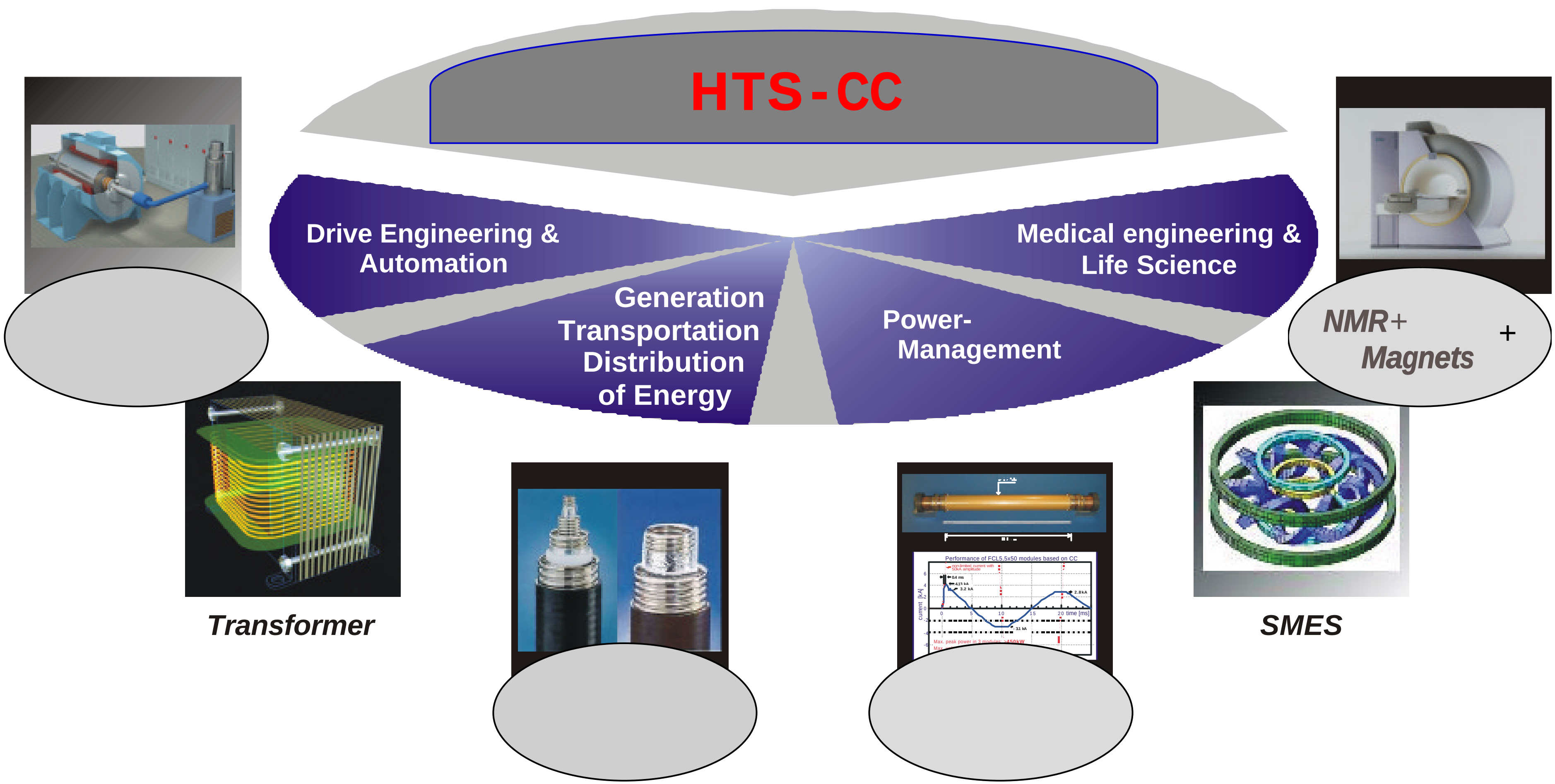
Panorama of the Coated Conductor Developments in Europe

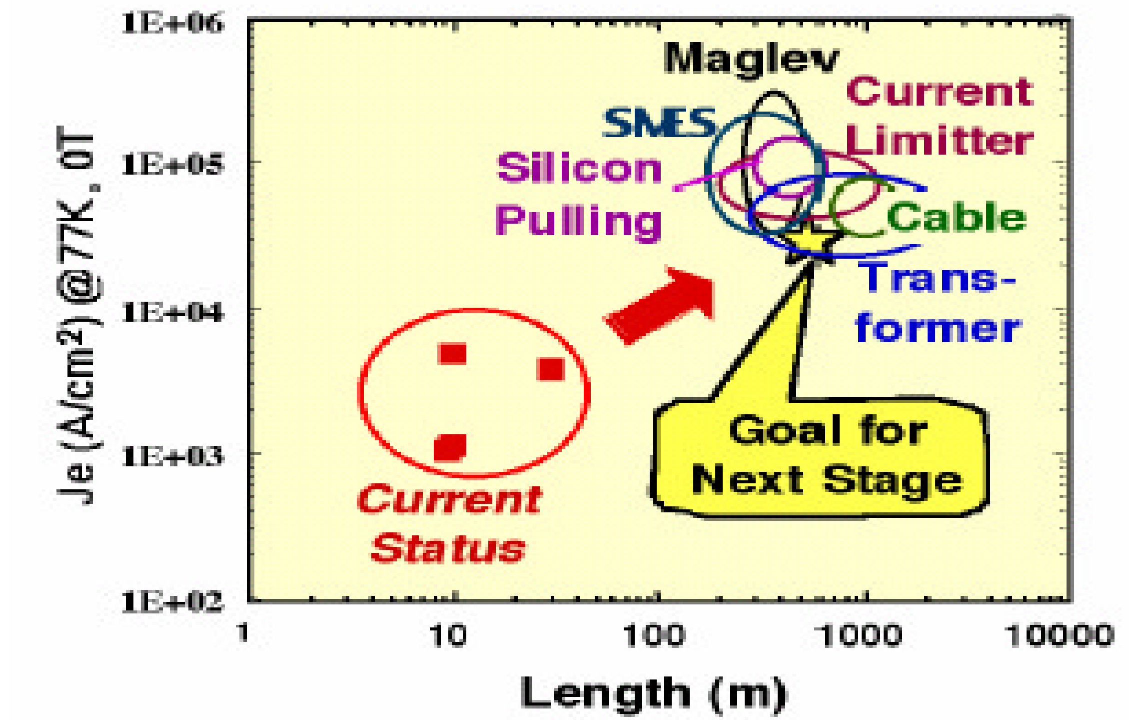
Herbert C. Freyhardt
Universität Göttingen & ZFW gGmbH Göttingen

HTS-CC Products & Market

Electrical & Power Engineering, Magnet Technology



Coated conductors: challenges



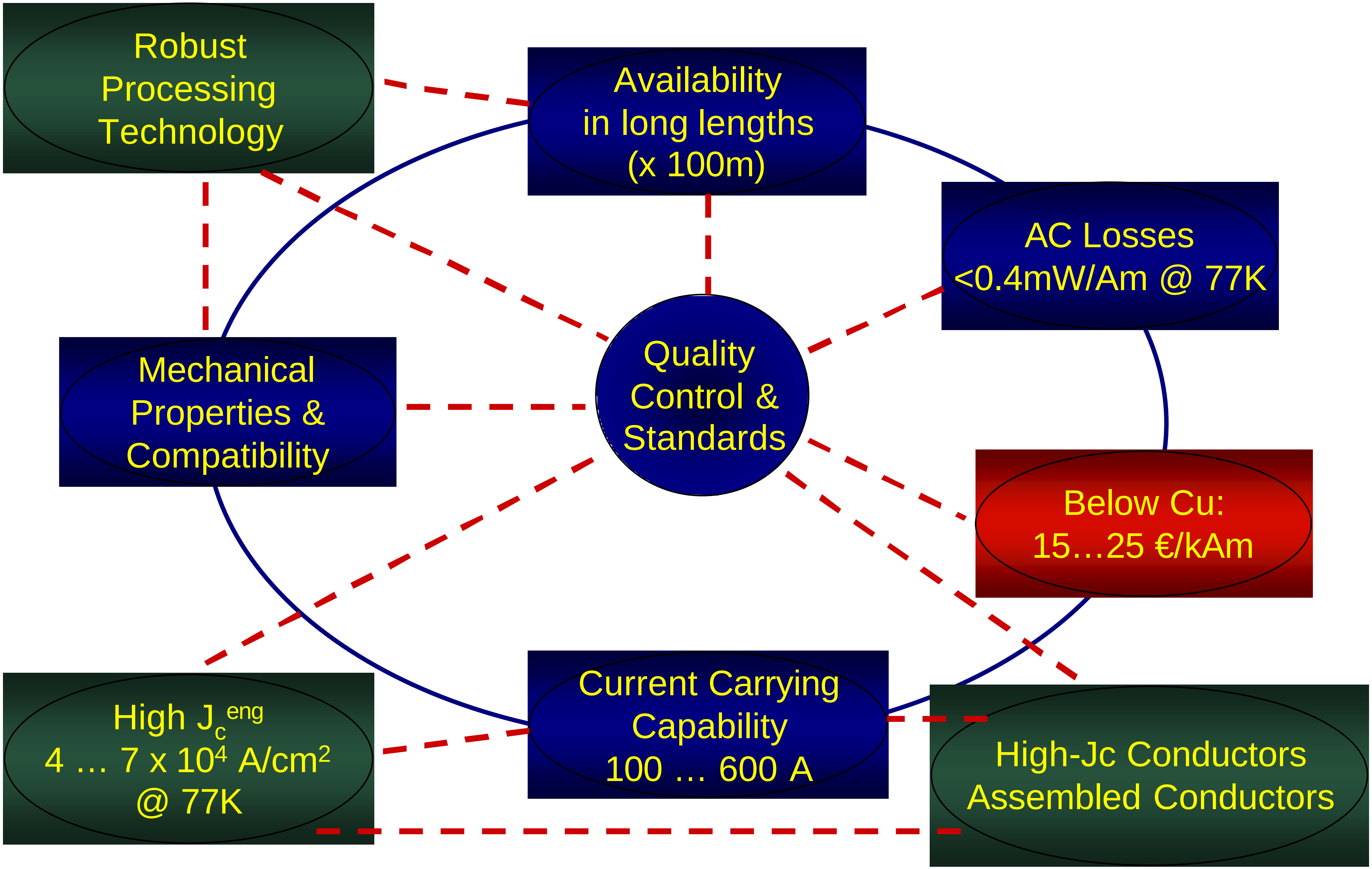
Japan targets 2007

- »70 $/kAm
- 500 m, 5 m/h
- I_c=300 A/cm-w

Yu. Shiohara / ISTEC

- •High performance
- •High processeing rate
- •Low production costs

CC for Applications in Electrical & Power Engineering



HTS must be available as

wires, tapes or assembled conductors

HTS conductors

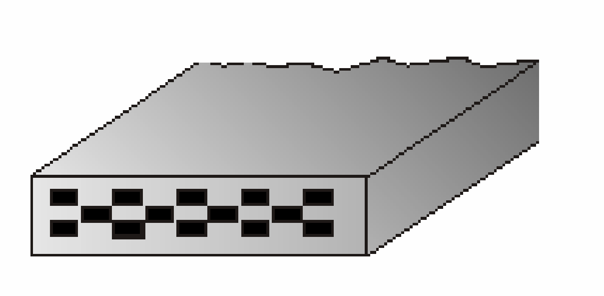
1st generation

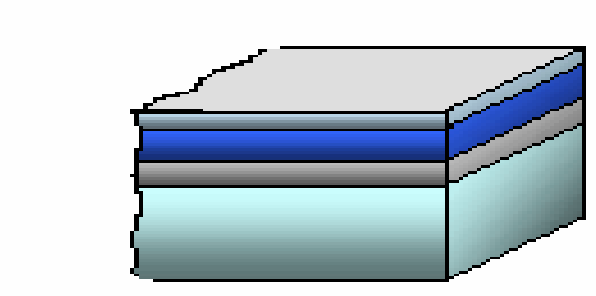
Bi-HTS

HTS conductors

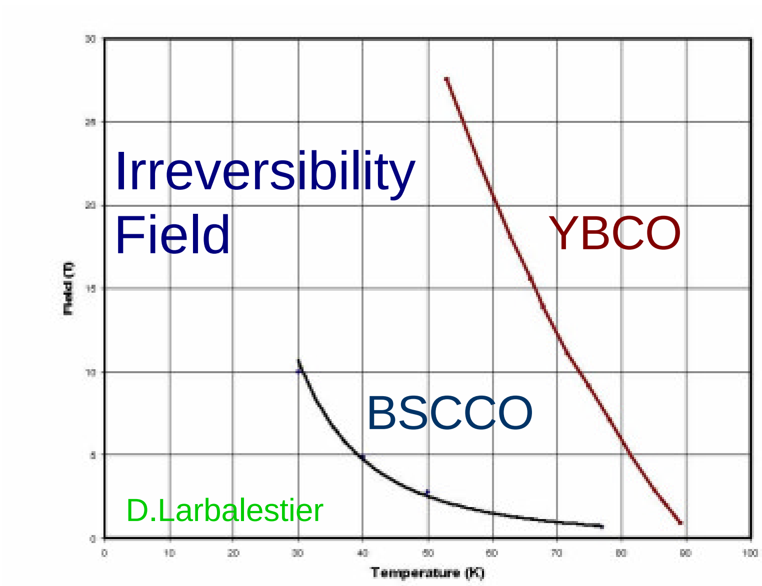
2nd generation

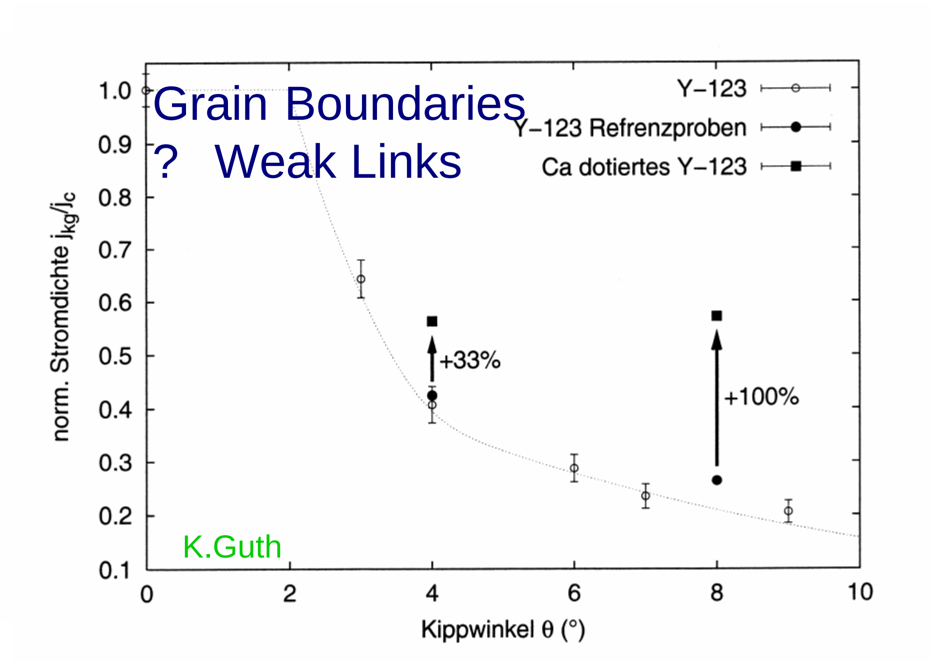
YBaCuO Coated Conductors





What is required for
? J_c high @ 77K, moderate magn. fields
@ 4.2K and below, high fields

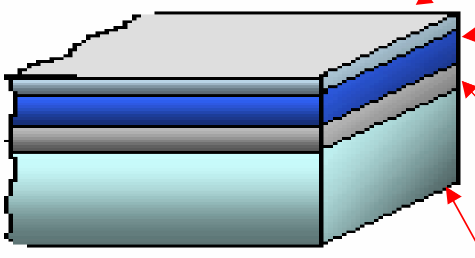




Highly textured films

- sufficient film thickness for high I_c
- thermal & mechanical stability …

Coated Conductors: A Multilayer Architecture



HTS Coated Conductor

CAP LAYER
•Proctective;
•Conductive

HIGH TEMP. SUPERCONDUCTOR
•J_c(T,B), J_c(e), ac losses

BUFFER ARCHITECTURES
•Diffusion barrier; Thermal Expansion
•Adhesion; Interface Reactions
•Texture transfer; Epitaxy
•Lattice matching; Surface Reconstruction

SUBSTRATES
•poly: SS, Hastelloy, ...
•Thermo-Mech. Treatment: Ni, Ni alloys,...

Material	Structure	T_m/ °C	a_0 (300K)	L_m	Misfit YBCO (%)	Misfit to Ni (%)	Misfit to NiO (%)
Ni	fcc	1455	3.52	3.52	-9.38	0.00	-18.47
YSZ	cubic / fluorite	2680	5.13	3.63	-6.06	3.03	-14.88
$Gd_2Zr_2O_7$	cubic / pyrochlore		10.52	3.72	-3.49	5.38	-12.10
Y_2O_3	cubic / Mn_2O_3	>2400	10.6	3.75	-2.67	6.13	-11.20
$LaAlO_3$	rhombohedral / perovskite	2100	5.36	3.79	-1.58	7.12	-10.03
$La_2Zr_2O_7$	cubic / pyrochlore	2300	10.8	3.81	-1.05	7.61	-9.45
Gd_2O_3	cubic / Mn_2O_3	>2400	10.81	3.82	-0.79	7.85	-9.16
$CaTiO_3$	orthorhombic / perovskite		5.38x5.44	3.82	-0.79	7.85	-9.16
CeO_2	cubic / fluorite	2600	5.41	3.83	-0.52	8.09	-8.88
Eu_2O_3	cubic / Mn_2O_3	>2300	10.87	3.84	-0.26	8.33	-8.59
$LaNiO_3$	rhombohedral / perovskite		5.45	3.84	-0.26	8.33	-8.59
YBCO	orthorhombic		3.83x3.88	3.85	0.00	8.57	-8.31
$Ca_{0.6}Sr_{0.4}TiO_3$	orthorhombic / perovskite		5.46x5.46	3.86	0.26	8.81	-8.03
$NdGaO_3$	orthorhombic / perovskite	1670	5.43x5.5	3.86	0.26	8.81	-8.03
Sm_2O_3	cubic / Mn_2O_3	>2300	10.93	3.86	0.26	8.81	-8.03
La_2NiO_4	tetragonal		3.86	3.86	0.26	8.81	-8.03
Sr_2RuO_4	tetragonal		3.87	3.87	0.52	9.04	-7.75
LSMO	rhombohedral / perovskite		5.49	3.88	0.77	9.28	-7.47
NdBCO	orthorhombic		3.87x3.92	3.89	1.03	9.51	-7.20
Pd	fcc	1555	3.89	3.89	1.03	9.51	-7.20
Gd_2CuO_4	tetragonal		3.89	3.89	1.03	9.51	-7.20
$SrTiO_3$	cubic / perovskite	2080	3.91	3.91	1.53	9.97	-6.65
$LaMnO_3$	orthorhombic / perovskite		5.54x5.74	3.91	1.53	9.97	-6.65
Nd_2O_3	cubic / Mn_2O_3	>2300	11.08	3.92	1.79	10.20	-6.38
$SrRuO_3$	orthorhombic / perovskite		5.57x5.54	3.93	2.04	10.43	-6.11
Nd_2CuO_4	tetragonal		3.94	3.94	2.28	10.66	-5.84
$BaTiO_3$	tetragonal / perovskite		3.99	3.99	3.51	11.78	-4.51
Ag	fcc	961	4.09	4.09	5.87	13.94	-1.96
$SrZrO_3$	orthorhombic / perovskite	2800	5.79x5.82	4.10	6.10	14.15	-1.71
$BaSnO_3$	cubic / perovskite		4.12	4.12	6.55	14.56	-1.21
NiO	cubic / rocksalt	1984	4.17	4.17	7.67	15.59	0.00
$BaZrO_3$	cubic / perovskite	2690	4.19	4.19	8.11	15.99	0.48
MgO	cubic / rocksalt	3100	4.21	4.21	8.55	16.39	0.95
TiN	cubic / rocksalt		4.24	4.24	9.20	16.98	1.65

