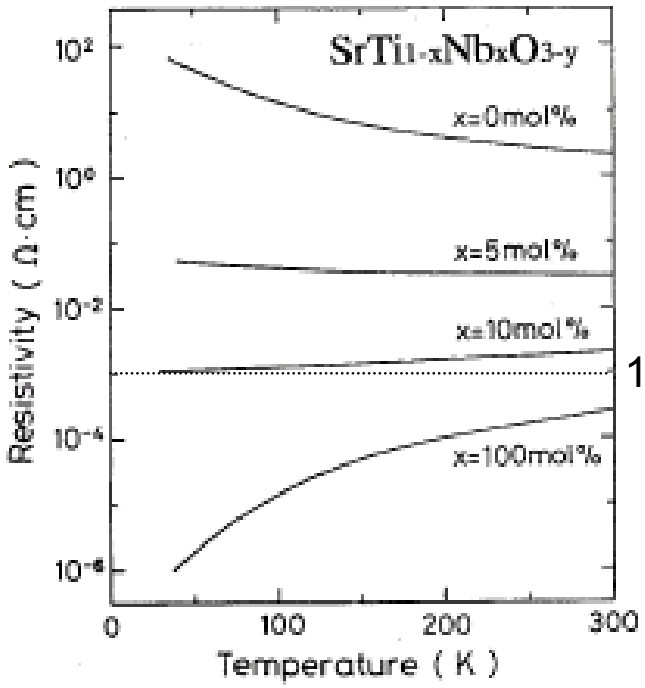
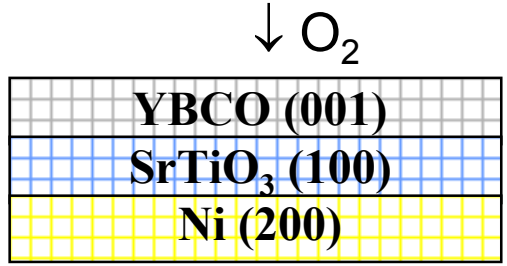
Why $SrTiO_3$?

- Compatible with YBCO
- Can be n-type doped to ρ = 1000 μΩcm,
  with low O_2 diffusion rates
- Low theoretical oxygen diffusion rate



1 mΩ cm

material	unit cell	D_{ox}(800°C) O diffusion coefficient
MgO	4.20Å	$2x10^{-19}$ cm^2/s
$CaTiO_3$	3.82Å (orth.)	$1x10^{-15}$ cm^2/s
$SrTiO_3$	3.91Å	$2x10^{-12}$ cm^2/s
$LaSrMnO_3$	3.90Å	
Ho_2O_3	3.75Å	$7x10^{-7}$ cm^2/s
YSZ	3.63Å	$2x10^{-7}$ cm^2/s



