INTERNATIONAL PERSPECTIVE ON COATED CONDUCTORS

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Argonne National Laboratory

Information Sources

- 10th International Workshop on Critical Currents, Göttingen, Germany, June 2001.
- International Cryogenic Materials Conf., Madison, July 2001.
- European Conf. on Appl. Superconductivity, Copenhagen, Denmark, Aug. 2001.
- International Sym. on Superconductivity, Kobe, Japan, Sept. 2001.
- Materials Research Soc. Fall 2001 Meeting, Boston, Nov. 2001.
- Superconductor Week, 2001.
- Grant (EPRI), Suenaga (N□BL), Shiohara (ISTEC), Izumi (ISTEC), Park (KERI, Korea).

Japanese Organizations Supporting Superconductor R&D

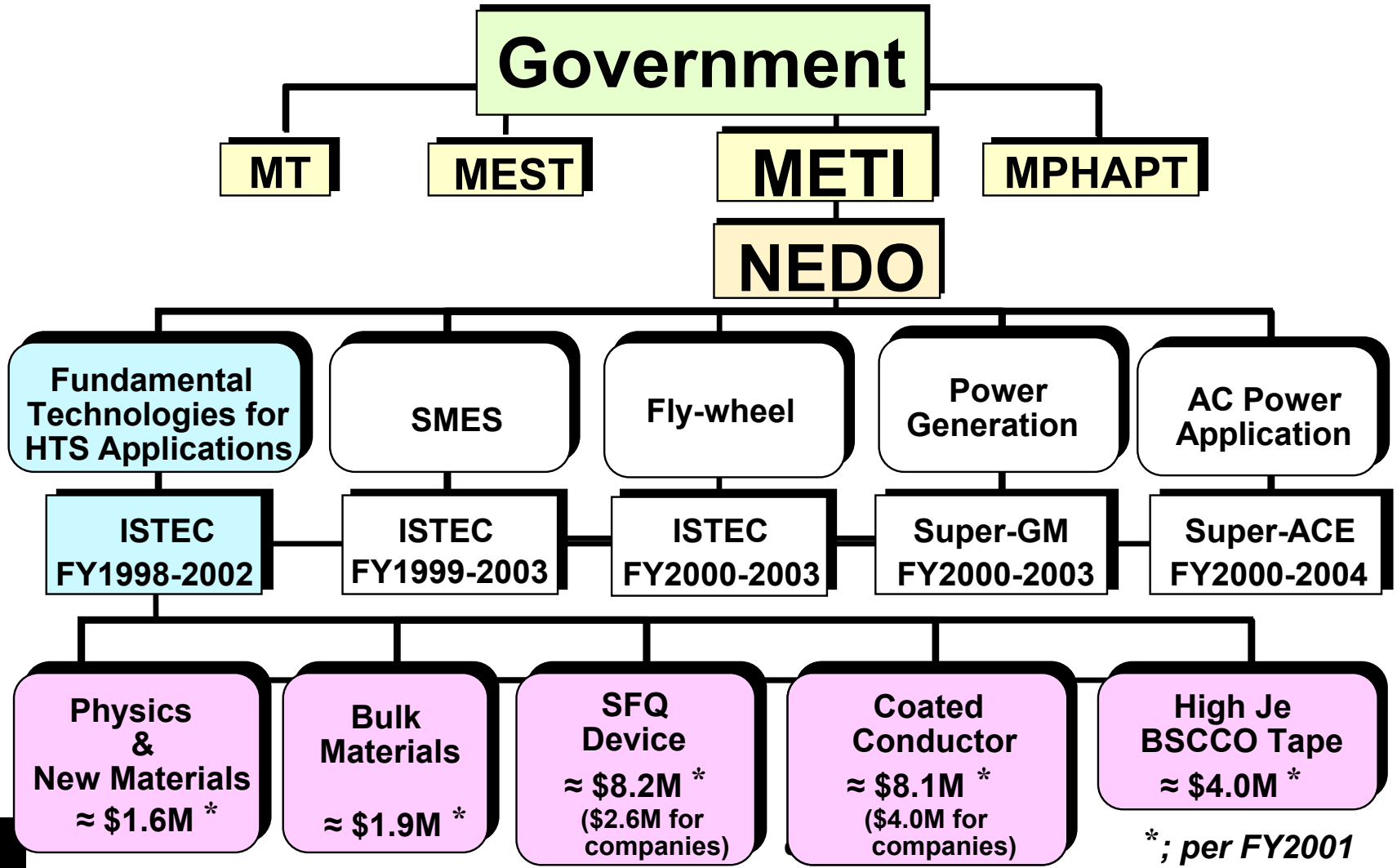
- METI - Ministry of Economy, Trade, and Industry
- NEDO - New Energy and Industrial Technology Development Organization
- MEST - Ministry of Education, Culture, Sports, Science and Technology
- MT - Ministry of Land, Infrastructure and Transport
- MPHAPT - Ministry of Public Management, Home Affairs, Post and Telecommunications