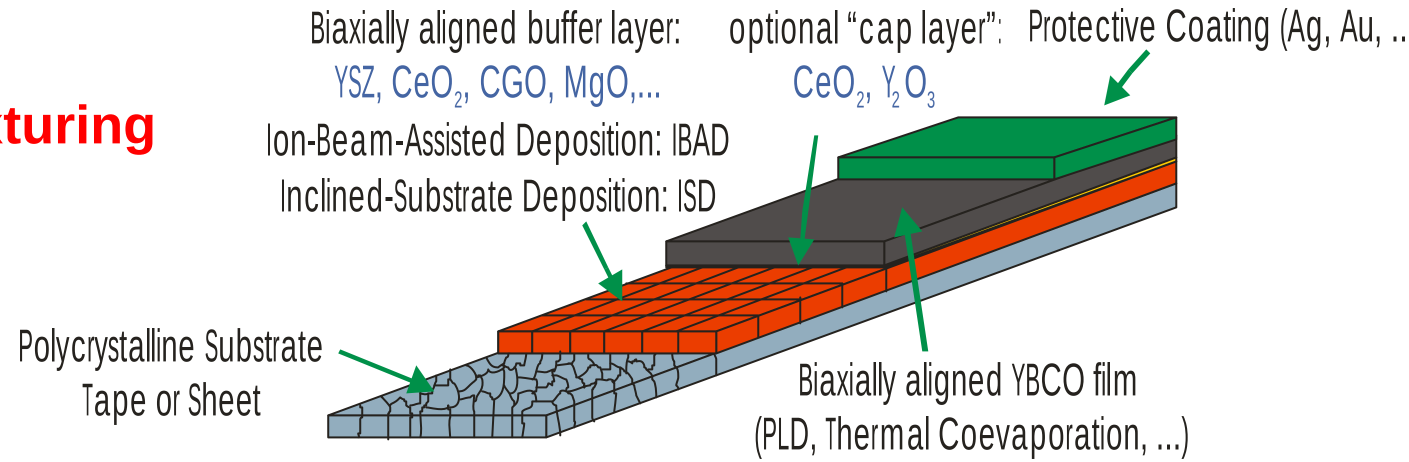
- perovskite
- rocksalt
- fcc structure
- spinel
- fluorite
- C-type RE
- pyrochlore

J.E.Evetts

Coated Conductors: two different routes

Forced Texturing

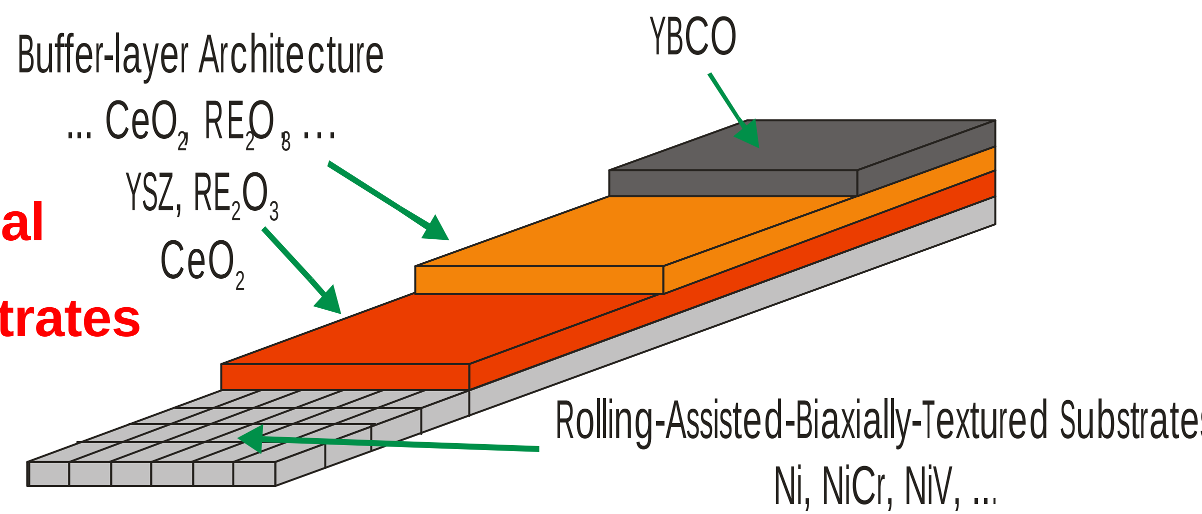
IBAD, ISD



Thermo-mechanical

Texturing of Substrates

(TMT), RABiTS



CC Developments in Europe

Essential Development Lines

•Ni-Cr SS /IBAD-YSZ/CeO2/PLD-YBCO ZFW, UGoe
•Hastelloy/ISD-MgO/homo-MgO/TCE-YBCO or –R.E.BCO Theva
•TMT-Ni,Ni-W/TCE-CeO2/TCE-YBCO EDISON,IMEM-CNR,Europa Metalli
•development of TMT substrates
 -Ni and Ni alloys together with CSD buffers mainly IFW Dresden
 -Cu based substrates La Farga Lacambra, Univ. Barcelona
•development of
 -MOCVD for buffer architectures and YBCO deposition on TMT and IBAD substrates Nexans, mainly INPG
 -CSD buffer systems and TFA-YBCO on TMT and IBAD substrates mainly ICMAB
•SOE (Surface Oxidation Epitaxy) of TMT tapes together with MOD and PLD buffers in combination with high-rate hybride LPE UCam

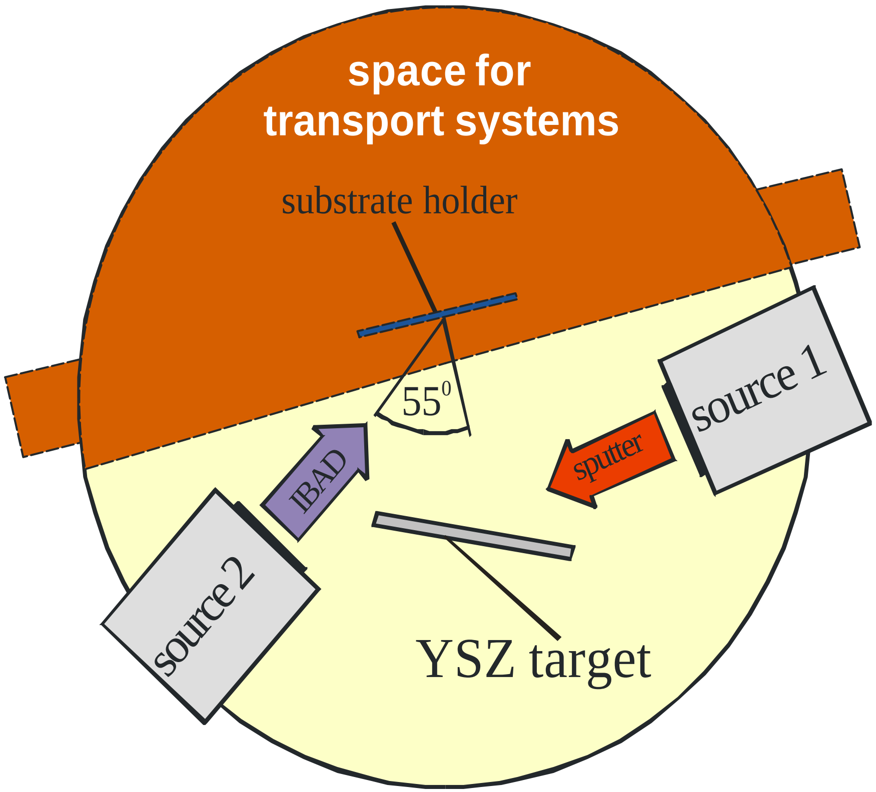
vac. deposition

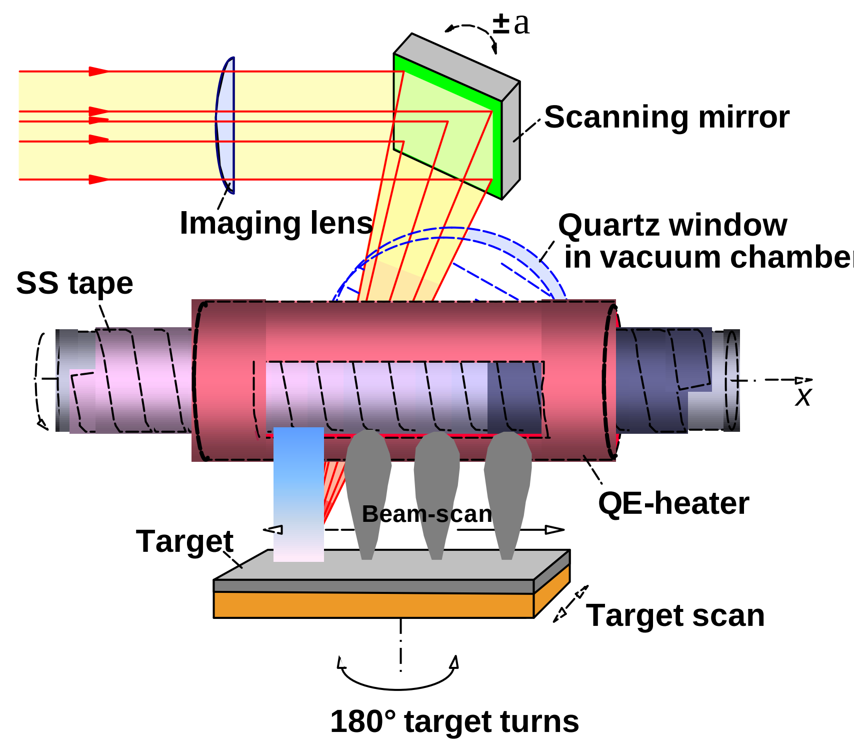
non-vac. depos.

Essential CC Developments

Substrates	Polycrystalline Substrates **Ni,Cr-based SS, Hastelloy, Inconel** **poly Ni**	Biaxially Textured S's : TMT, RABiTS **Ni, Ni-W, Ni-Mo, Ni-Cr, Ni-Cr-Al, Ni-V, …** **composite tapes Cu-based tapes**
Buffer Layer Architect.	Forced Texturing of Buffer Layer **IBAD-YSZ; IBAD-ZGO; IBAD-MgO** **+ CL or CLs** **ISD-MgO/homo-MgO** **CeO2, Y2O3,… MOCVD** **perovskite-type,… CSD**	**on Ni, Ni-alloys/Ni & Ni, Ni-alloys/SOE-NiO** **no SOE-NiO CeO2:TCE,EB; Y2O3/YSZ/CeO2, …** **MOCVD: CeO2, YSZ,Y2O3,Gd2O3,LNO** **CSD: CeO2; BZO, STO, SZO, LAO, LZO, NCO,...** **spray: CeO2** **on SOE-NiO: PLD-BZO,-SZO,-CSTO** **on SOE-NiO: MOD-BZO,-SZO**
YBCO R.E.BCO	**PLD-YBCO, HoBCO** **TCE-YBCO, DyBCO** **on SS-IBAD-YSZ** **MOCVD-YBCO** **TFA-YBCO**	**YBCO-PLD, YBCO-TCE** **YBCO-MOCVD, spray pyrol.** **YBCO BaF2-method** **YBCO-TFA** **LPE; HR hybride LPE**

Cr-Ni-SS / IBAD -YSZ / PLD -YBCO





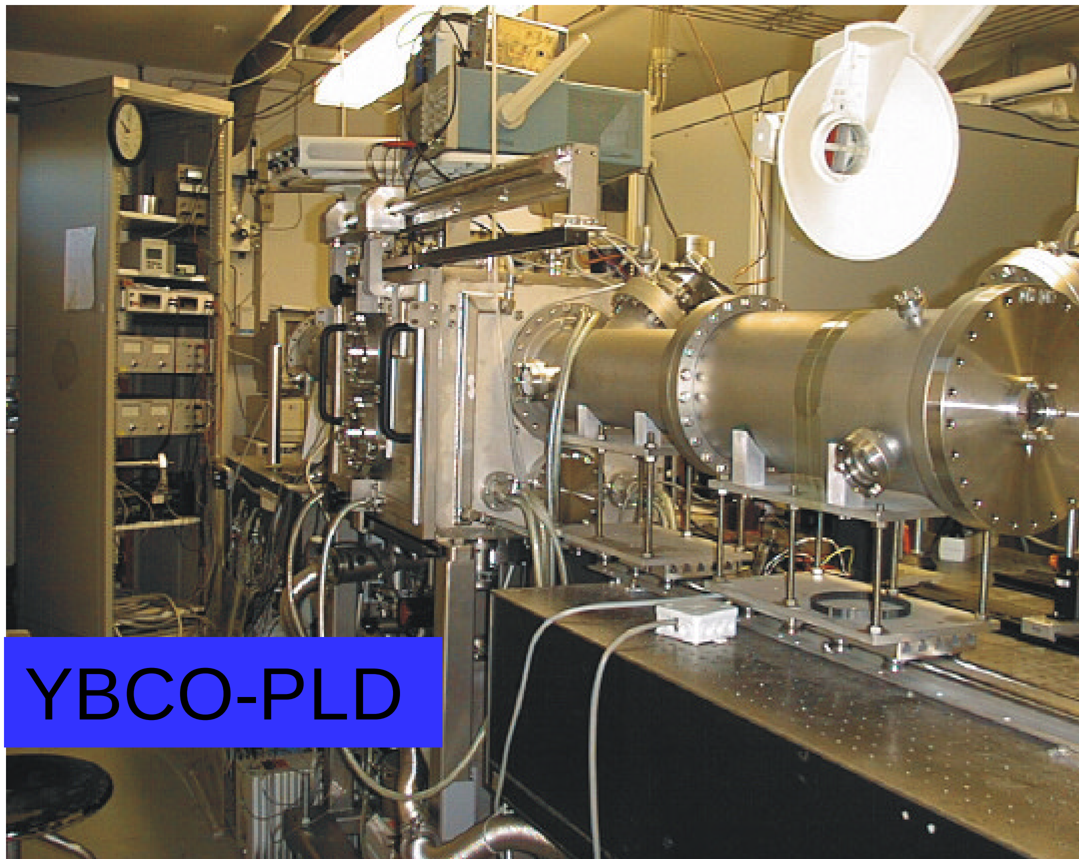
IBAD

HR-PLD

Ion Beam Assisted Deposition

High-Jc SS/IBAD-YSZ/PLD-YBCO

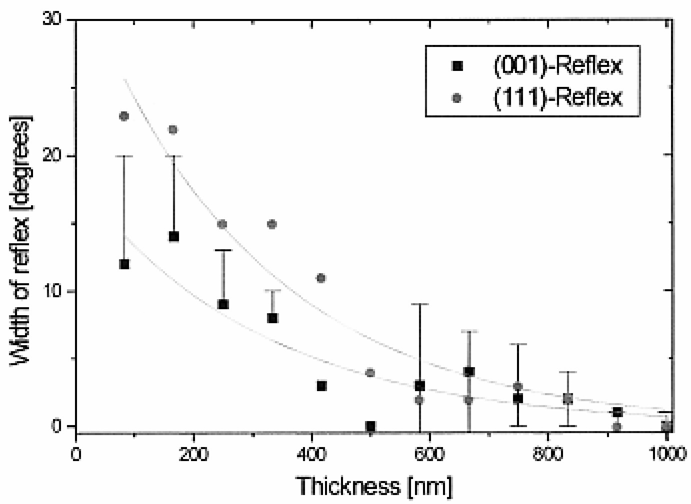
ZFW gGmbH



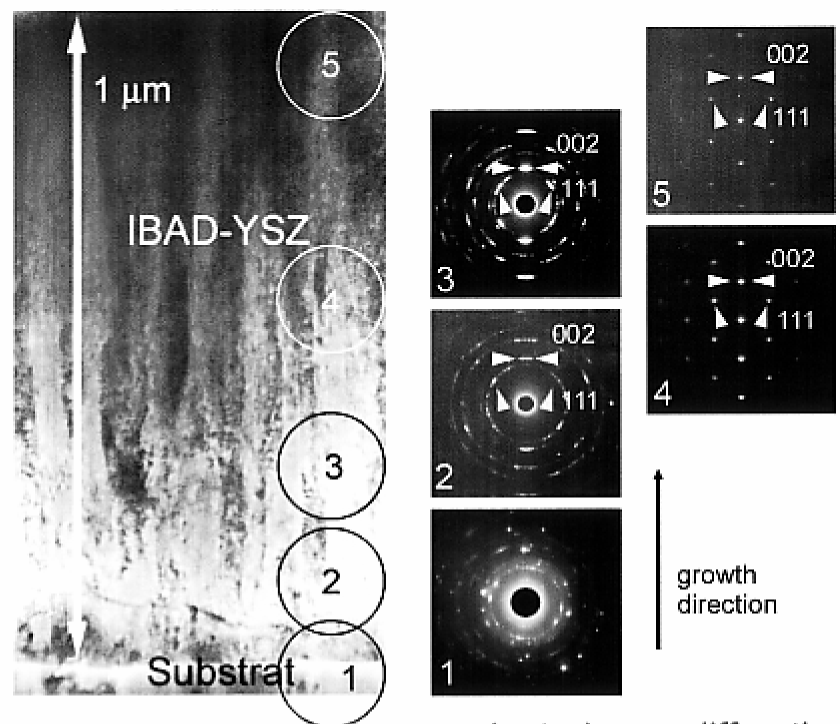
TEM & HR-TEM Investgations of the texture development

SS/IBAD-YSZ

Improvement of the out-of-plane-texture

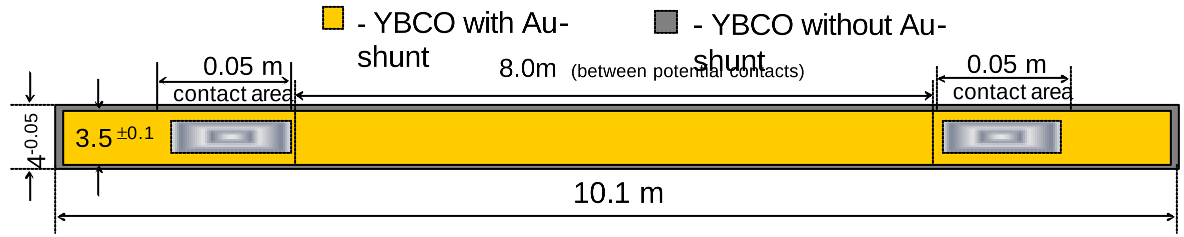


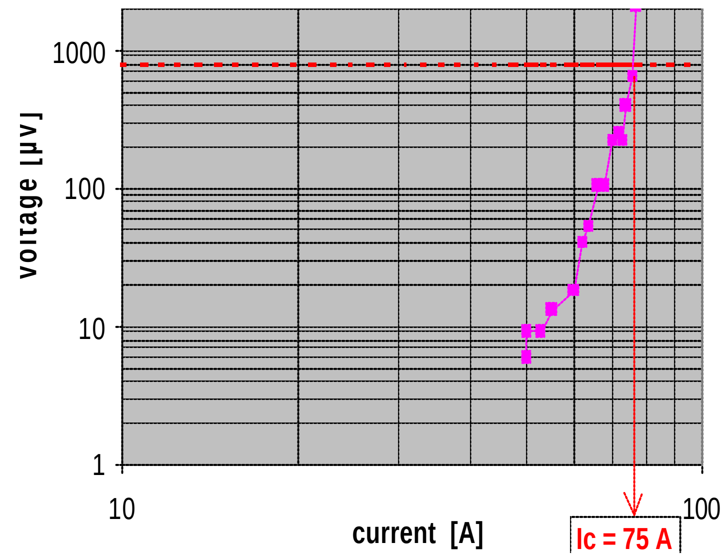
TEM cross-sectional view of IBAD-YSZ



selected area diffraction

Coated Conductors: Long YBCO coated SS tapes





A. Usoskin
A. Issaev
H. C. Freyhardt

Nov. 2002

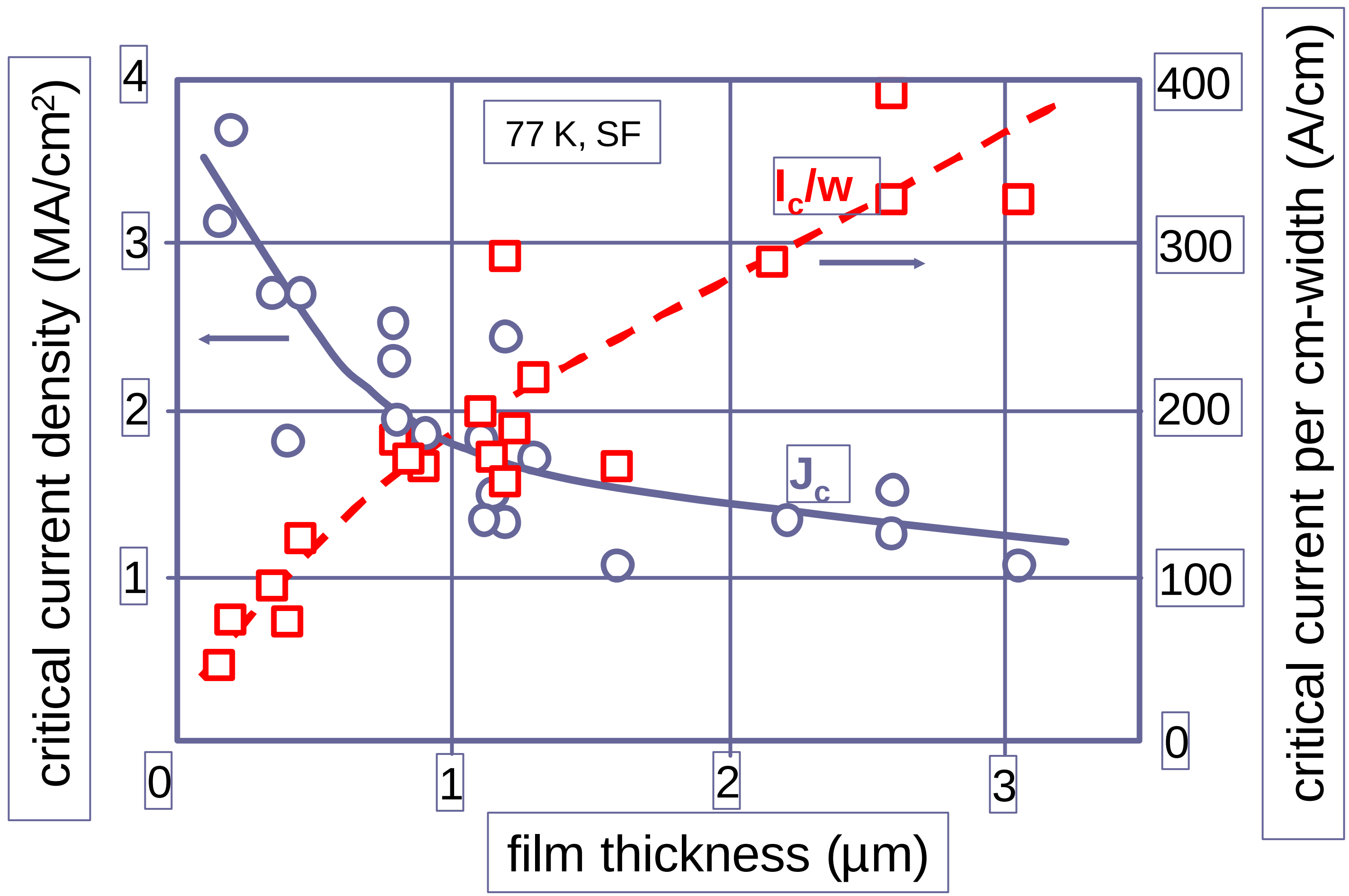
- SS tape (0.1 mm) // IBAD-YSZ (1.5 µm) // CeO_2 (<0.1 µm) // YBCO (1.1 µm)
- Coated Conductor : **8m long, 4mm wide, with 3.5mm-wide YBCO film**
- Critical current, I_c, and current density J_c :