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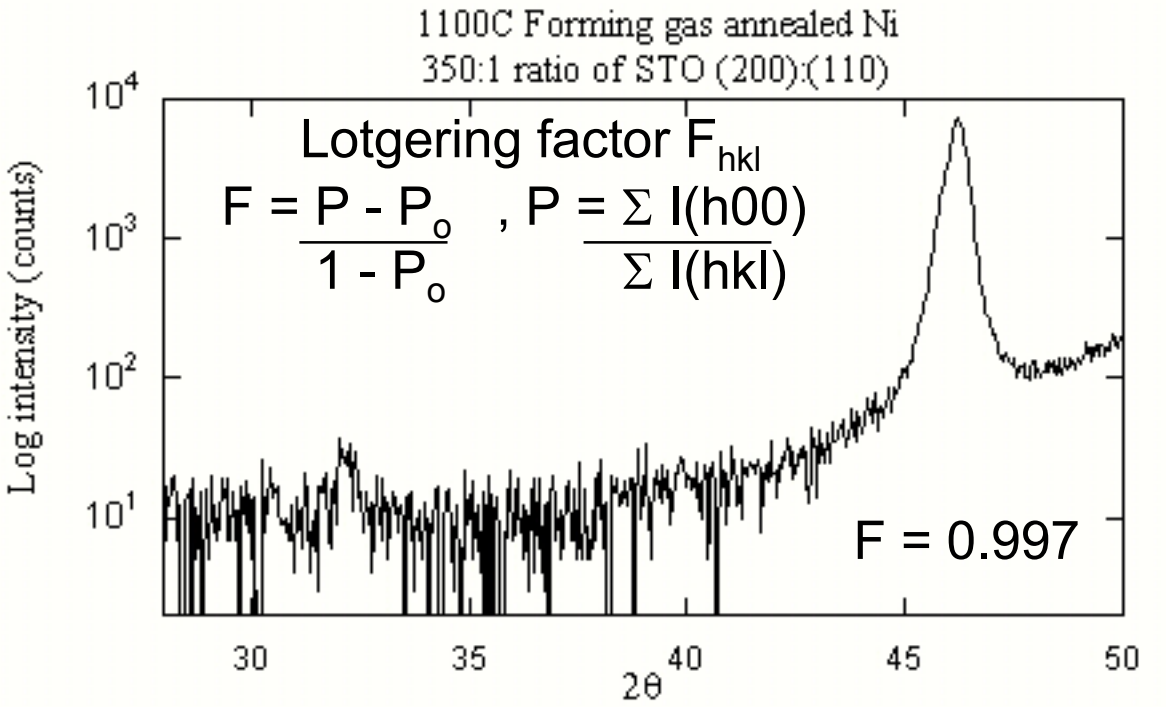
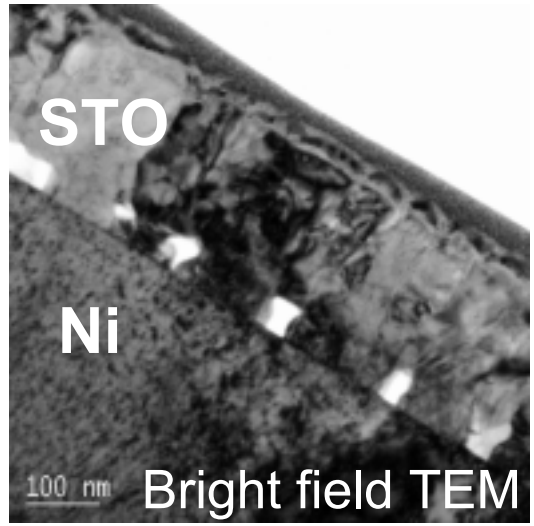
Solution-deposited epitaxial $SrTiO_3$ on Ni

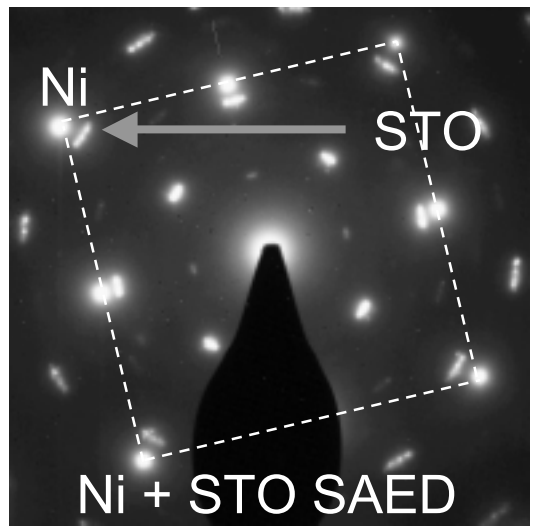
TFA addition avoids carbonates in sol-gel YBCO and other oxides, including $BaTiO_3$ and $SrTiO_3$.

Enables epitaxial $SrTiO_3$ growth as low as 500ºC.

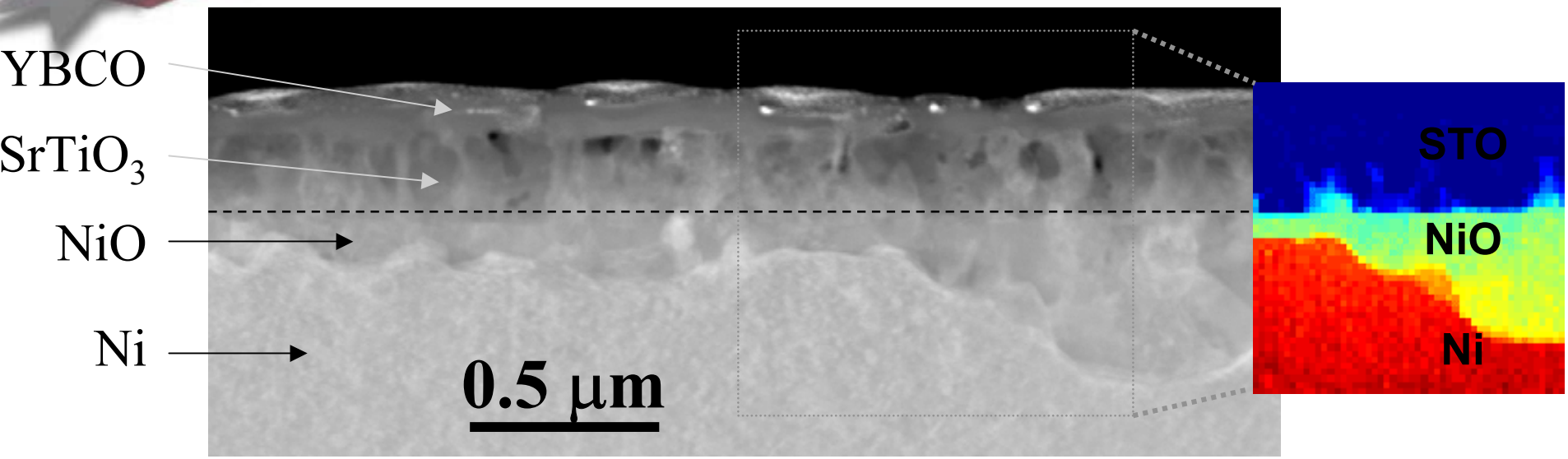
Currently depositing $SrTiO_3$ on Ni/Ni-W