FY2001 (April '01 - March '02) Budget for Superconductivity-related R&D in Four Ministries

(Unit: million yen)

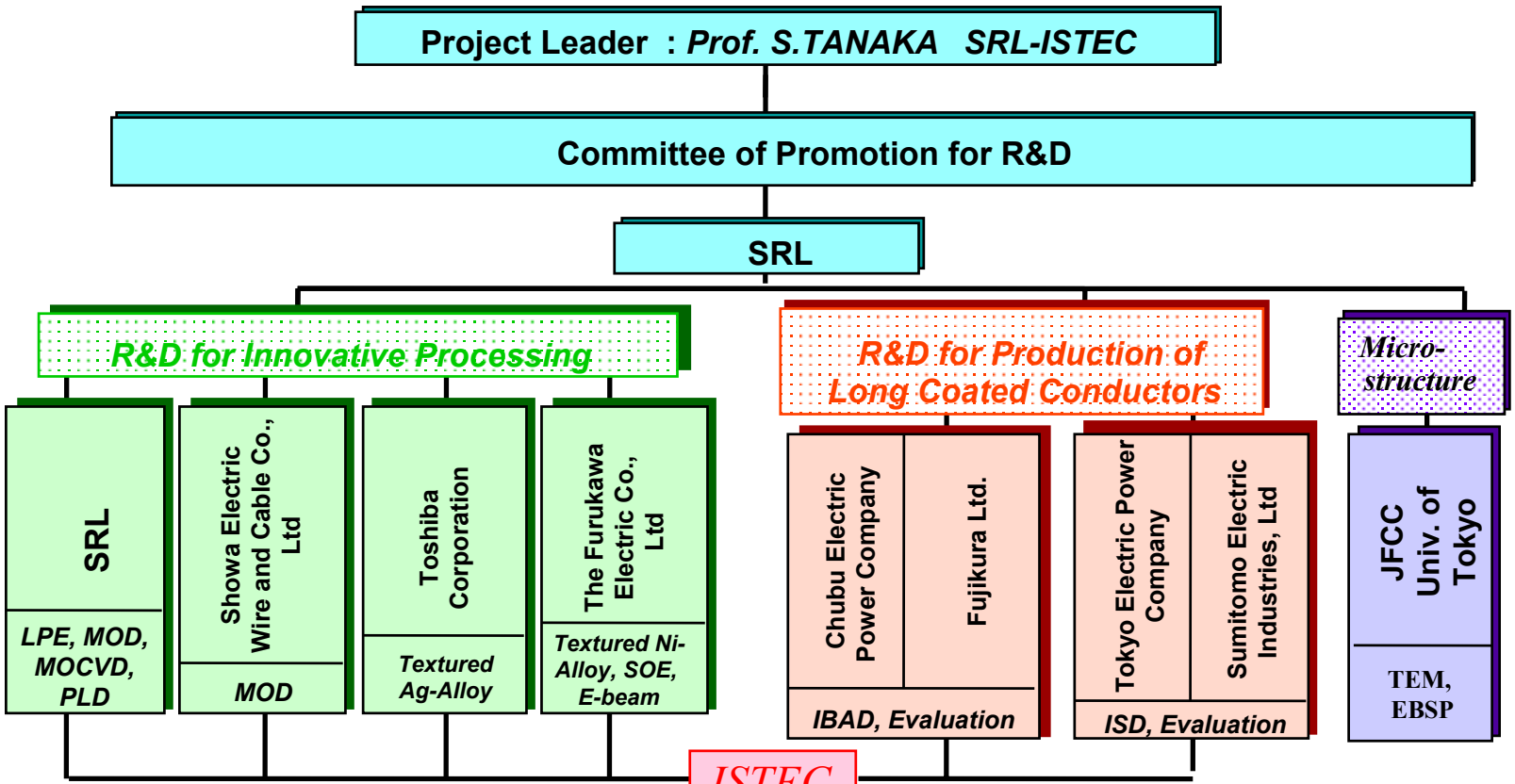
Name of Ministry	Themes	FY2000 Budget	FY2001 Requested Budget
METI	R&D on superconducting generators, flywheel, AC power application, and R&D on fundamental technologies for superconducting applications	8,025	9,093
MEST	Multi-core project for superconducting material studies, nuclear fusion, etc. Consolidation of superconductivity-related research and educational systems	3,275	3,261
MT	MAGLEV	1,184	1,380
MPHAPT	Research on ultrahigh frequency and high-speed circuit technology using superconducting devices	111	Budget within 19,184
	Total	**12,594**	**13,733**