$I_{c,min}$ = 75 A => $J_{c,min}$ = 1.95 MA/cm^2 & Ic/w = 214 A/cm (77K, SF)

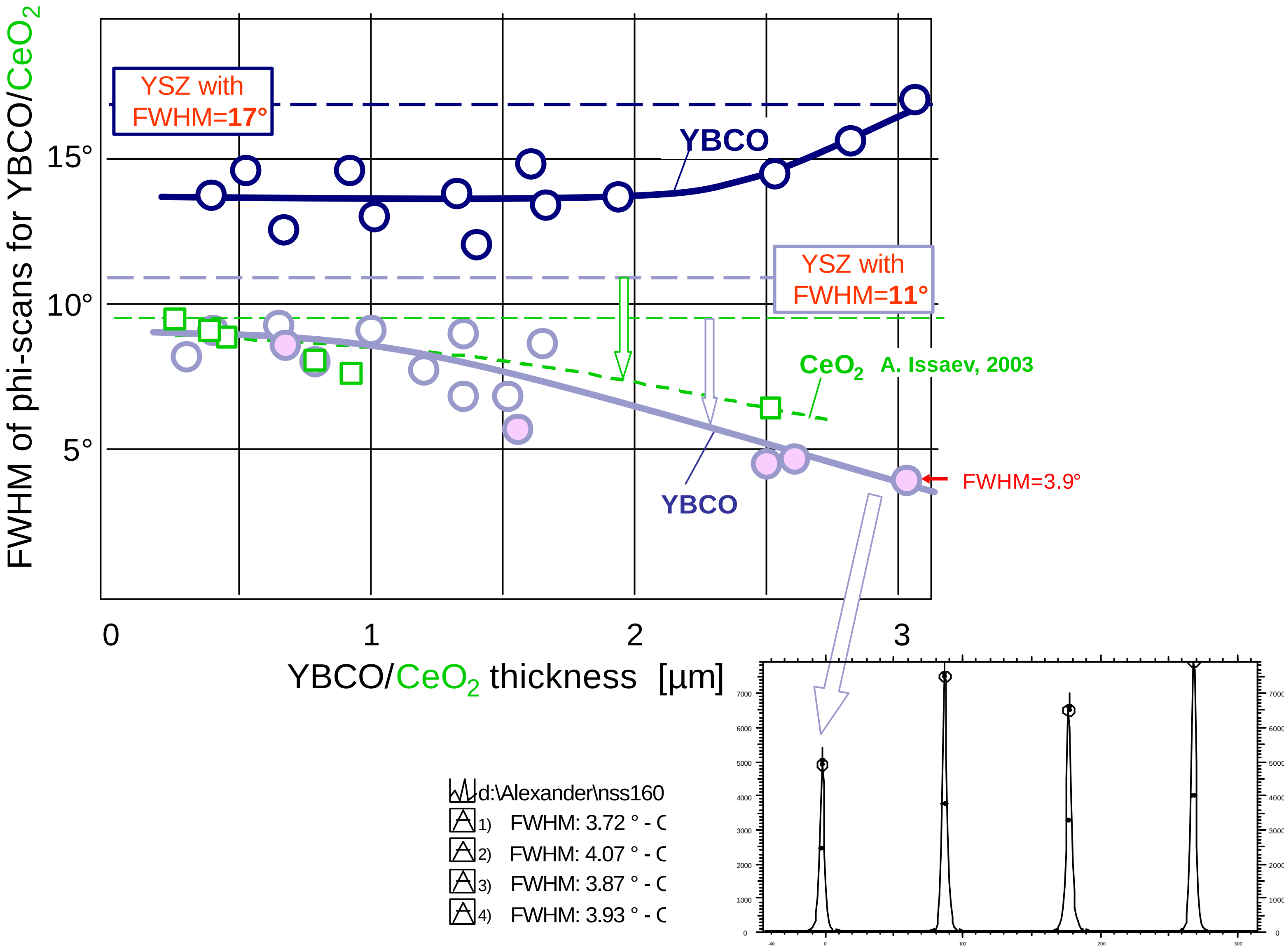
Parameter	Unit	Sample.no						
		N1148	N1148	N2154	N2159	N2161a	N2161b	N3190
Length, L	m	1.9	1.9	9.0	10.3	1.0	0.2	6.2
Effect. width, w^*	mm	92	9.2	3.4	3.5	9.5	3.5	3.7
YBCO thickness	µm	1.25	1.25	1.1	1.0	2.4	2.6	2.8
T_c	K	89.5	89.5	89.5	91.2	90.0	90.0	90.1
Temp. of I_c Test	K	77	67	77	77	77	77	77
I_c	A	142	290	67	78	301	137	125
I_c/w^*	A/cm	154	315	197	223	317	391	
J_c	MA/cm^2	1.23	2.52	1.79	2.23	1.32	1.51	1.21
Engg.current d. J_e	kA/cm^2	15.4	31.5	19.7	22.3	31.7	391	**338**
I_{quench}	A	153	-	67	79	310	153	136

Latest Results 08 2003: 357 A/cm-w (6.1m, 3.5mm, 3.2µm YBCO)

Thickness Dependence of J_c & I_c

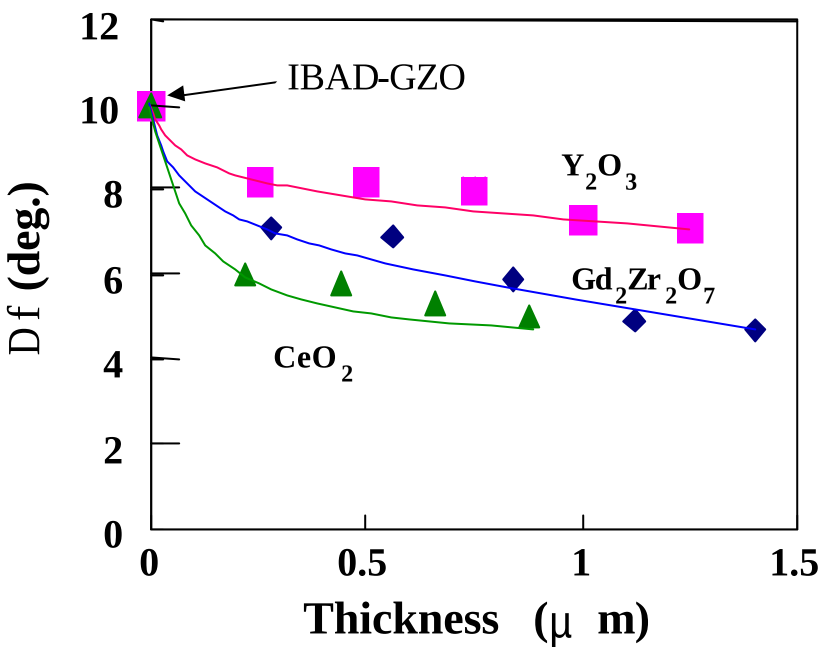


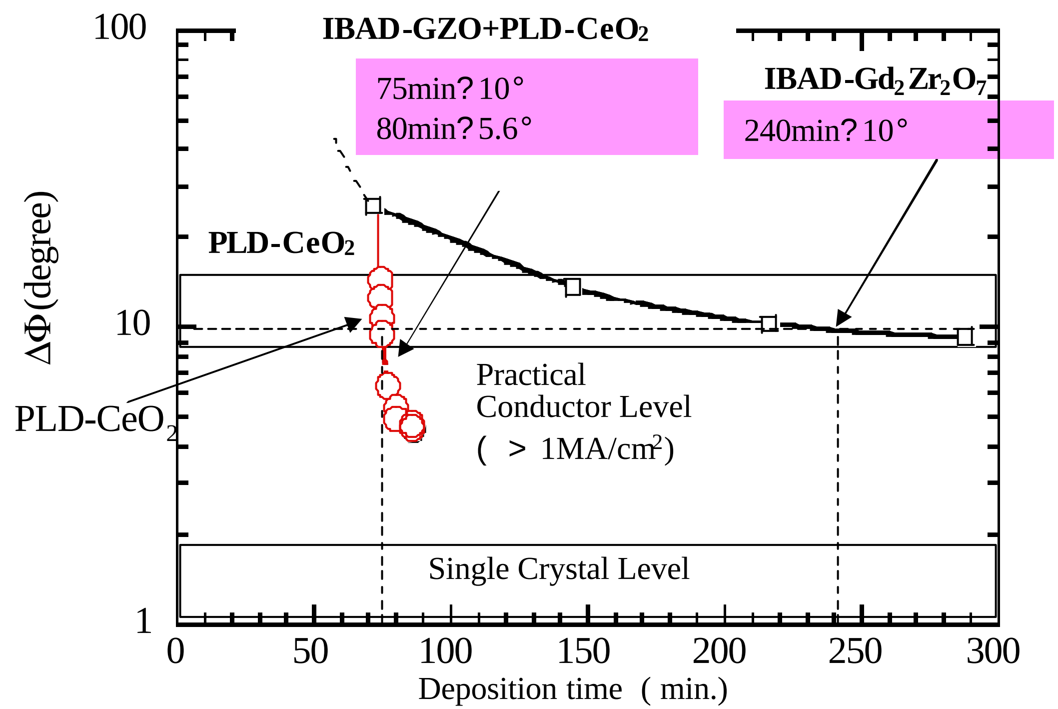
Coated Conductors: YBCO Texture

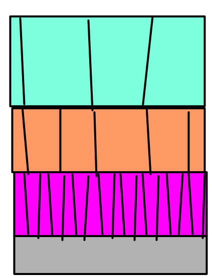


Self-epitaxy of buffer layers

PLD secondary template







PLD-YBCO Δϕ~ 3-4 º

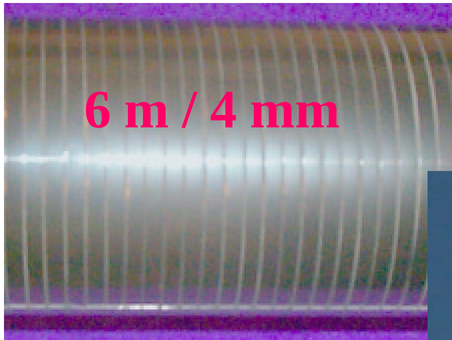
PLD-CeO_2 (GZO) Δϕ ~ 5º

IBAD-GZO Δϕ ~ 10º

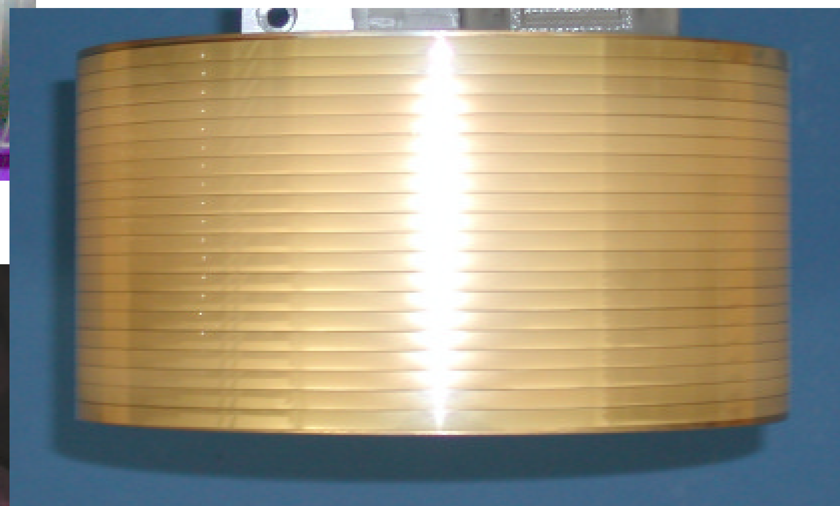
PLD/IBAD (Fujikura/ISTEC)

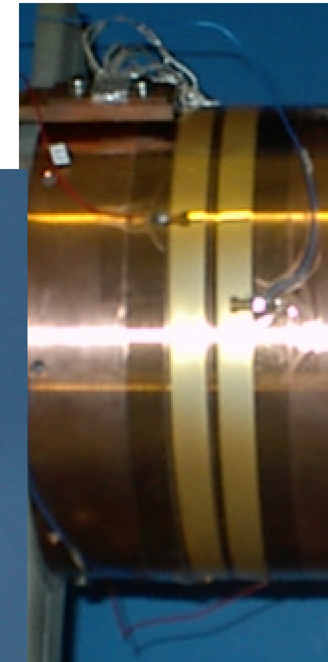
Coated Conductors

YBCO coated SS tapes

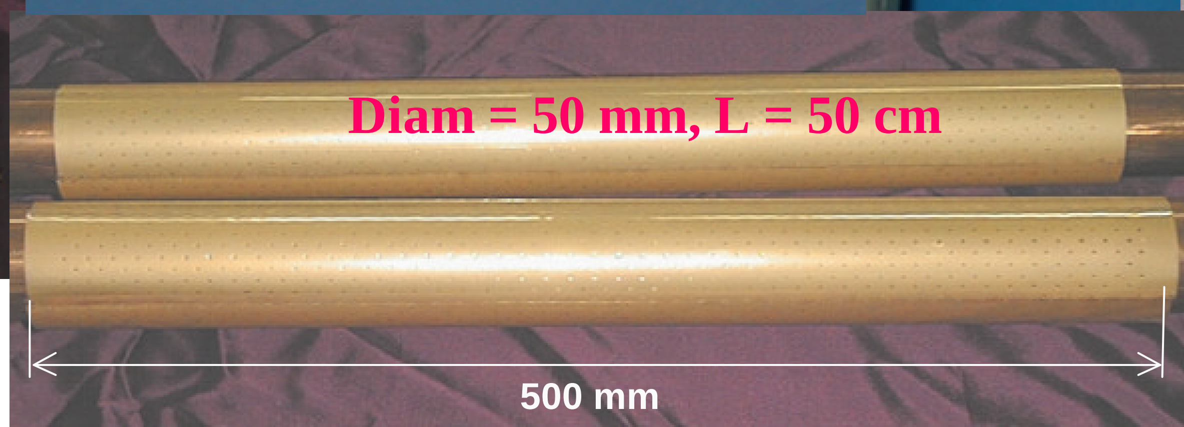


10.3 m / 3.5 mm

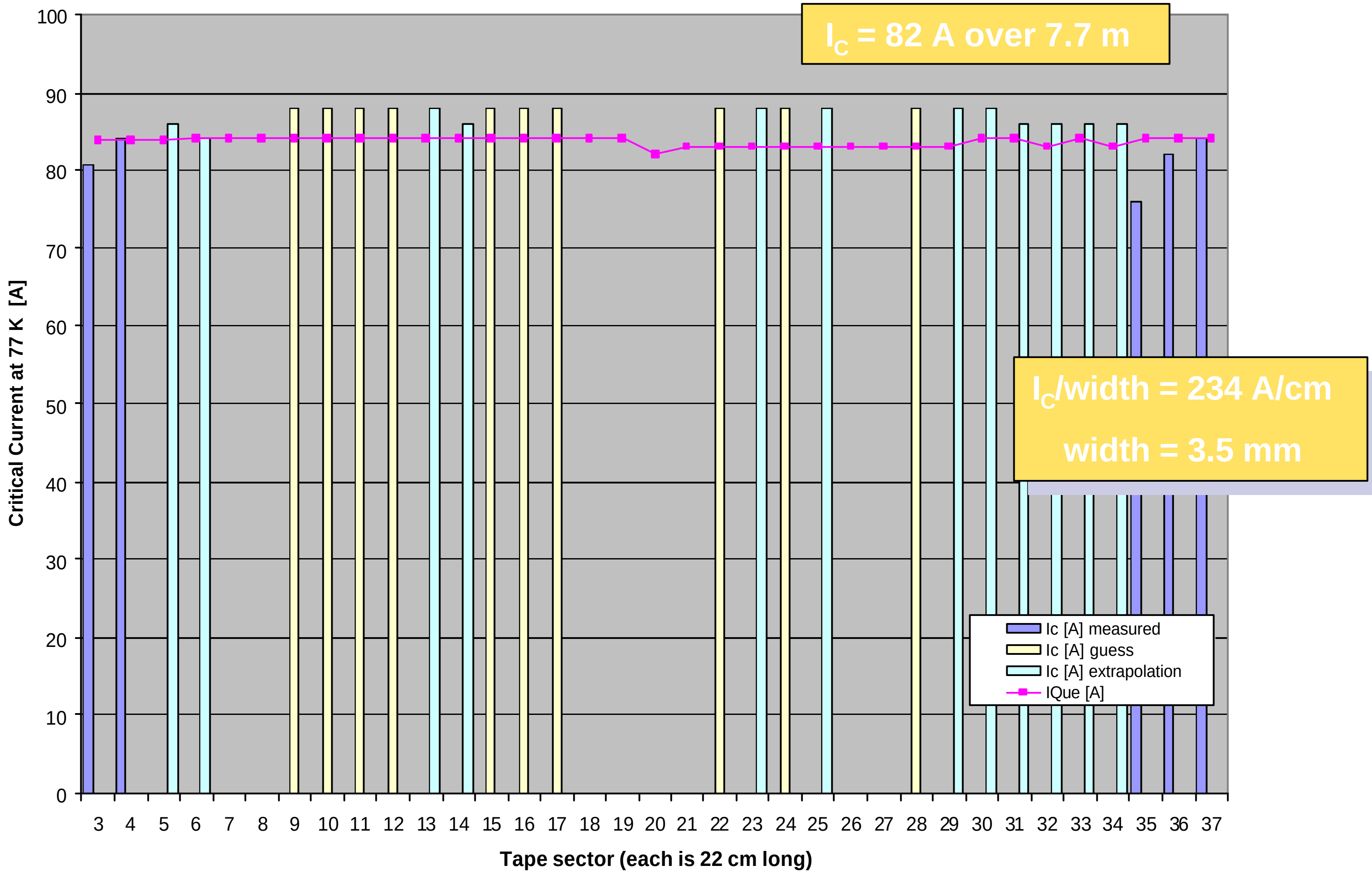




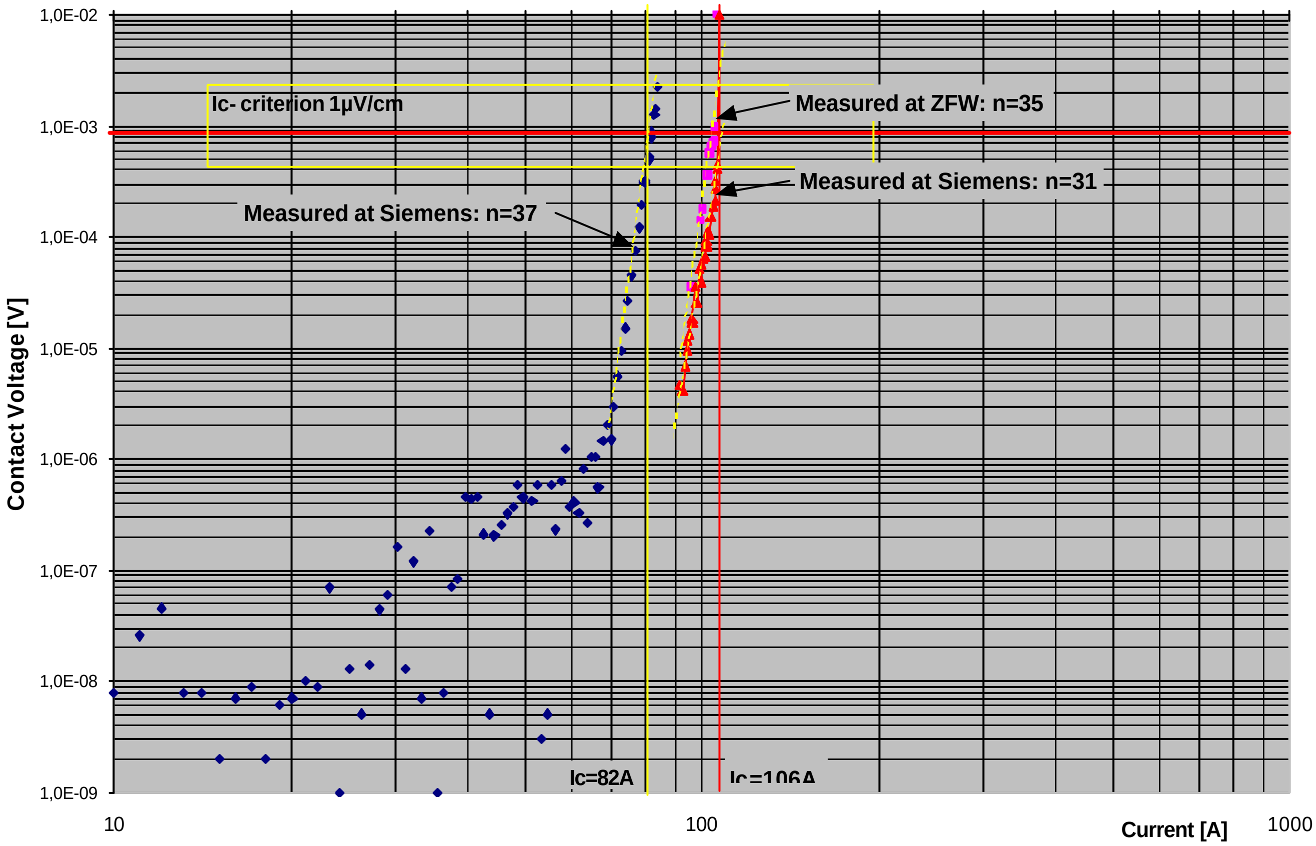
2 m / 10 mm



Tape testing:
Best I_C measurement result (NSS 170)