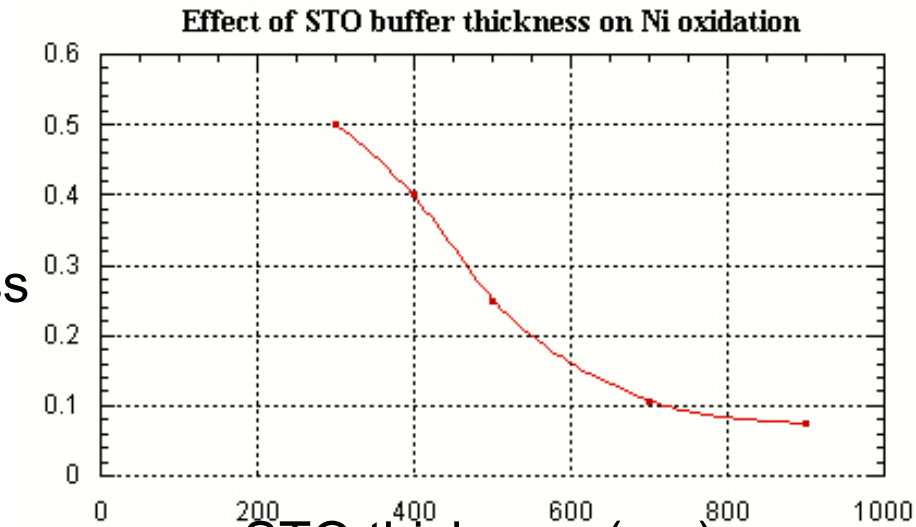




Control of Ni substrate oxidation



Increasing $SrTiO_3$ thickness suppresses Ni oxidation.
STO ≥ 500nm has been the best support for YBCO to date.