Superconductivity Projects in JAPAN



*; per FY2001

Organization for Development of CC



(10m)

$10^5 \sim 10^6$ Amps/cm^2

(2002)

HTS layer thickness ≥ 5 μm

2nd Stage

(1000m)

$10^5 \sim 10^6$ Amps/cm^2

(100m)

$10^4 \sim 10^5$ Amps/cm^2

(2002)

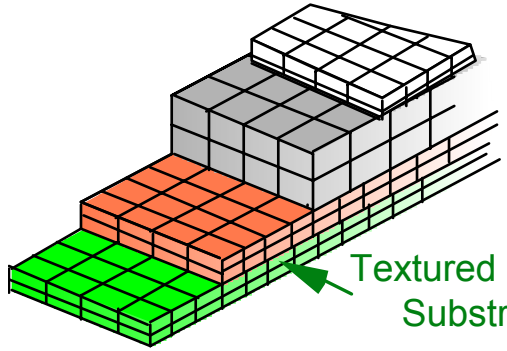
Tape production rate ≥ 1 m/hr

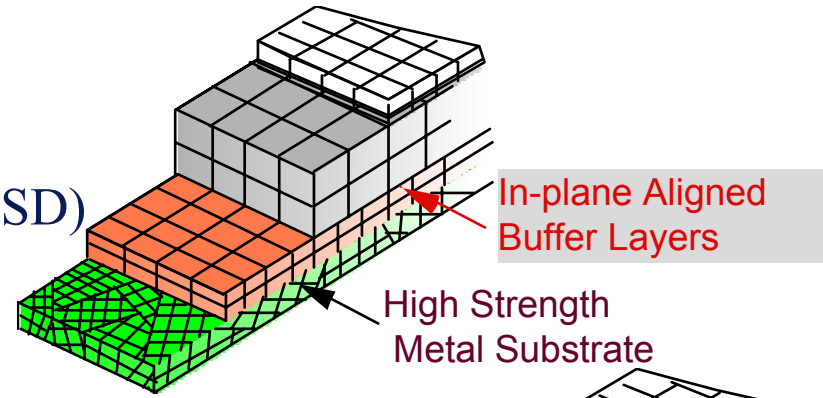
ISTEC/SRL Funding Situation (Japanese Fiscal Year April 1- March 31)