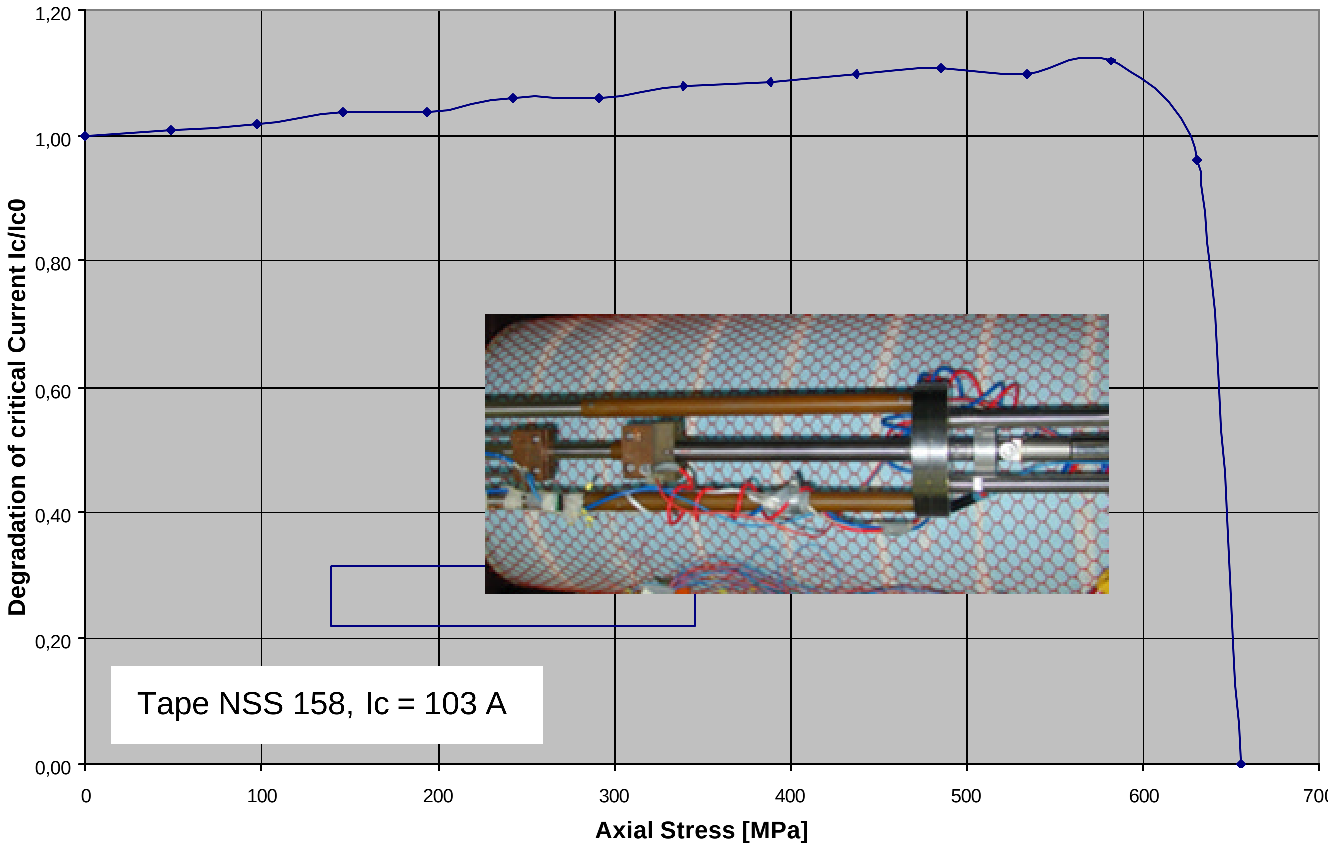
Coated Conductors:
Long YBCO coated SS tapes



Attractive n values: 31 … 35 @ 77K, sf

Measurements performed at both Siemens and ZFW

Tape Testing:
I_C Degradation by Mechanical Stress (NSS 158)



vac. deposition

non-vac. depos.

Essential CC Developments

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Buffer Layer Architect.	Forced Texturing of Buffer Layer **IBAD-YSZ; IBAD-ZGO; IBAD-MgO** **+ CL or CLs** **ISD-MgO/homo-MgO** **CeO2, Y2O3,… MOCVD** **perovskite-type,… CSD**	**on Ni, Ni-alloys/Ni & Ni, Ni-alloys/SOE-NiO** **no SOE-NiO CeO2:TCE,EB; Y2O3/YSZ/CeO2, …** **MOCVD: CeO2, YSZ,Y2O3,Gd2O3,LNO** **CSD: CeO2; BZO, STO, SZO, LAO, LZO, NCO,...** **spray: CeO2** **on SOE-NiO: PLD-BZO,-SZO,-CSTO** **on SOE-NiO: MOD-BZO,-SZO**
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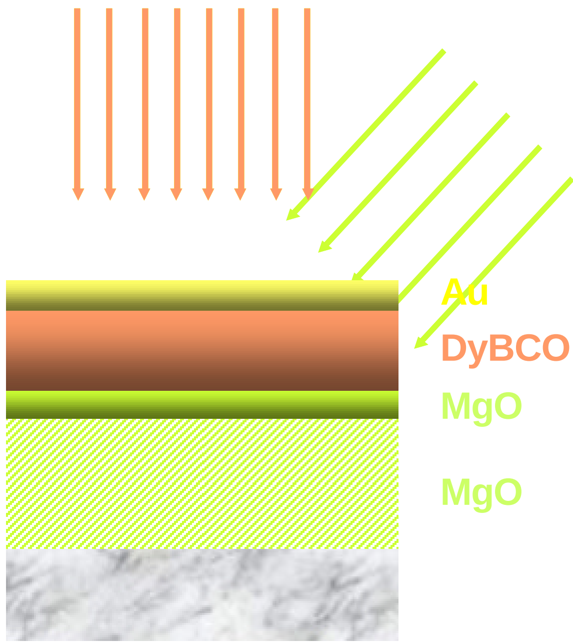
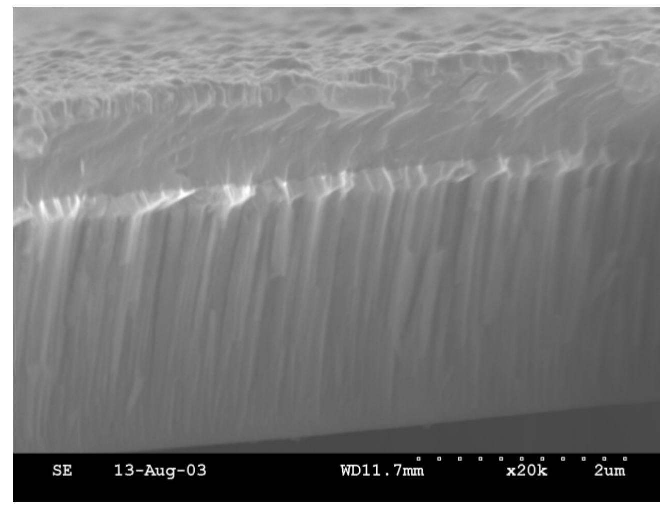
ISD – texturing & DyBCO - evaporation



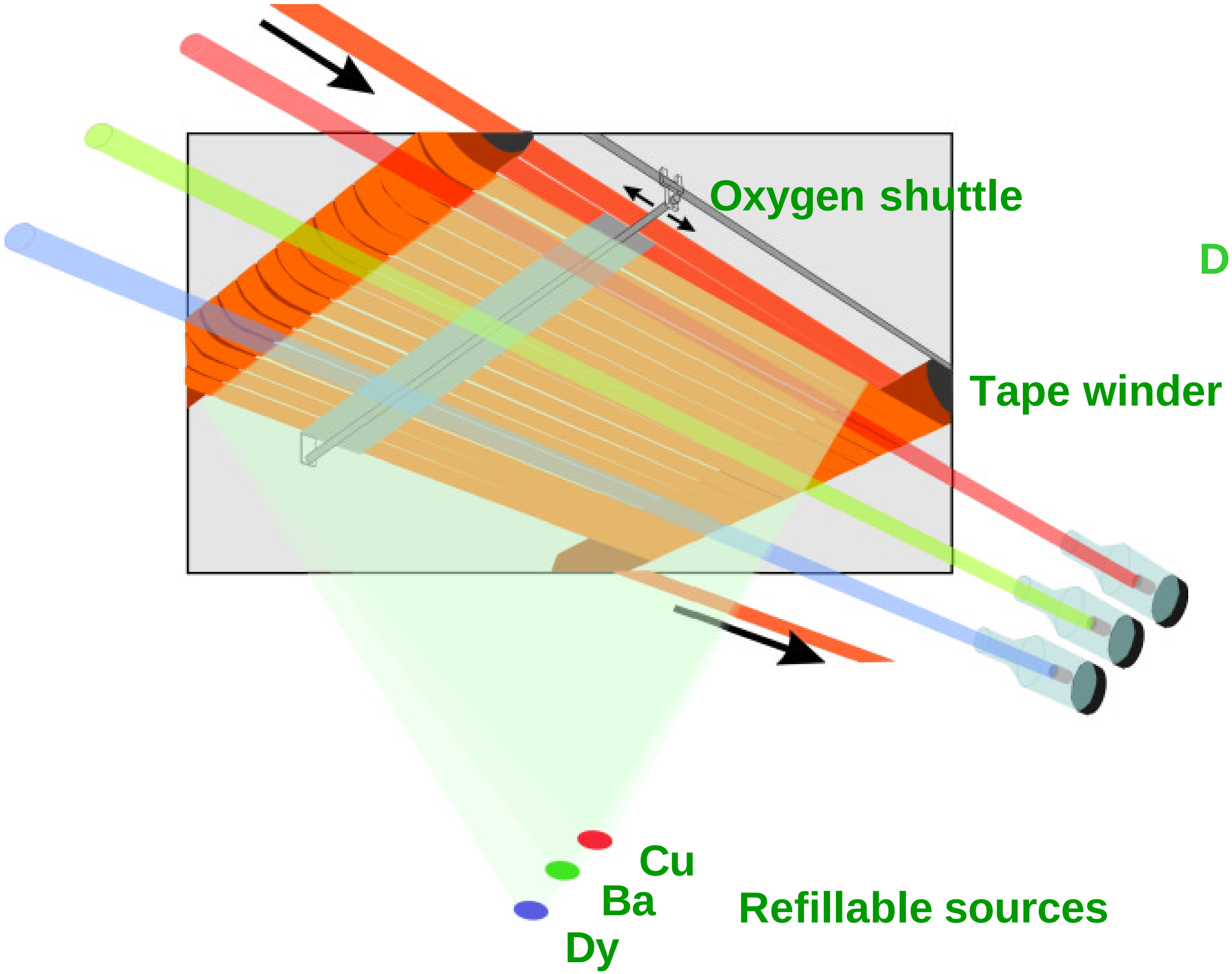
50 mm Hastelloy

CC cross section



THEVA

Reel to reel DyBCO - evaporation



Chamber pressure

7-8·10^{-5} mbar

Deposition temperature

670°C

AAS rate control

THEVA

Latests results
(all reel to reel ISD)

- **30 m ISD – MgO buffer deposition (10 mm wide)**
- **10 m DyBCO by evaporation**

10 m DYBCO tape

- **Short samples (5 – 20 cm)**

j_c = 1.6 – 1.9 MA/cm^2

I_c = 340 A/cm @ 2.4 μm

- **1m tape samples I_c = 60 – 80 A**

Problems to be solved:

Local defects due to handling problems

Essential CC Developments

vac. deposition

non-vac. depos.

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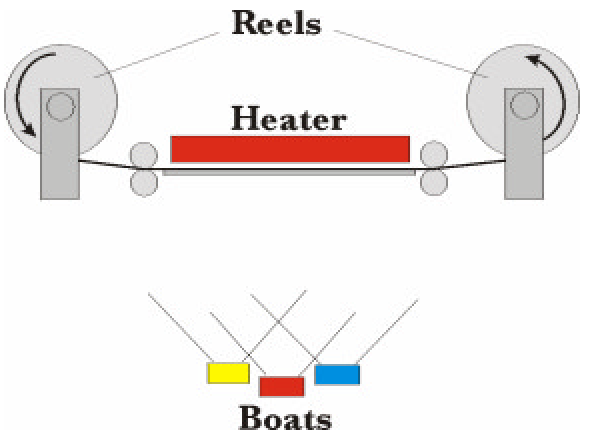
YBCO R.E.BCO	**PLD-YBCO, HoBCO** **TCE-YBCO, DyBCO** **on SS-IBAD-YSZ** **MOCVD-YBCO** **TFA-YBCO**	**YBCO-PLD, YBCO-TCE** **YBCO-MOCVD, spray pyrol.** **YBCO BaF2-method** **YBCO-TFA** **LPE; HR hybride LPE**

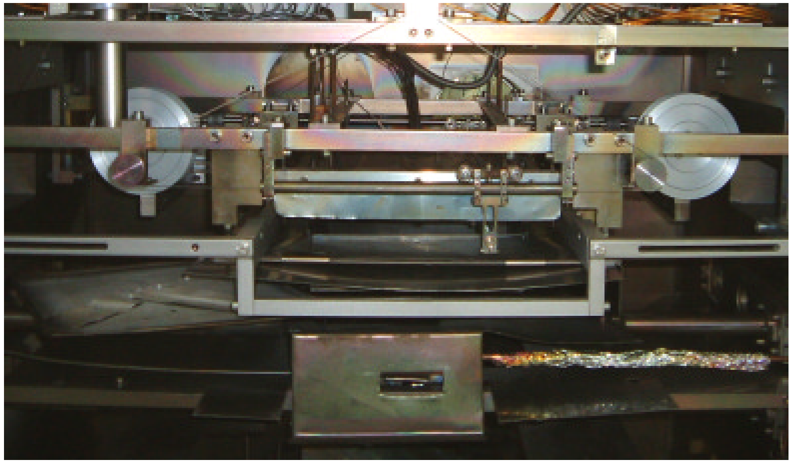
Moving tapes: TCE

- Deposition rate = 3 Å/sec
- Simple single-pass system to investigate deposition under tape movement

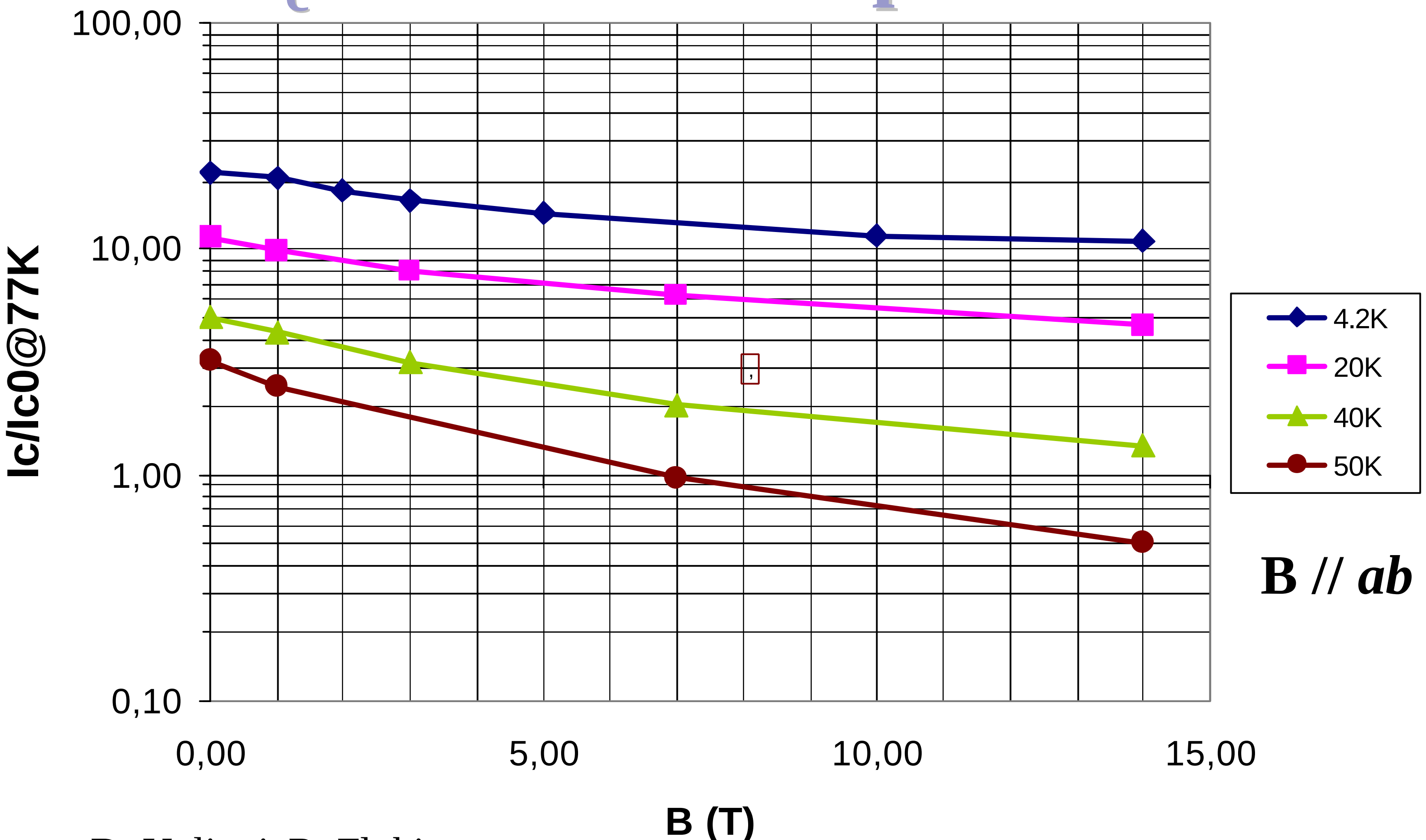


Sample length = 20 cm
YBCO width = 0.7 cm
YBCO thickness = 0.6 μm

I_c/w (77 K) = **110 A/cm-width**
(stationary) 220 A/cm-w
J_c (77K) = **1.8 MA/cm^2**



J_c vs B at low temperature



D. Uglietti, R. Flukiger
Département de Physique de la Matière Condensée, Université de Genève

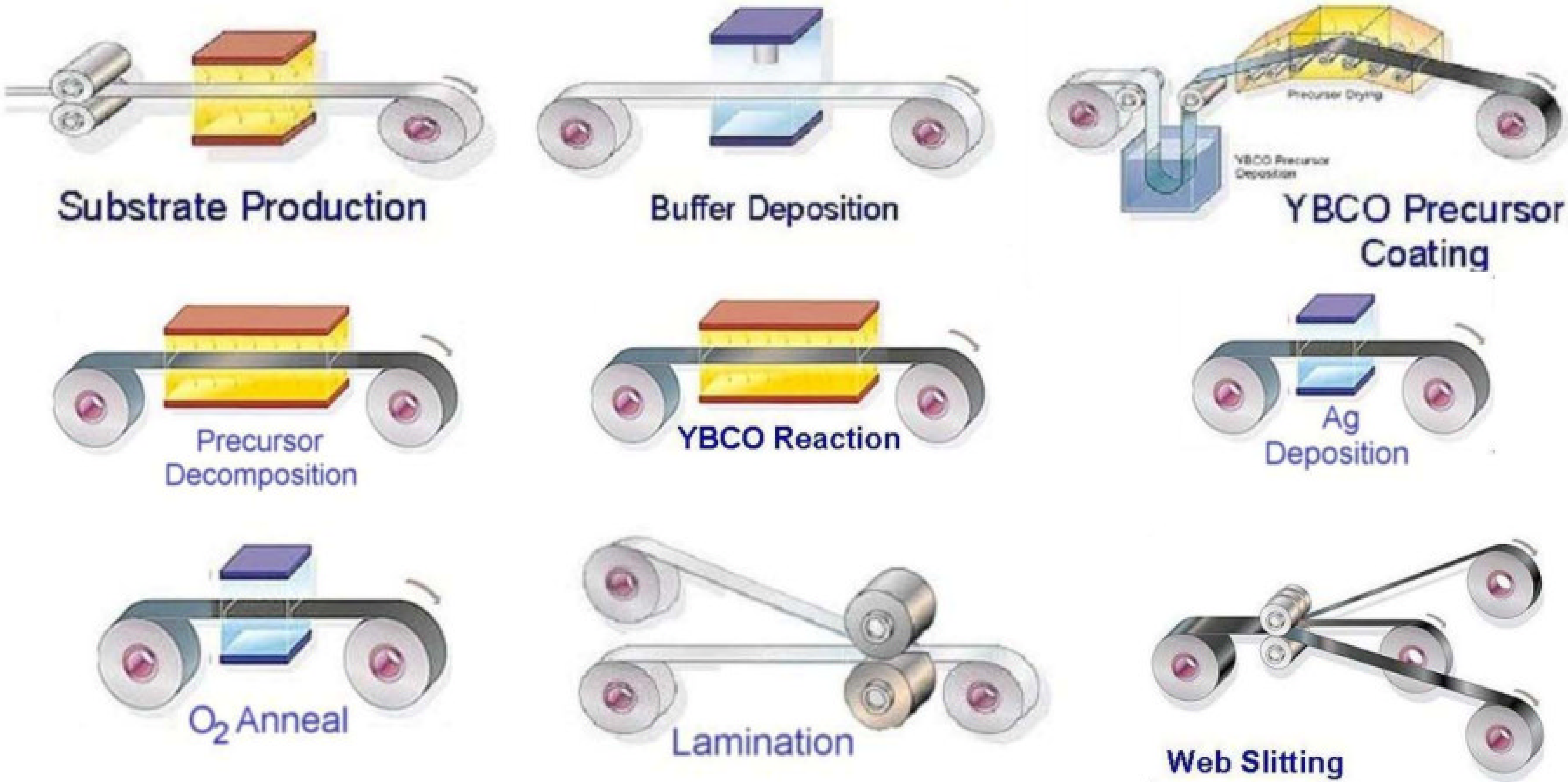
Essential CC Developments

vac. deposition

non-vac. depos.