Results for YBCO grown on STO/Ni at 800ºC, 30 min

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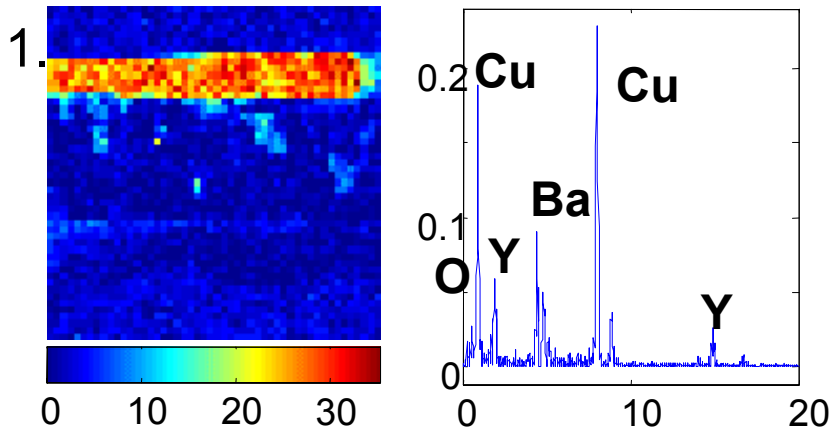
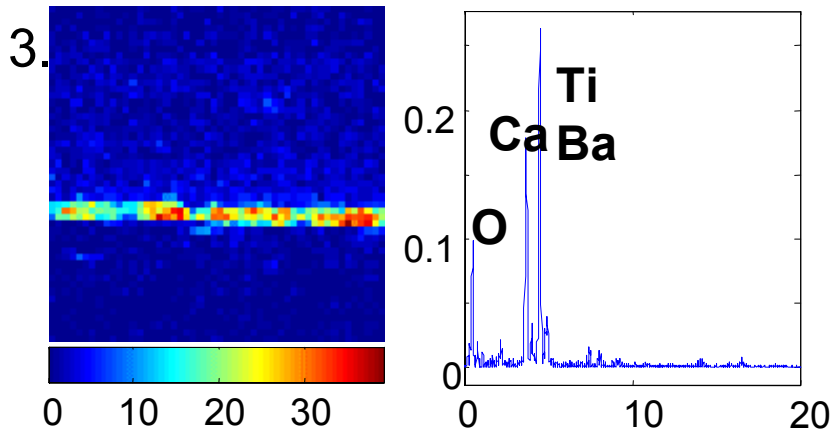
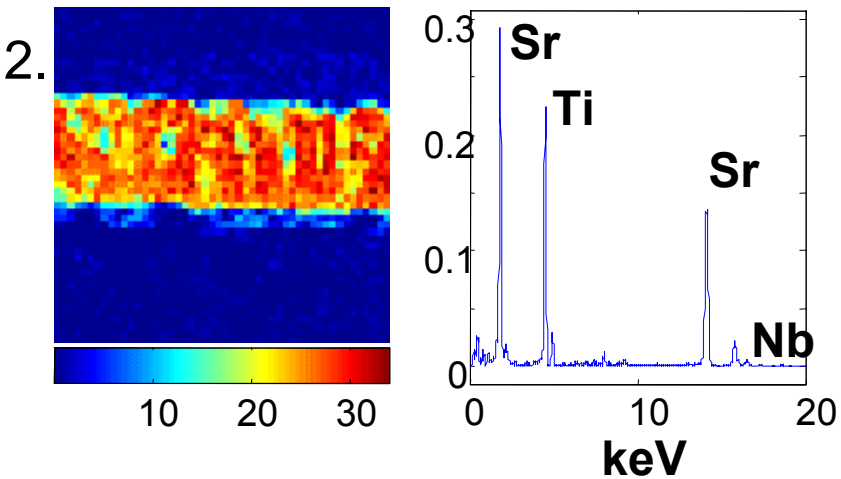
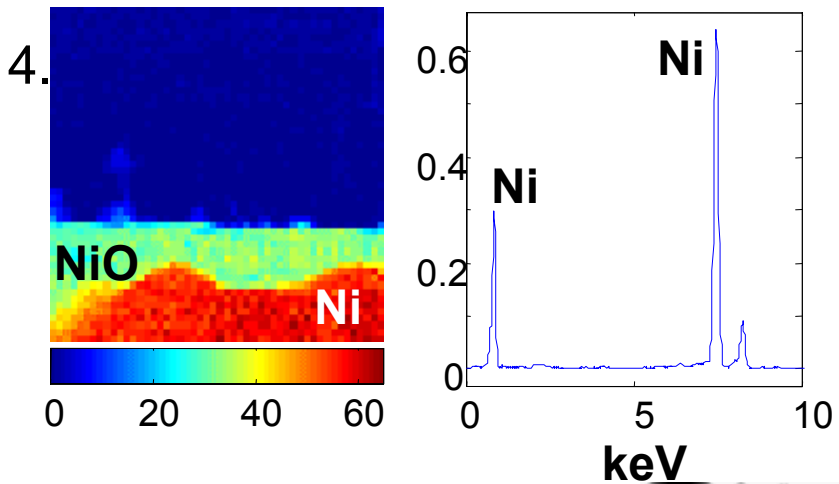
Process Integration TEM: X-ray Spectral Image Analysis

YBCO/STO/BCT/Ni(100)









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2003 Development Goals

Increase density in buffer layer (suppress NiO formation)

Scale-up from 25 cm to > 1 meter lengths with ORNL ACCI facility

Collaborate with ORNL on TFA-YBCO conversion

- ultimate goal: 1 μm YBCO, J_c = 2MA/cm^2, 200 A/cm

TFA-YBCO conversion time/process is key limitation

<u>Production/cost predictions</u>

Capacity: coating at 3-10 cm/s, 1-3 million meters/year

Easy regeneration: 1 km YBCO $\approx$ 100 ml of solution

YBCO, buffer materials cost (today, 500g lots) < $ 1/kA-m

Expect: 0.25 μm YBCO, 2MA/cm^2 on buffer/Ni $\rightarrow$ 50A/cm

1.0 μm YBCO, 1MA/cm^2 on buffer/Ni $\rightarrow$ 100A/cm

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