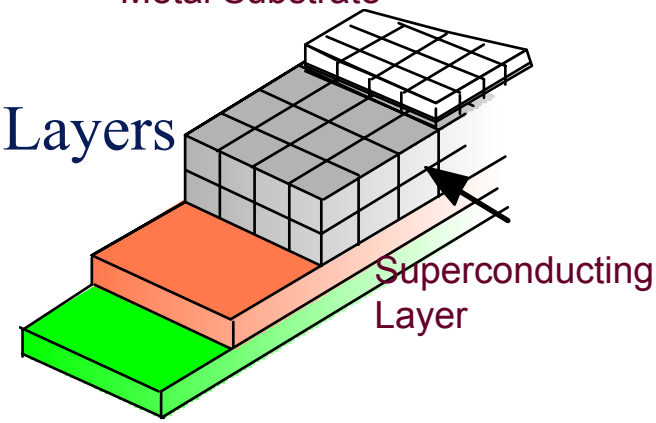
- FY 2002 (starts April '02) is expected to get ≈ 10% increase.
- Fundamental Technologies for HTS Applications program will have 2.7 Billion Yen (≈ $25 M).
- Current 5-yr program ends at the end of JFY '02 (March '03).
- ISTEC will propose to METI an extension to another 5-yr term.
  - will have an intermediate set of goals to fill in the first two years.

Approach

- Process for Textured Metallic Substrate
  - RABiTS™
  - SOE, Cute
- Process for In-Plane Aligned Buffer Layers
  - Inclined Substrate Deposition (ISD)
  - Ion Beam Assisted Deposition (IBAD)
- Innovative Process for Superconducting Layers
  - Liquid Phase Epitaxy (LPE)
  - Metal Organic Deposition (MOD)