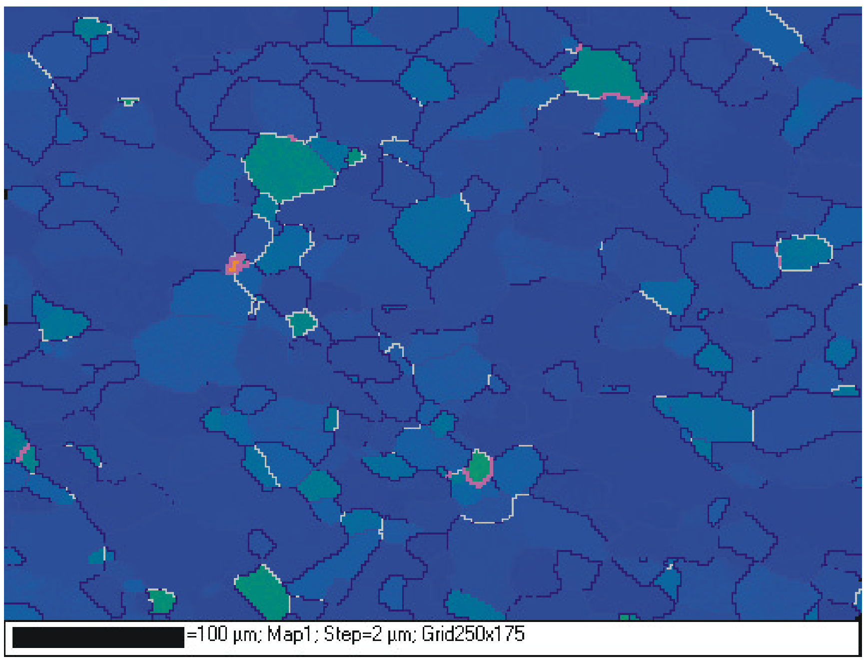
Substrates	Polycrystalline Substrates **Ni,Cr-based SS, Hastelloy, Inconel** **poly Ni**	Biaxially Textured S‘s : TMT, RABiTS **Ni, Ni-W, Ni-Mo, Ni-Cr, Ni-Cr-Al, Ni-V, …** **composite tapes Cu-based tapes**
Buffer Layer Architect.	Forced Texturing of Buffer Layer **IBAD-YSZ; IBAD-ZGO; IBAD-MgO** **+ CL or CLs** **ISD-MgO/homo-MgO** **CeO2, Y2O3,… MOCVD** **perovskite-type,… CSD**	**on Ni, Ni-alloys/Ni & Ni, Ni-alloys/SOE-NiO** **no SOE-NiO CeO2:TCE,EB; Y2O3/YSZ/CeO2, …** **MOCVD: CeO2, YSZ,Y2O3,Gd2O3,LNO** **CSD: CeO2; BZO, STO, SZO, LAO, LZO, NCO,...** **spray: CeO2** **on SOE-NiO: PLD-BZO,-SZO,-CSTO** **on SOE-NiO: MOD-BZO,-SZO**
YBCO R.E.BCO	**PLD-YBCO, HoBCO** **TCE-YBCO, DyBCO** **on SS-IBAD-YSZ** **MOCVD-YBCO** **TFA-YBCO**	**YBCO-PLD, YBCO-TCE** **YBCO-MOCVD, spray pyrol.** **YBCO BaF2-method** **YBCO-TFA** **LPE; HR hybride LPE**

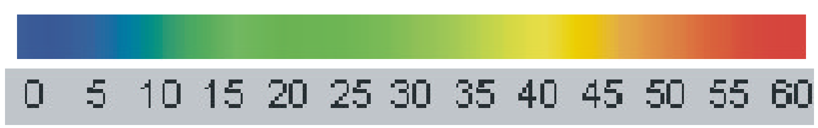
TMT / RABiTS METHOD poly Ni alloy/multi buffer/TFA-YBCO



ORNL CRADA contributes to improving process stability, material uniformity, and product yield

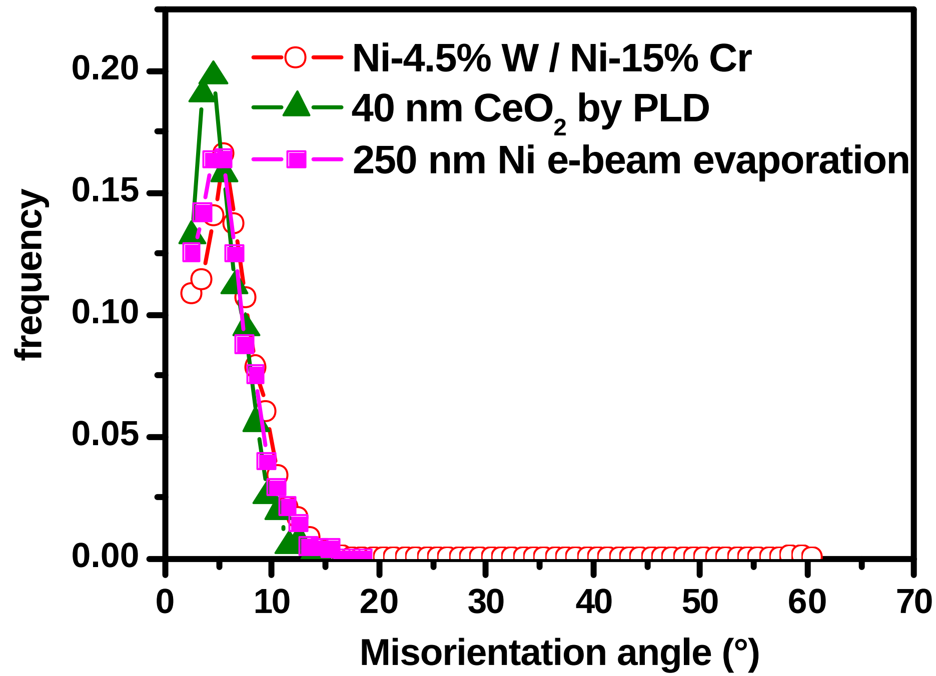
Texture in the Ni-4.5%W/ Ni-15% Cr composite after recrystallisation





Deviation from cube orientation (°)

GBs > 15°

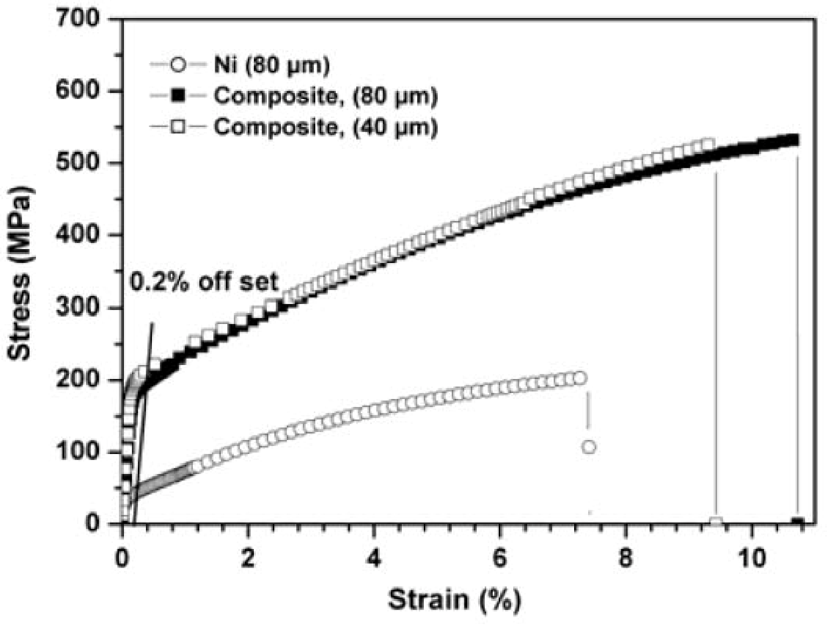


IFW/DD

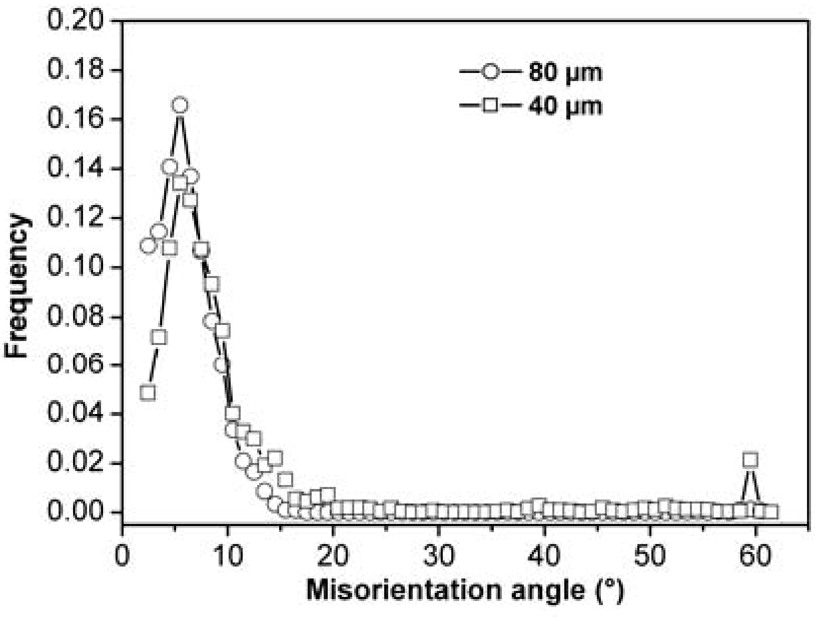
TMT tapes : IFW Dresden

Ni, Ni5W, Ni0.1Mo, Ni13Cr, Ni9V: up to 30m, *in-plane* FWHM = 8º

Ni4.5W/Ni15Cr composite tapes (yield strength 200 MPa)



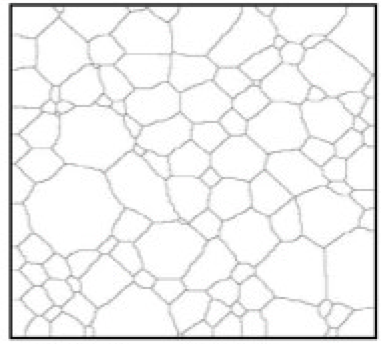
RT Yield Strength



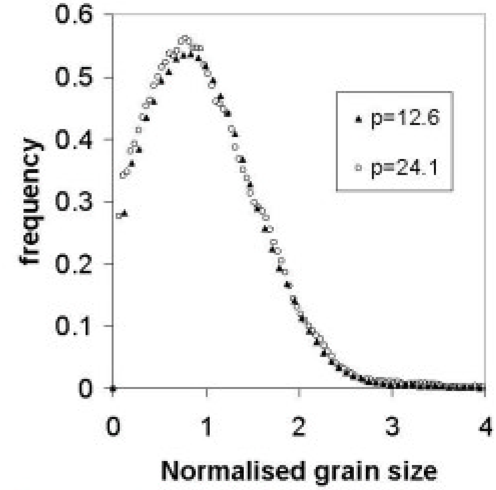
EBSD maps after 2-step recrystallization

Simulation of grain structure and misorientation of grain boundaries

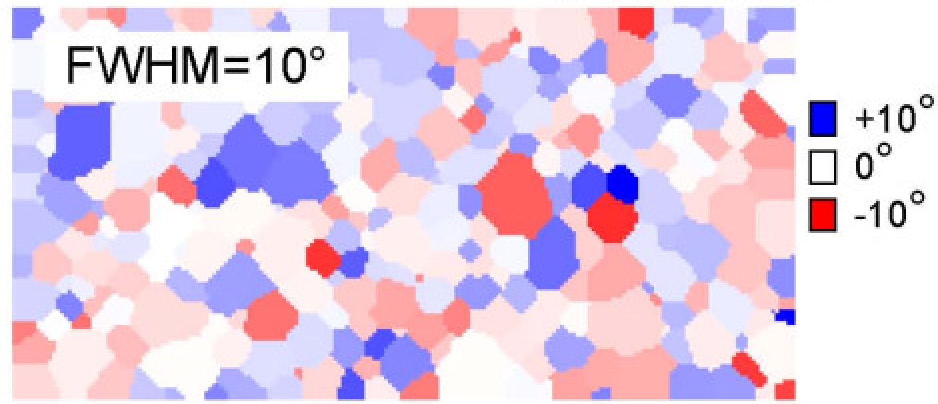
A. Simulation of a realistic grain structure is done using the Monte Carlo Potts method



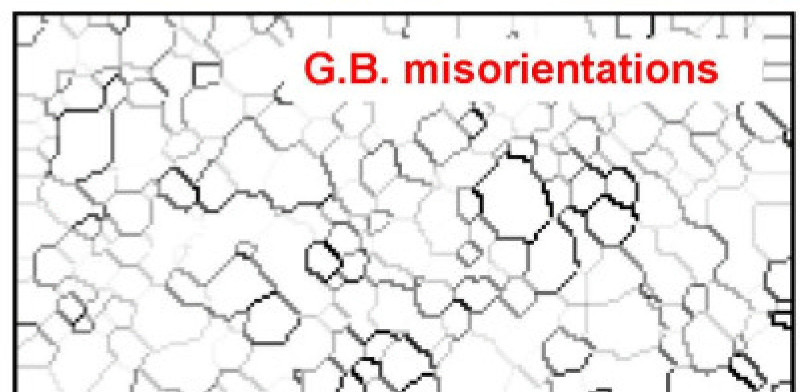
MCS = 1000



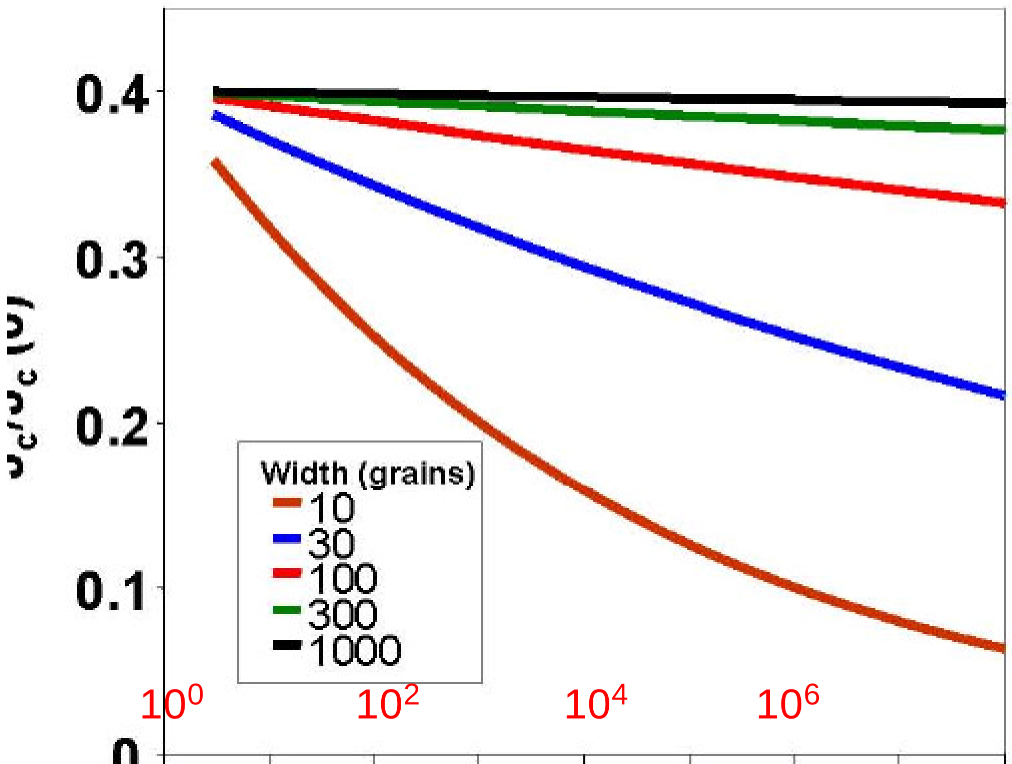
B. Individual grains are assigned an orientation based on the global texture determined by the X-ray FWHM which is well simulated by a gaussian, assuming no correlations between neighbors

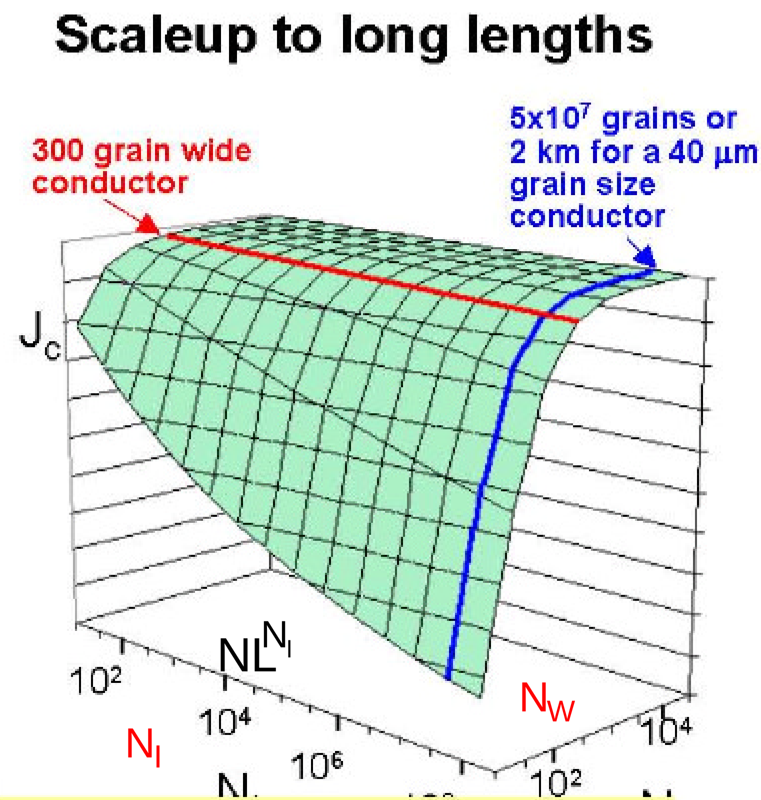


C. The misorientation angles of grain boundaries are calculated and a grain boundary map generated



Effect of conductor dimensions

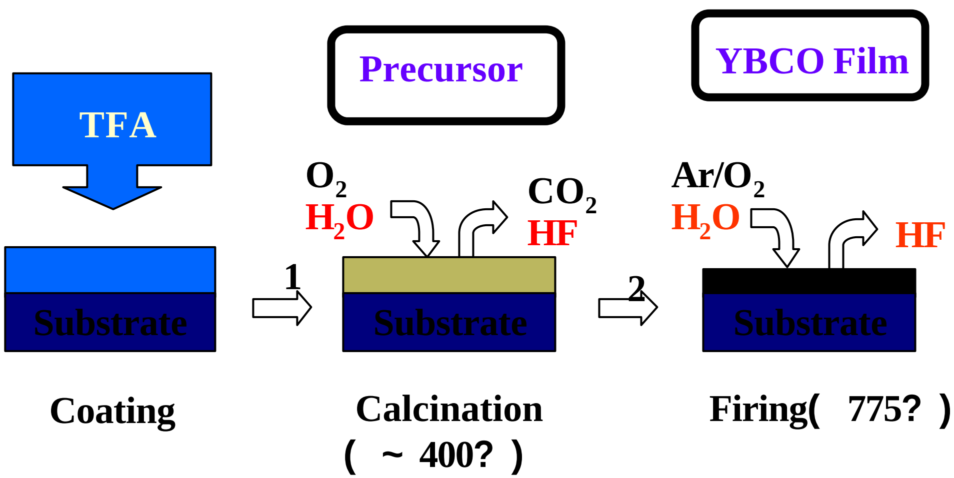


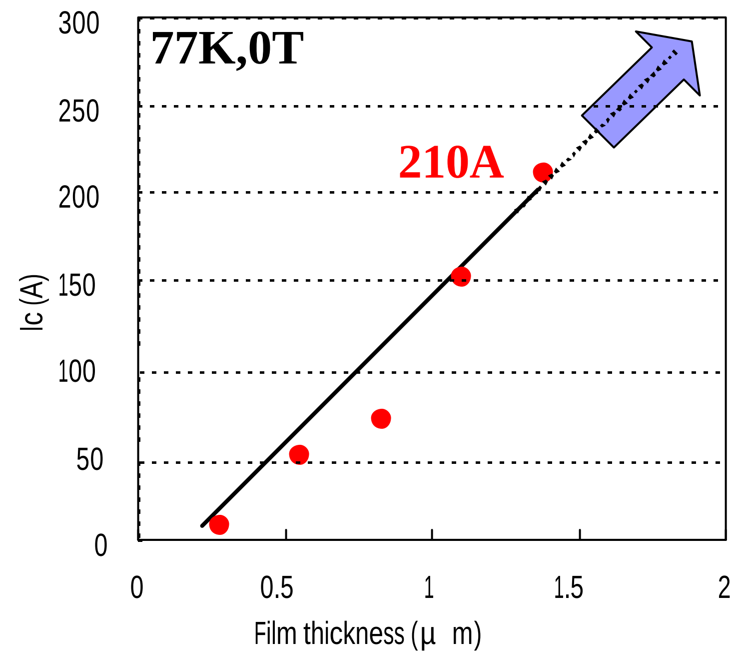


As long as the conductor is at least 100 grains wide, even after considering a realistic grain size distribution, the improved percolation model shows that J_c is not significantly reduced and that a percolative pinch-off is not expected