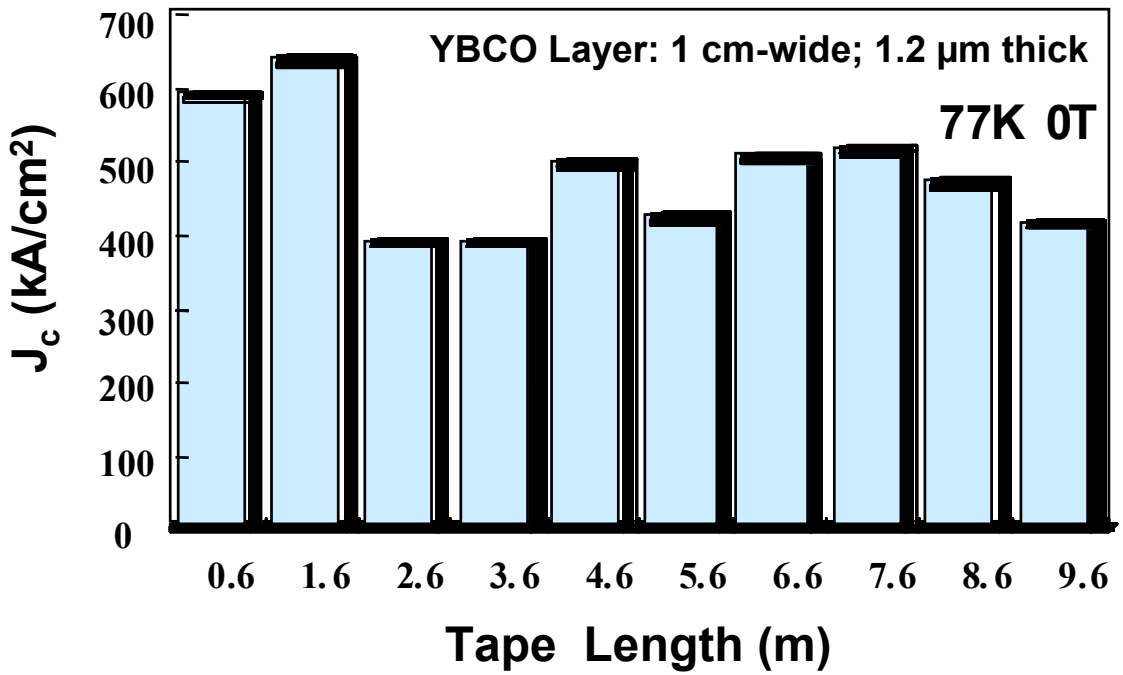


Major Results – Japan

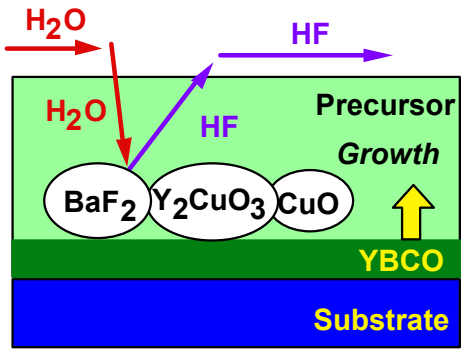
- Textured Metallic Substrates
  - $J_c = 3 \times 10^5$ A/cm^2 on SOE (short sample)
  - $J_c > 10^5$ A/cm^2 on 5-m Ag-Cu/Ag-Ni clad-type tape
- ISD
  - Produced 50-m long textured YSZ with CeO_2 cap-layer (ISD speed: 1.0 m/h)
  - $J_c = 10^5$ A/cm^2 on 10-m long tape (PLD speed: 1.2 m/h)
- IBAD
  - 60-m long IBAD/$Gd_2Zr_2O_7$ tape (IBAD speed: 1 m/h; in-plane FWHM = 16-18°)
  - $I_c = 50$ A ($J_c = 0.42$ MA/cm^2) on 9.6-m long 1-cm wide, 1.2 μm thick tape (PLD speed: 1 m/h; in-plane FWHM = 9°)
  - $I_c = 150$A ($J_c = 1.2$ MA/cm^2) on 8-cm long tape.

Major Results

Measuring Length ; 9.6m
YBCO Thickness ; 1.2 μm
I_c (77K, 0T) ; 50A
J_c (77K, 0T) ; 4.2x10^5 A/cm^2



Innovative Process for Superconducting Layer (MOD)



- Major Results
  - Technology for High Quality Film Deposition;

$J_c \approx 11$ MA/cm^2 on 50-mm dia. film.

Achieved High J_c in Combination of IBAD & TFA-MOD
J_c = 2.5 MA/cm^2 (0T), 0.17 MA/cm^2 (5T) @77 K

  - Process for Thick Film Deposition;

acetylacetonate process

Improved I_c & J_c by means of Triple Coating (0.9 - 1μm) in TFA-MOD

on Single Crystal Sub. I_c*=280 A/cm-width, J_c= 3.1 MA/cm^2

on Metal Sub. (IBAD) I_c*=153 A/cm-width, J_c=1.6 MA/cm^2

  - Technology for Long Length Production
    - Deposition of 10 cm long tape by dip-coating & beed-coating