Development of C.C. by TFA Processing (SRL-ISTEC)

Improvement of Ic by Thickening YBCO Layer on IBAD by TFA-MOD





YBCO Film

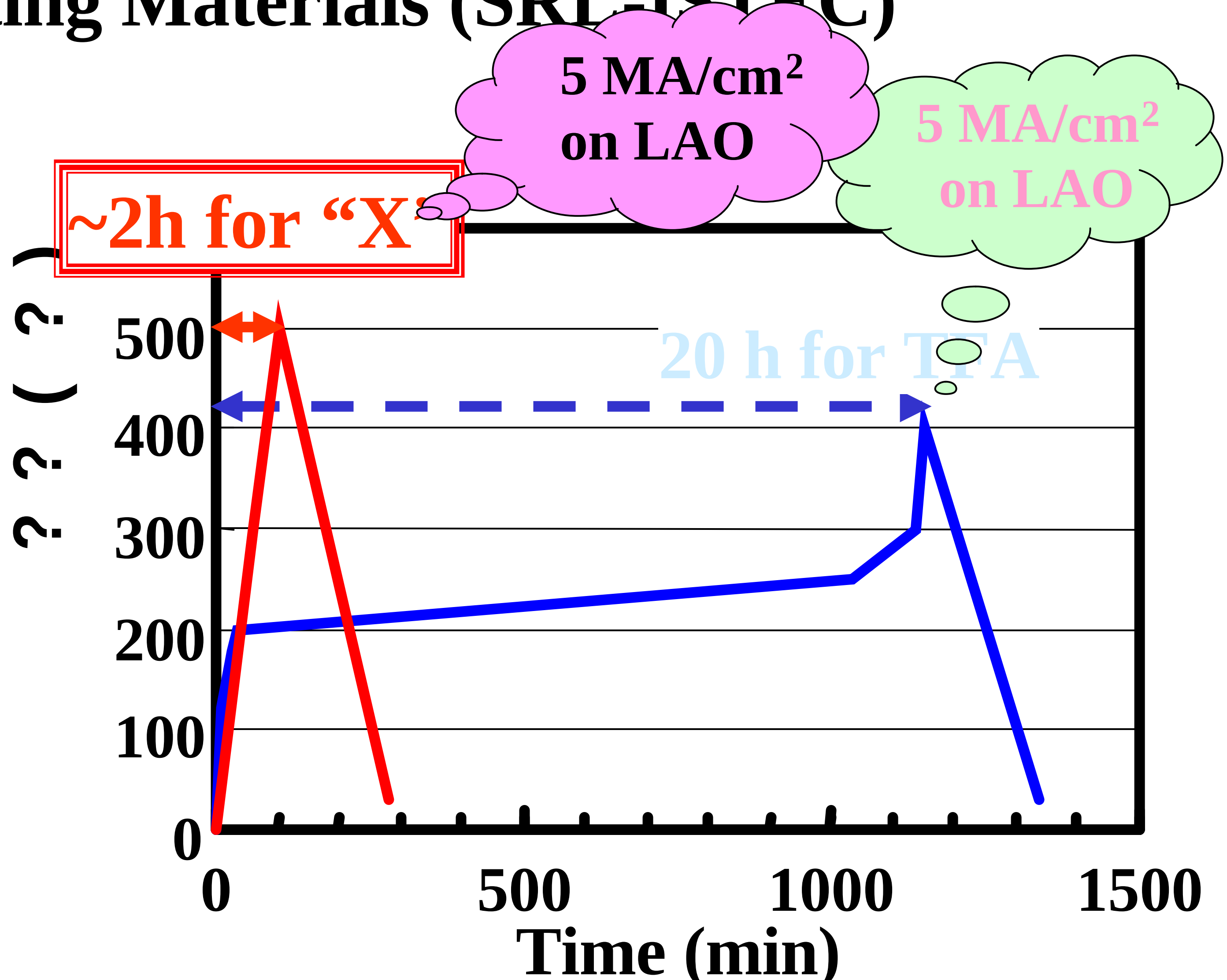
CeO_2 / IBAD-$Zr_2Gd_2O_7$ / Hastelloy

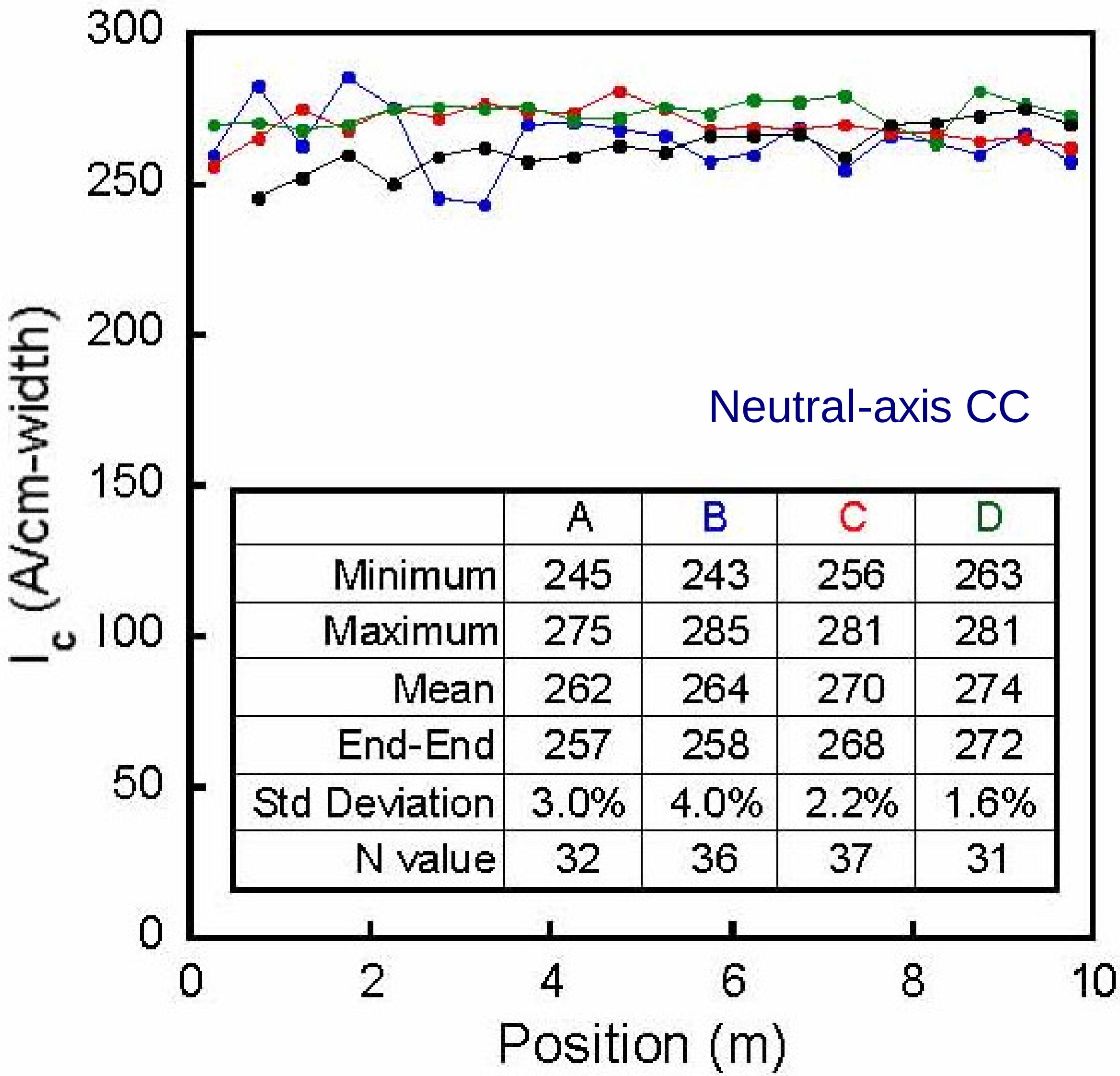
High Production Rate using New Starting Materials (SRL-ISTEC)

All TFA Salts
$Y(CF_3COO)_3$
$Ba(CF_3COO)_2$
$Cu(CF_3COO)_2$

New Materials
$Y(CF_3COO)_3$
$Ba(CF_3COO)_2$
$Cu(F\text{-}free)_X$

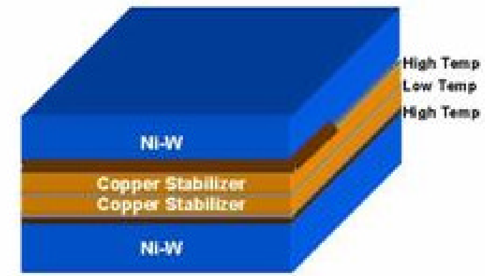
Reduction of F

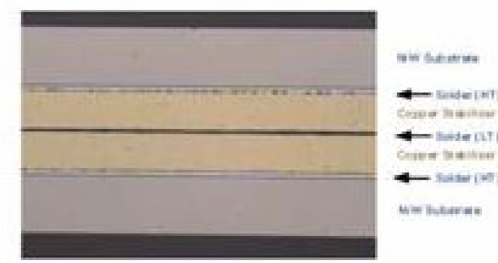




	A	B	C	D
Minimum	245	243	256	263
Maximum	275	285	281	281
Mean	262	264	270	274
End-End	257	258	268	272
Std Deviation	3.0%	4.0%	2.2%	1.6%
N value	32	36	37	31

Sandwich Architecture

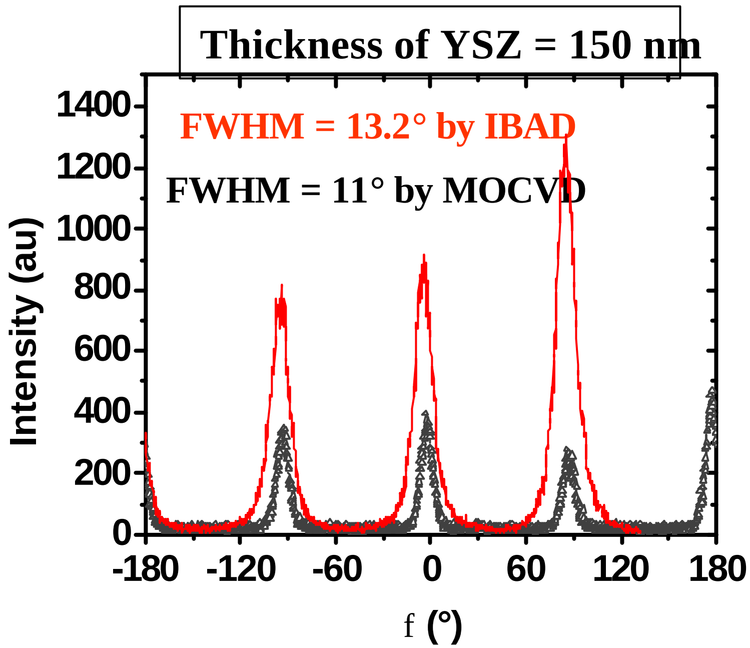


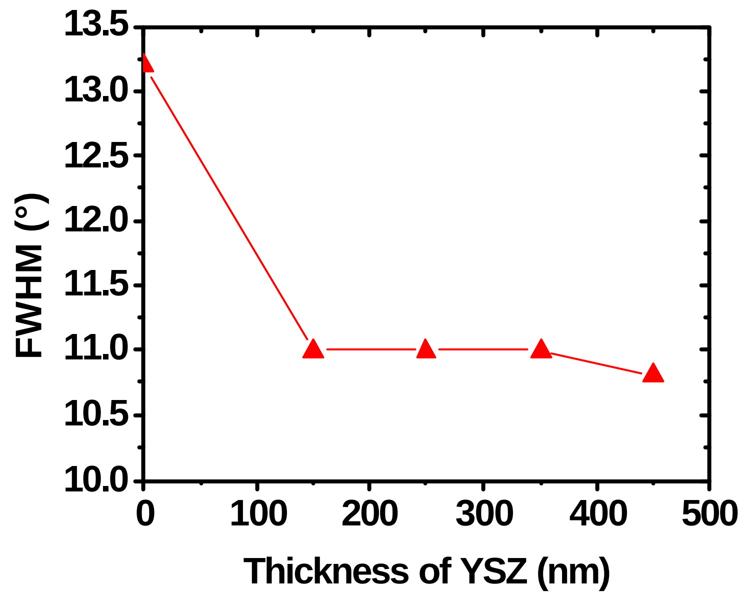


AMSC Results: March 2004

Buffer layers : SS/YSZ// YSZ

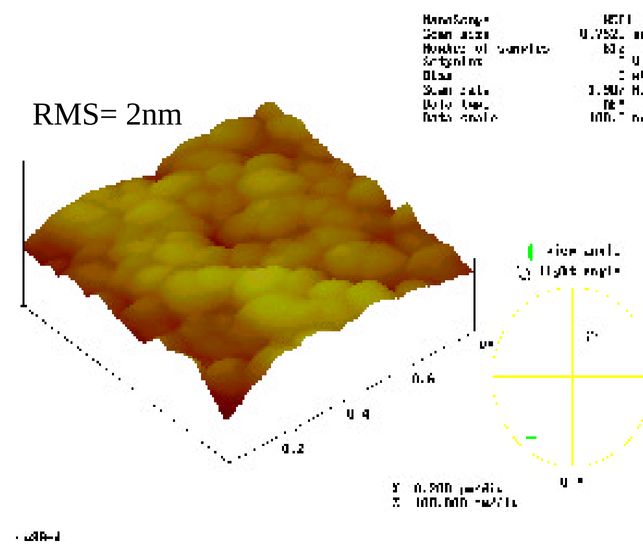
MOCVD





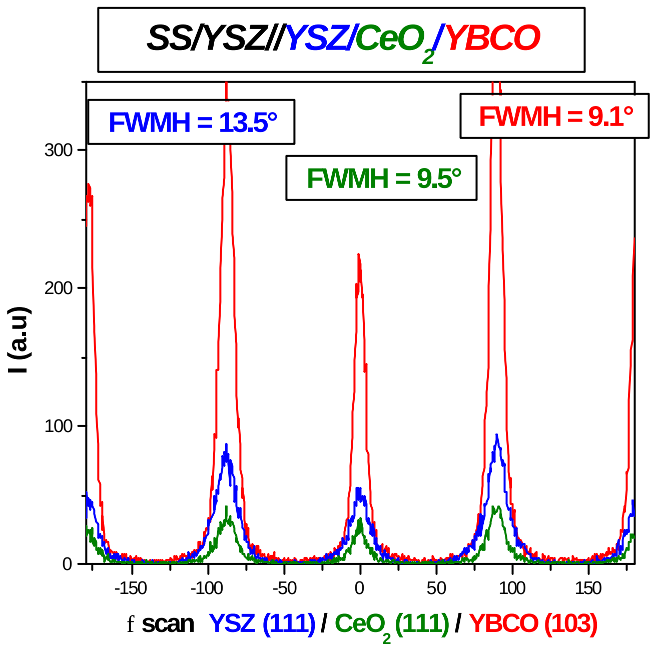
<u>FWHM of Rocking Curves:</u>

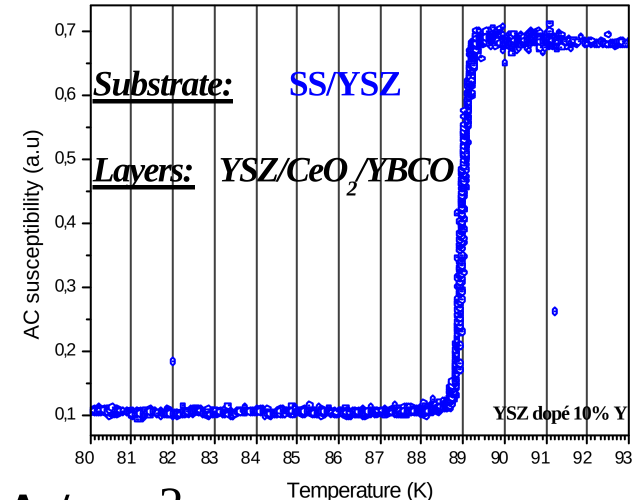
YSZ (200) = 9.6° ® 5.5°



➔ Improvement of the BL quality

SS/YSZ //YSZ/CeO2/YBCO



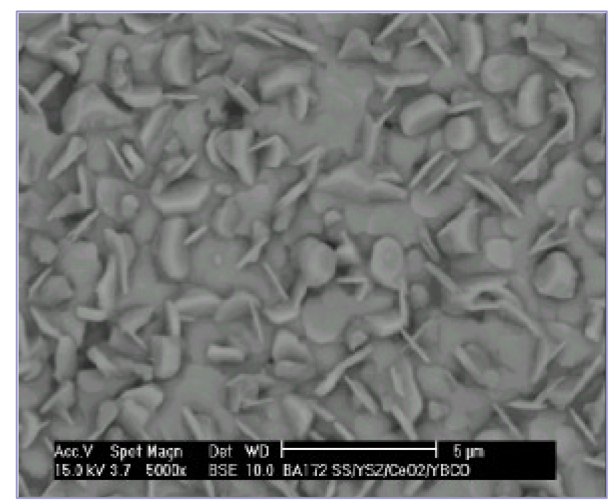


$Jc = 10^6 A/cm^2$

ROC YSZ (200) = 4.6°

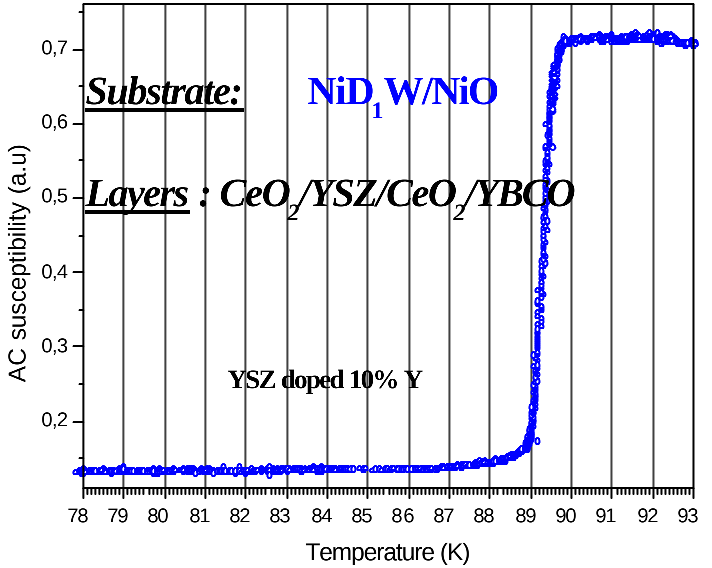
ROC CeO_2 (200) = 4.6°

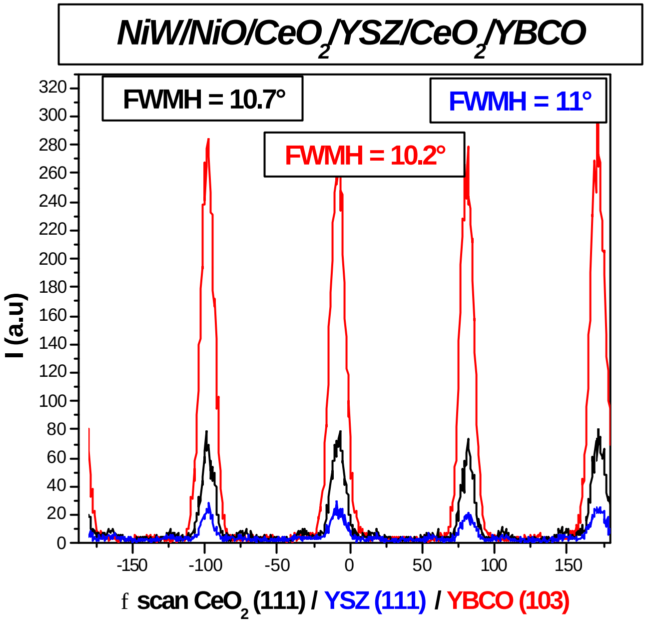
ROC YBCO (005) = 2.8°



➔ Best heterostructure

NiW/NiO//CeO_2/YSZ/CeO_2/YBCO





FWHM of Rocking Curves:

CeO_2 (200) =9.1°

YSZ (200) = 10.2°

YBCO (006)= 8.5°

$Jc = 5.10^{5}$ A/cm^2

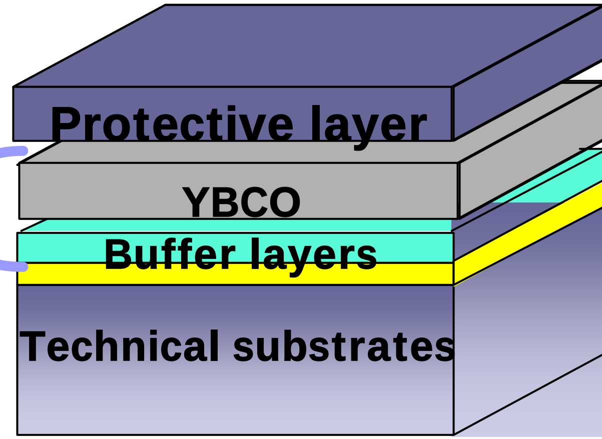
➔ Best heterostructure

READY Project

INPGrenoble

All sol-gel coated conductor

MOD



IBAD-YSZ : UGOT

RABiT Ni: IFW

Ni/NiO: UCAM

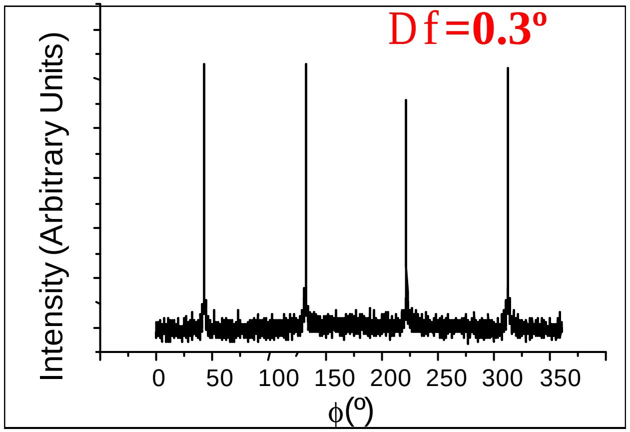
Buffer layers:

Compatibility with metallic substrates (RABiT and IBAD)

Grain size, thickness and roughness can be modified by processing

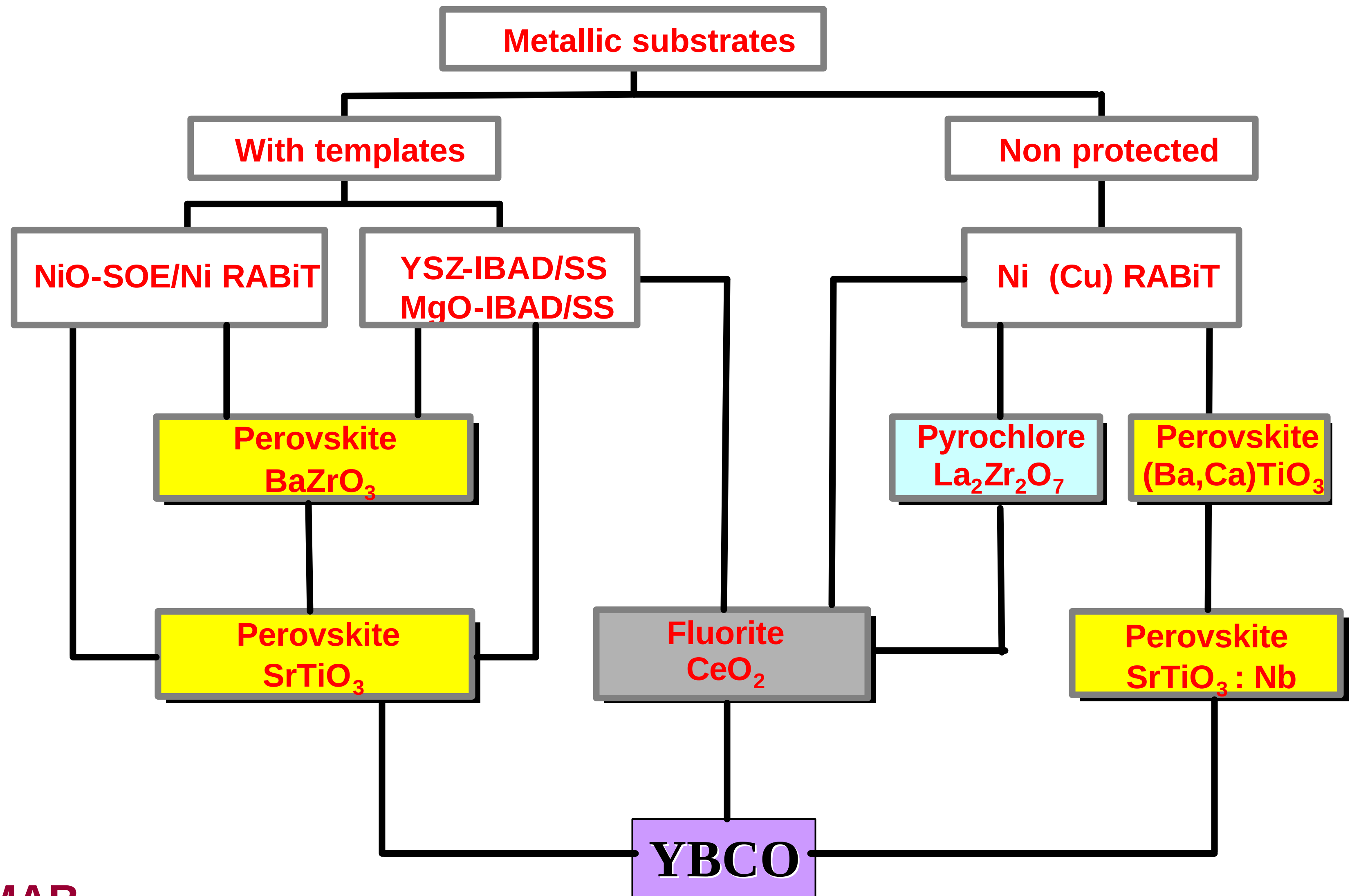
Fluorite : CeO_2

Perovskite : $BaZrO_3$, $SrTiO_3$, $LaAlO_3$



Precursors: pentadionate, isopropoxide, acetate, sec-butoxide, ethylhexanoate

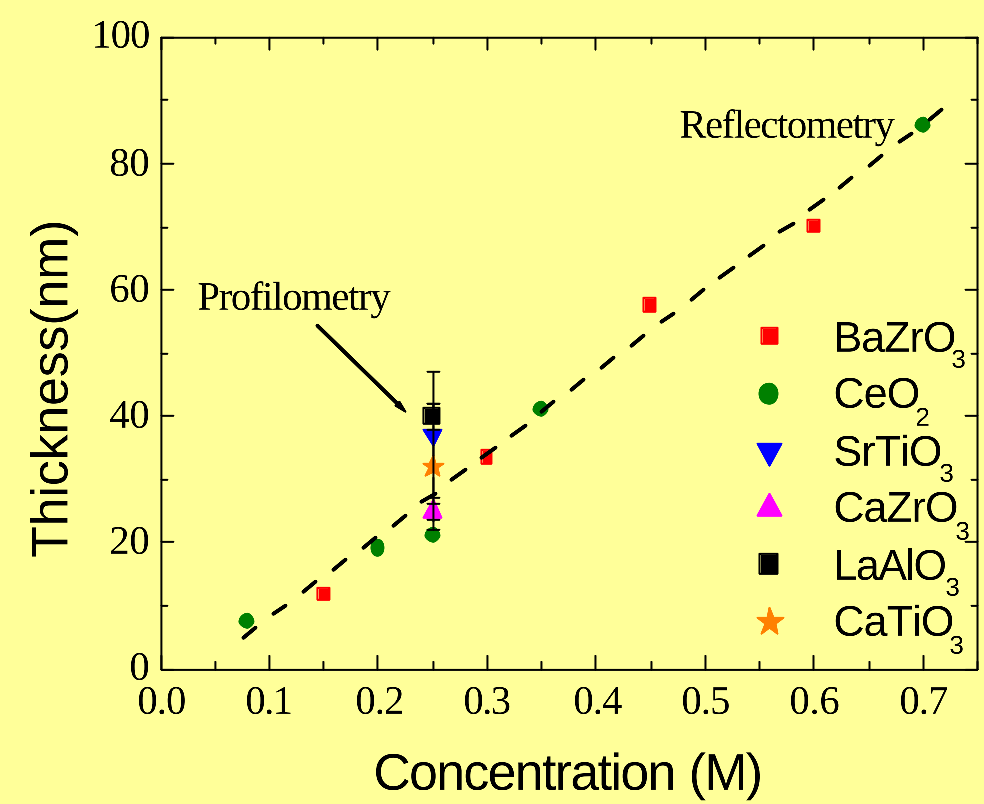
All CSD tapes architectures



ICMAB

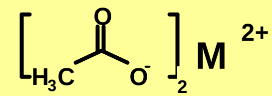
CSD of oxide buffer layers

Soluble metallorganic chemical precursors



Thickness control through solution concentration and viscosity

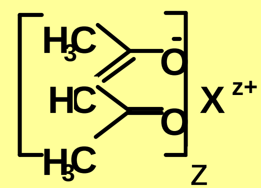
Acetates



M=Ba, Sr, Ca

Solvents : acetic acid, methanol, methoxyethoxy

2,4-X- Pentadionate



X=Ce, Zr

Al, Ti, La isopropoxydes

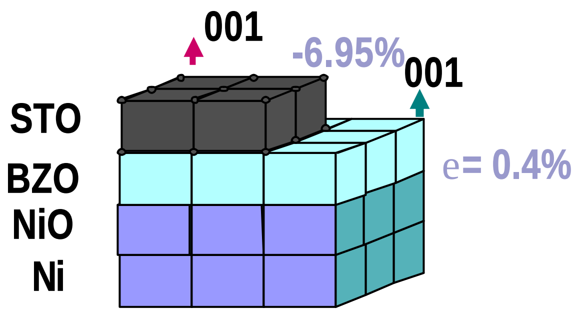
Heterometallic alkoxydes : Sr-Ti, Ba-Zr

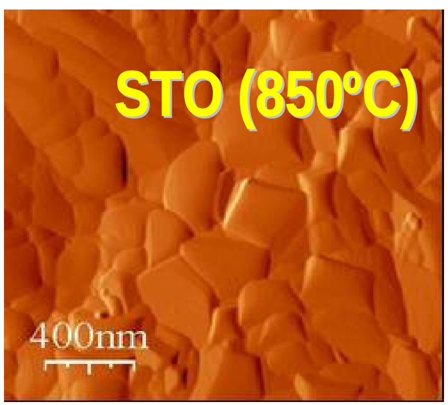
$SrTiO_3/BaZrO_3$ on NiO/Ni

Collaboration with Univ. Cambridge and Dresden

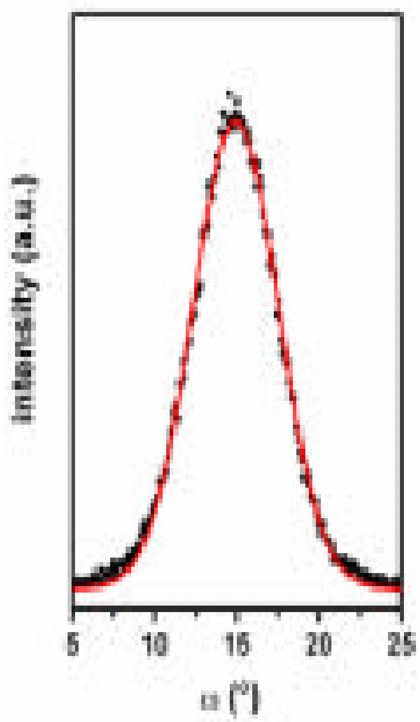
NiO grown by Surface Oxidation Epitaxy

ICMAB

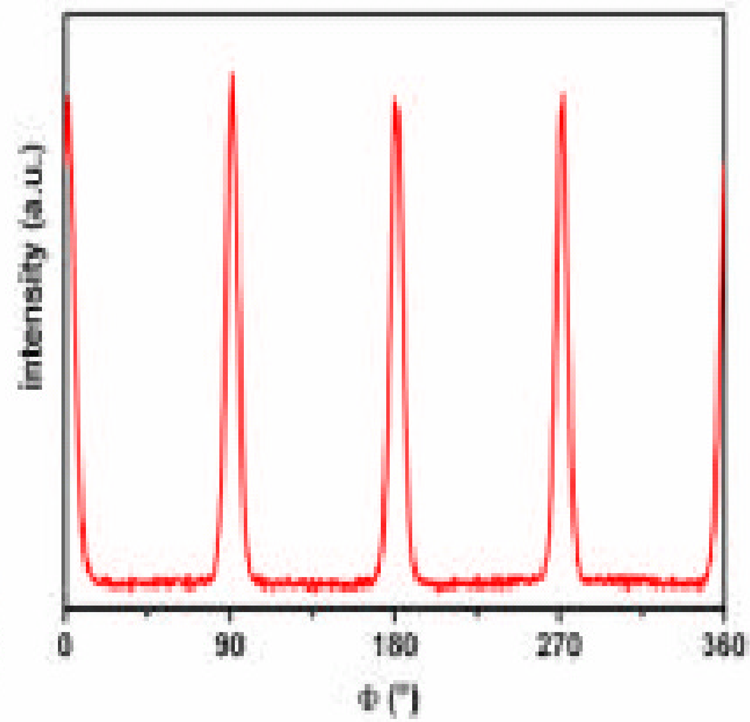




rms ~ 45-100 nm



out-of-plane FWHM = 5.2°



in-plane FWHM = 6.7°

Non-reactive buffers matched with similar texture than the NiO template layer. Roughness must be improved

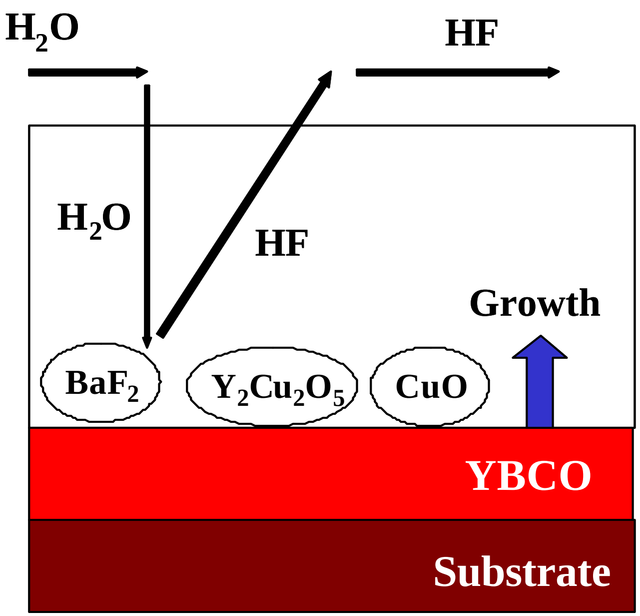
YBCO : Trifluoroacetates route

$Cu(TFA)_2 + Ba(TFA)_2 + Y(TFA)_3$ ® $CuO + BaF_2 + Y_2O_3 + (CF_3CO)_2O + CO_2 + CO + H_2O$

Pyrolysis: T»300ºC

$$2\ BaF_2 + 2\ CuO + 1/2\ Y_2Cu_2O_5 + 2\ H_2O \longrightarrow YBa_2Cu_3O_{6.5} + 4\ HF$$

Reaction: T»700-800ºC



Growth ? HF removal

$P(H_20)$

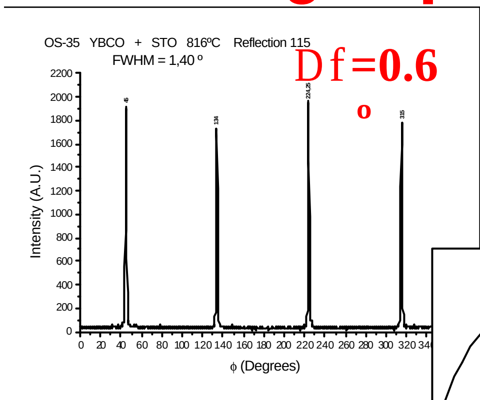
P_{total}

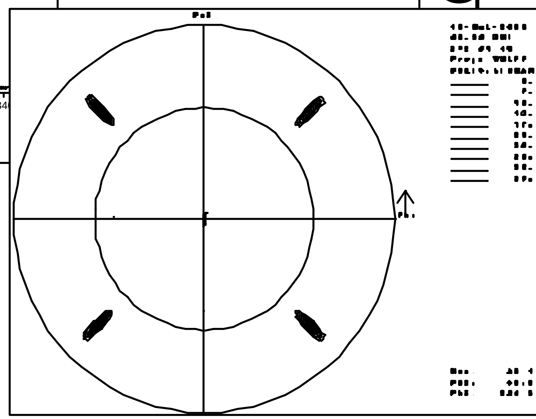
$T_{reaction}$

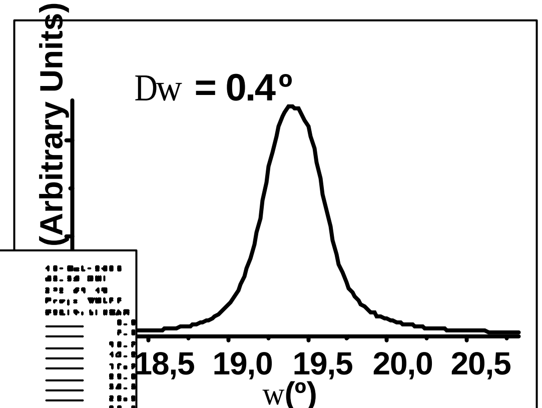
Gas flow

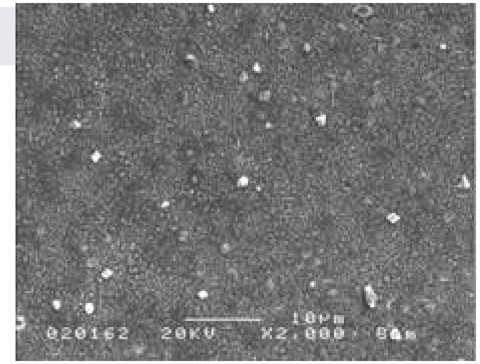
0.04 nm/s < G < 2 nm/s

High quality YBCO thin films

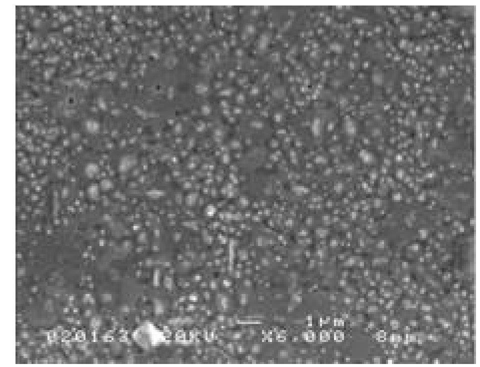




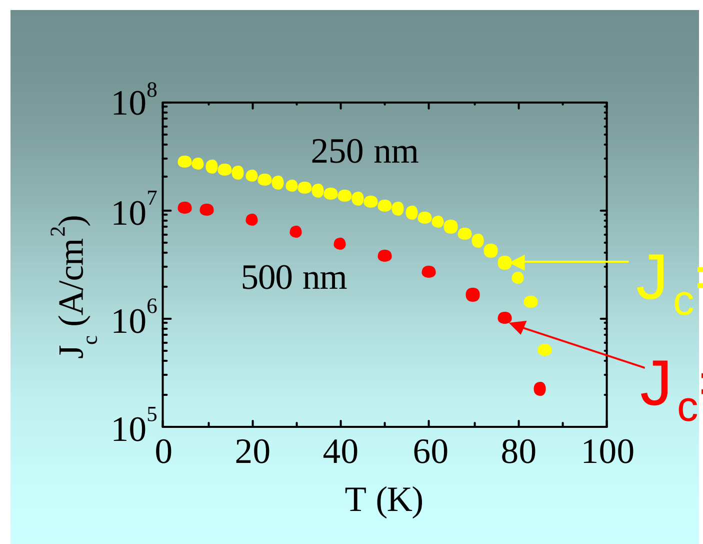




No porosity



- Nucleation and growth rate can be controlled
- Multideposition can be performed
- Thickness dependence is still an issue