Current Status & Future Prospect

Present Status (FY2001)	Goal of This Project (FY2002)	Future Targets for Real Industrial Application
<Long Length Production> 1.Length : ≒10m 2. Jc (77K, 0T): $>10^5$A/cm² 3. . Production Rate: 1m/h <Innovative Processing> 1.Length : ≒10cm 2.Jc : Jc (77K, 0T) ≒2.5×10^6A/cm² Jc (77K, 5T) ≒1.7×10^5A/cm²	<Long Length Production> 1. Length : >50m 2. Jc (77K, 0T): $>10^4$A/cm² 3. Production Rate: 1m/h 4.SC Thickness : ≒100μm <Innovative Processing> 1.Length : >1m 2. Jc : Jc (77K, 0T) ≒10^6A/cm² (L=20cm) Jc (77K, 5T) ≒3×10^5A/cm² (L=20cm)	<Tape for Low Field Application> 1. Length : ≒1,000m 2. Ic (77K, 0T) : >40A Jc (77K, 0T) =1×10^6A/cm² 3. Production Rate: >60m/h 4. Sub.Width/Thickness : ≒50μm /≒4mm 5.Cost : <$30-50/kA・m <Tape for High Field Application> 1 Length : ≒500m 2. Ic (64K, 5T): >40A Jc (64K, 5T) =10^5A/cm² 3. Production Rate: >20m/h 4. Sub.Width/Thickness : ≒50μm /≒10mm 5.Cost : <$30-50/kA・m

$146 Million Korean Superconductivity Initiative
(Government: $100M; Industry: $46M; 2001-2010)

Organization

Minister of Korean Ministry of Science and Technology

Steering Committee

Director of CAST

Technical Advisory Committee

DAPAS research group

- Power devices group
- Digital devices group
- Common technology

Administration Office

- Administrative manager
- Technical manager
- . . . . . .

Shared Research Facility

- 15 Industries
- 23 Universities
- 15 Research labs
- 4 Foreign institution

⇒ More international participants wanted

DAPAS -- Dream of Advanced Power system by Applied Supercon. Technol.

Projects of DAPAS

Main category	Projects	Institution
Superconductivity Power devices	◘ Underground cable	KERI
	◘ Transformer	Korea Polytechnic Univ.
	◘ Fault-current limiter	Yonsei Univ./ KEPRI
	◘ Motor	KERI
Superconductivity Digital devices	◘ ALU (Arithmetic Logic Unit)	KOPTI
Superconductivity Common technology	◘ HTS PIT wire	KERI / KIMM
	◘ HTS CC wire (PVD / MOCVD)	KERI / KAERI
	◘ Cryogenic technologies	Neuros
	◘ Electric insulation technologies	Gyeongsang Univ.
	◘ Fundamental technology of HTS coil	KBSI
	◘ (joint, AC loss, etc.)	
	◘ Power system application technologies	KERI

Korean Institutes

- KERI Korea Electrotechnology Research Institute
- KOPTI Korea Photonic Technology Institute
- KIMM Korea Institute of Machinery and Materials
- KAERI Korea Atomic Research Institute
- KBSI Korea Basic Science Institute