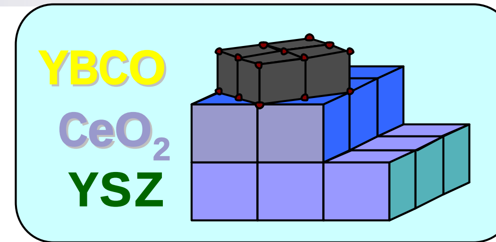
T = 77 K

J_c = 3.3 MA/cm^2

J_c = 1.0 MA/cm^2

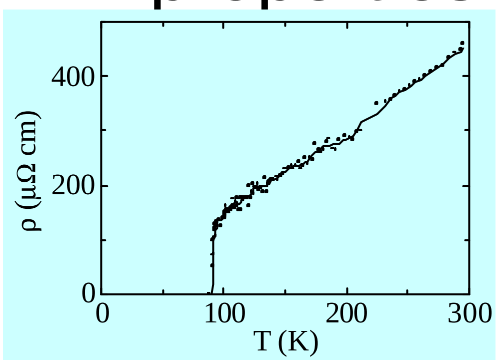
ICMAB

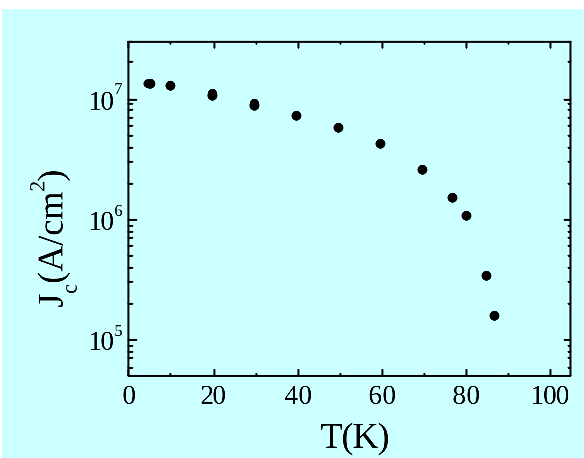
Model system – All fluorite $YBCO/CeO_2^{CSD}/YSZ$



ICMAB

- If CeO_2^{CSD} surface has been treated
  - Excellent YBCO superconducting properties





•Metallic r (T)

•T_c = 90 K

•J_c (5K) = 1.5 x 10^7 A/cm^2

•J_c (77K) = 1.6 x 10^6 A/cm^2

•c-axis fraction ~ 0.9

YBCO on CeO_2^{PLD}/YSZ-SS tapes

J_c (5K) = $1.4x10^6$ A/cm^2

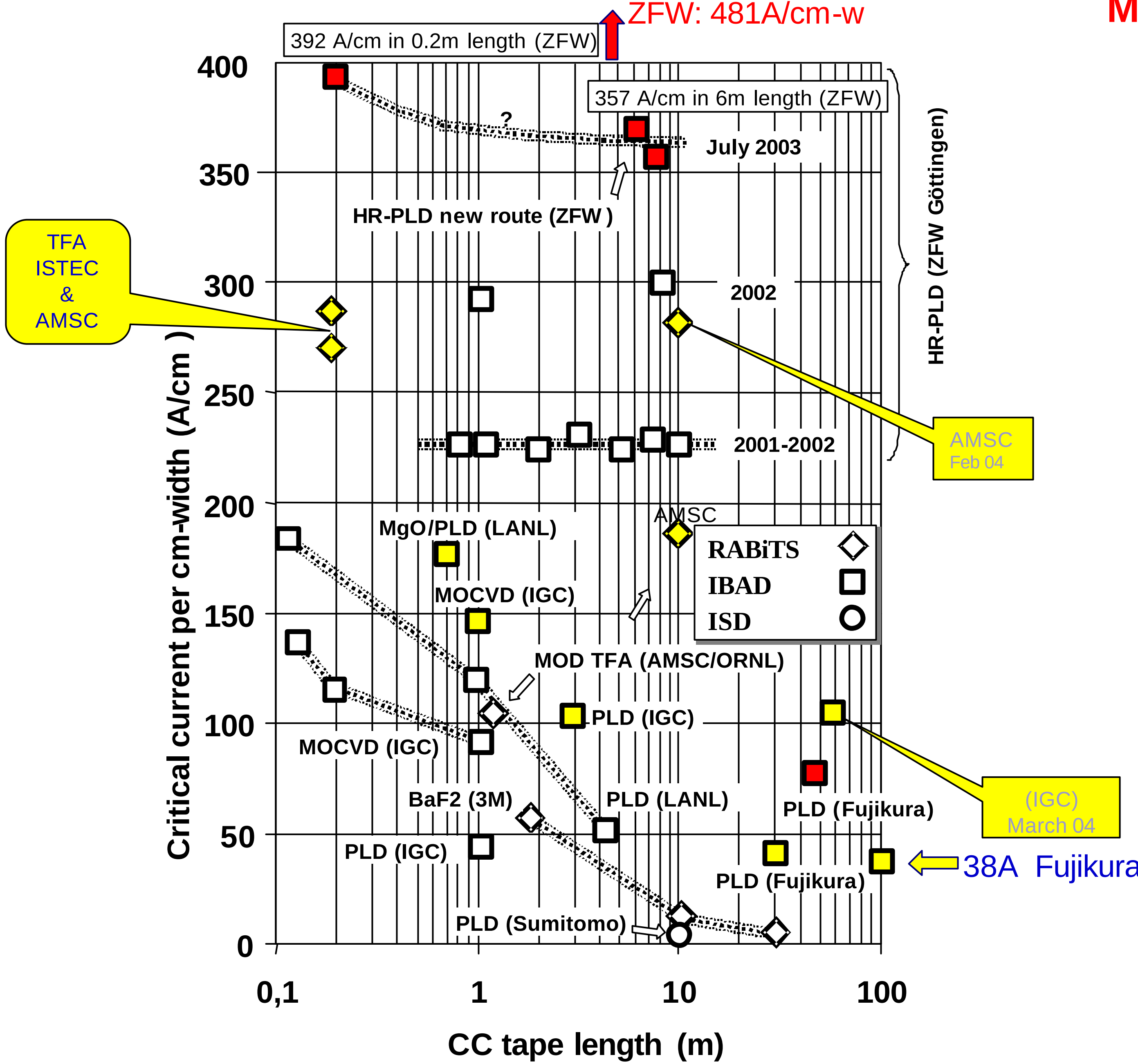
Long length CSD superconducting tapes

- European project "Novel Sol Gel Technology For Long Length Superconducting Coated Tapes" (SOLSULET)

Nexans

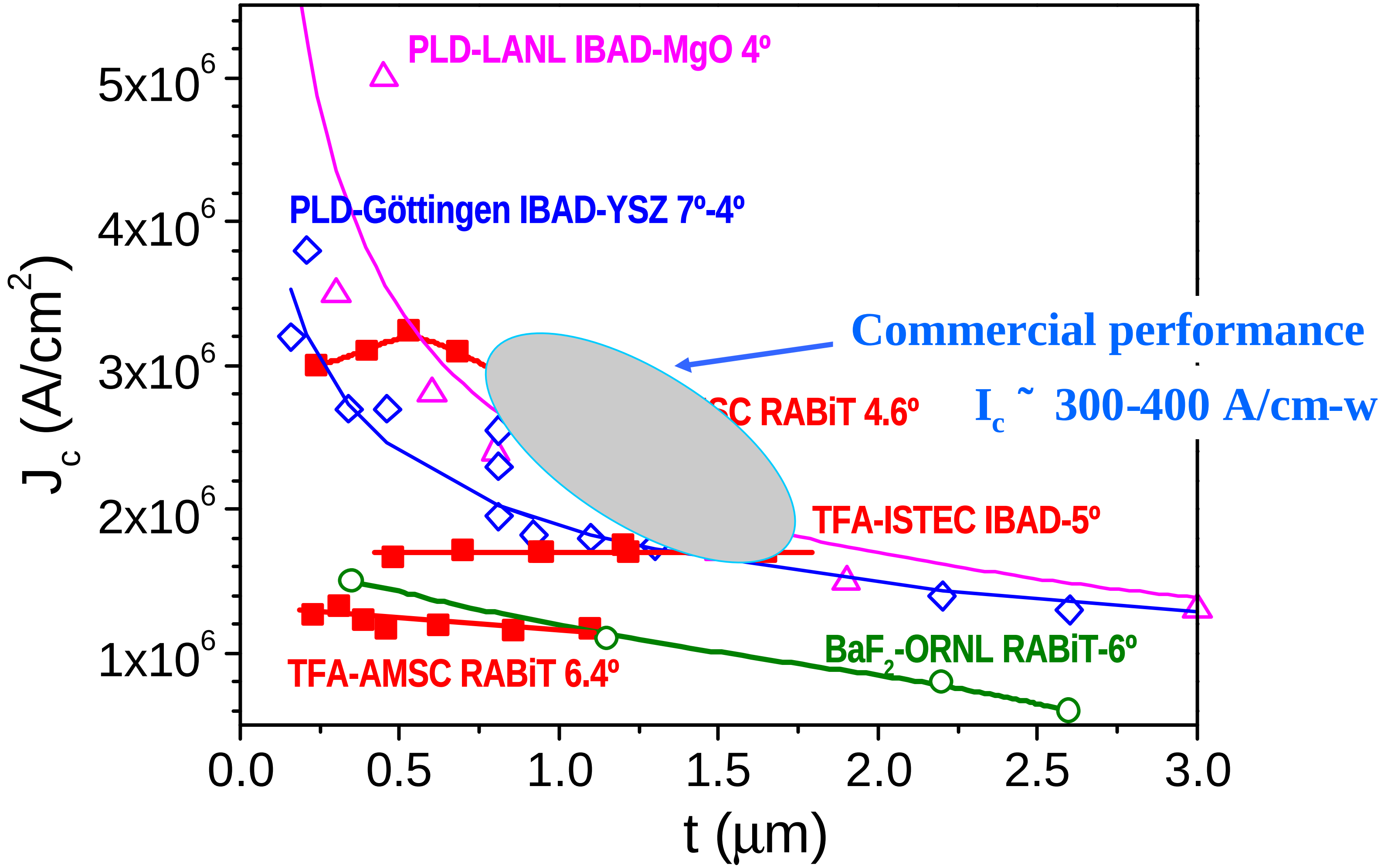
Batch furnace system for 35m CC tape with control of P_{tot}

March 2004

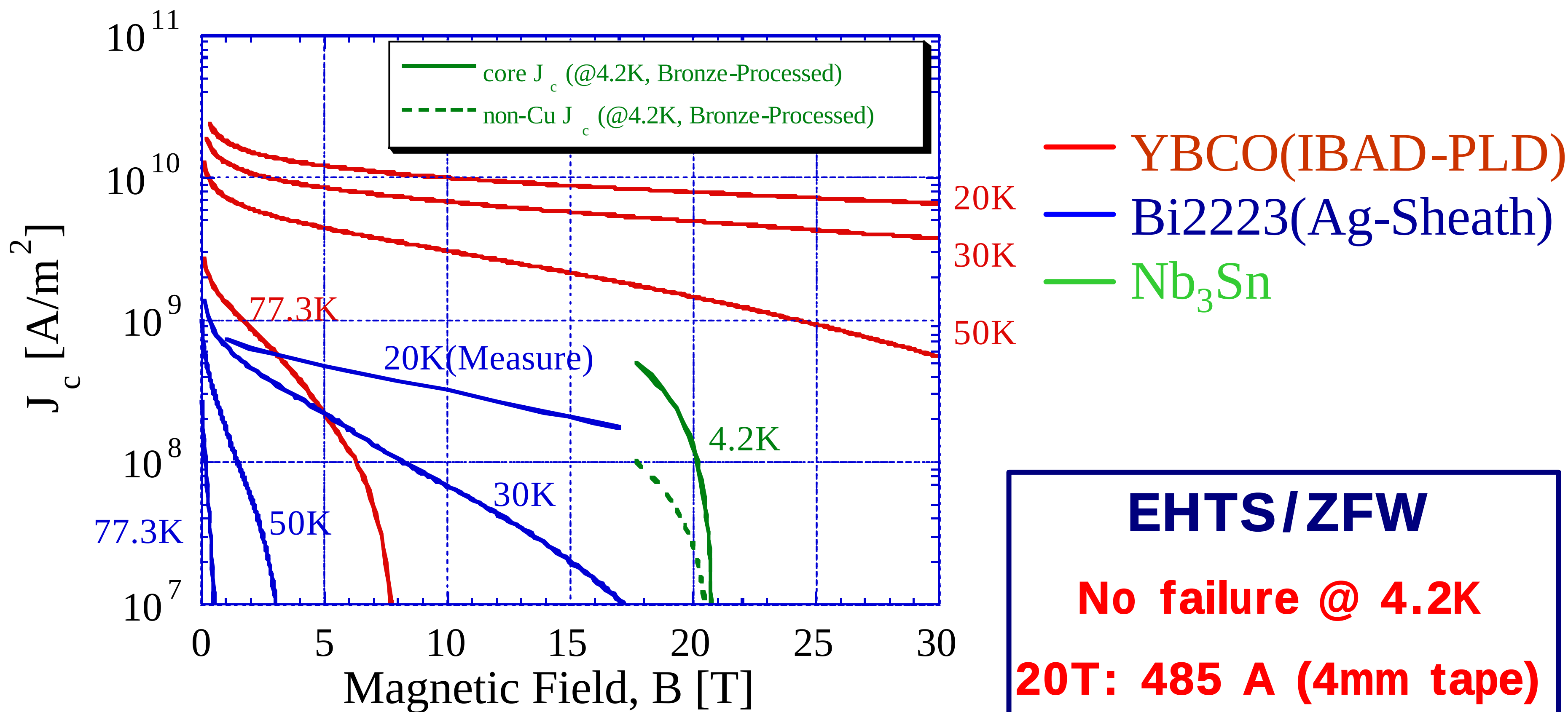


ZFW: 481A/cm-w
392 A/cm in 0.2m length (ZFW)
357 A/cm in 6m length (ZFW)
?
July 2003
HR-PLD new route (ZFW)
HR-PLD (ZFW Göttingen)
TFA
ISTEC
&
AMSC
2002
AMSC
Feb 04
2001-2002
MgO/PLD (LANL)
AMSC
RABiTS
IBAD
ISD
MOCVD (IGC)
MOD TFA (AMSC/ORNL)
PLD (IGC)
MOCVD (IGC)
BaF2 (3M)
PLD (LANL)
PLD (Fujikura)
(IGC)
March 04
PLD (IGC)
38A Fujikura
PLD (Fujikura)
PLD (Sumitomo)
Critical current per cm-width (A/cm)
400
350
300
250
200
150
100
50
0
0,1
1
10
100
CC tape length (m)

Superconducting performance Vacuum vs chemical deposition



Jc-B Properties in IBAD-PLD Tape (Fujikura Ltd. & Kyushu Univ.)

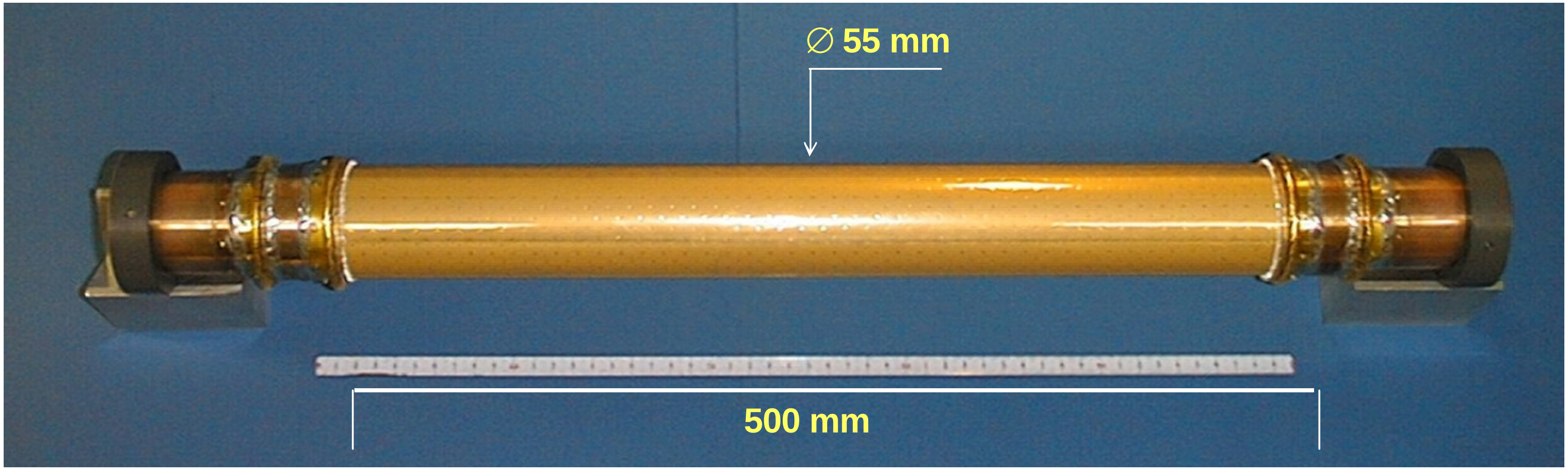


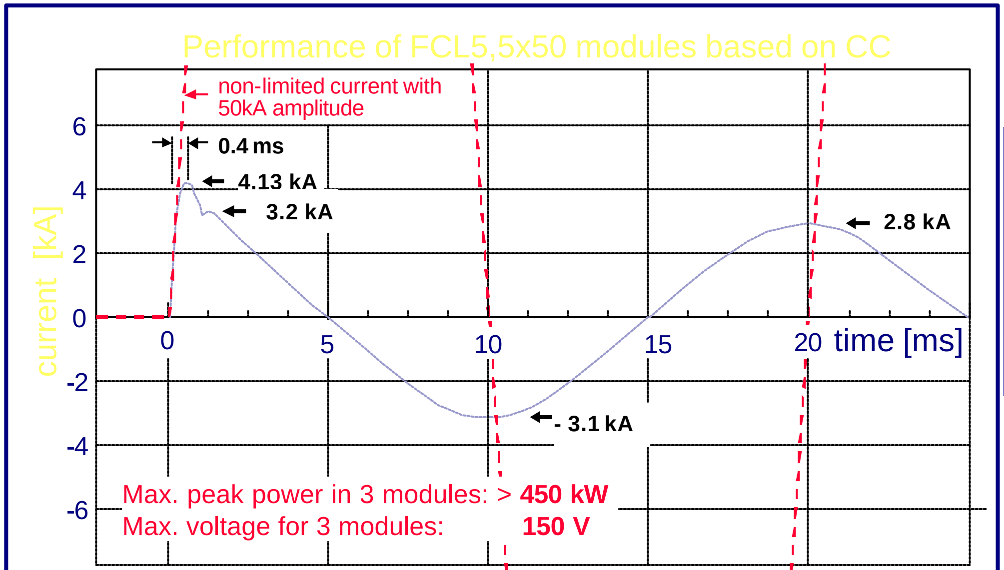
EHTS/ZFW

No failure @ 4.2K

20T: 485 A (4mm tape)

FCL-modules based on YBCO coated SS tapes





Nominal (non-limited) current	2 500 A (ampl.)
Nominal power losses	~ 0.5 W
Fault current, max.	50 000 A (ampl.)
Peak power at fault current:	150 000 W

REQUIREMENTS & STRATEGIC GOALS

Reproducible Processing of YBCO-CC , S.E.BCO-CC

? YBCO CC in lengths of 100 m J_c^{eng} 400-700A/mm² @ 77K

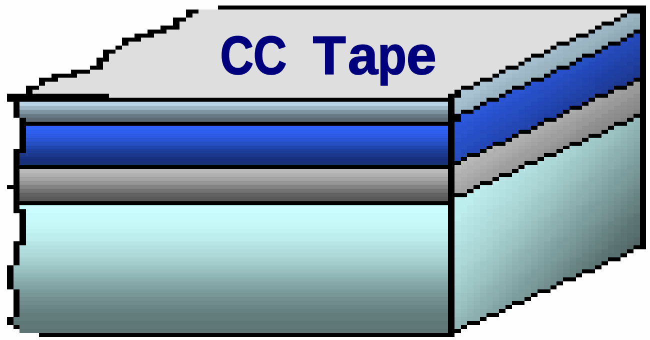
•with cross-sectional architectures and properties (I_c (T,B,e,…), ac losses, mechanical & electro-mechanical prop. , ease of handling; …) determined by the particular application

•assembled conductors

? YBCO CC in km lengths (for use at 77K) until 2005/6 at costs of < 50 €/kAm

? Mass production in 2010/2012 at costs 10 ... 25 €/kAm

How to increase I_c ?



I_c : 100A/cm-w

J_c : 1 MA/cm^2

d_{YBCO} : 1μm

I_c : 300A/cm-w

J_c : 3 MA/cm^2

d_{YBCO} : 1μm

I_c : 600A/cm-w

J_c : 3 MA/cm^2

d_{YBCO} : 2μm