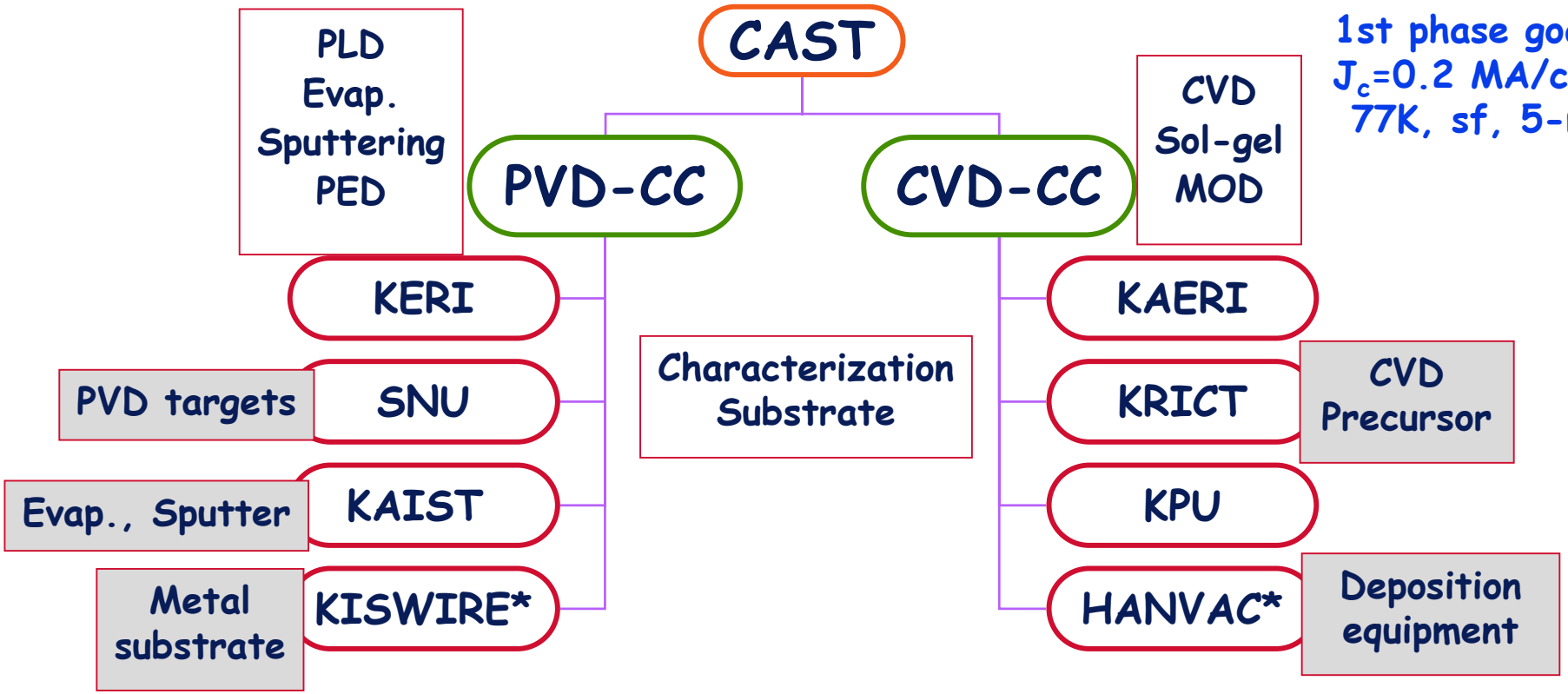
Development Targets of Each Phase

1st Phase	2nd Phase	3rd Phase
2001 2002 2003	2004 2005 2006	2007 2008 2009 2010
Develop HTS wire and system technology suitable for use in electric devices	Develop and test prototypes of electric devices	Develop and test commercial-scale electric devices

Devices: Transmission cable
Transformer
Fault-current limiter
Motor
Arithmetic logic unit

CAST

Coated Conductor Program in CAST



KERI; Korea Electrotechnology Research Institute
SNU; Seoul National Univ.
KAIST; Korea Advanced Institute of Sci. & Tech.

KAERI; Korea Atomic Energy Research Institute
KRICT; Korea Research Institute of Chemical Technology
KPU; Korea Polytechnic Univ.

* industry

EUROPEAN FRAMEWORK PROGRAM PARTICIPANTS

- U. Göttingen & ZFW
- IFW - Dresden
- TU - München
- Forschungszentrum - Julich
- Siemens
- THEVA GmbH
- Inst. Tech. Phy. - Karlsruhe
- Europa Metalli SpA
- IRC - Cambridge
- Imperial College
- U. Birmingham
- Oxford Instruments
- Atomic Institute - Vienna
- U. Geneva
- MASPEC- Parma
- Alcatel

Results of the European Program

- IBAD @ Göttingen
  - 17.5-m-long IBAD tape (in-plane FWHM = 11-13°; Dep. time: 14 hr)
  - 2-m-long tape with I_c = 142 A (J_c = 1.23 MA/cm^2; 10-mm wide; 1.23 μm thick YBCO)
  - YBCO deposition rate using HR-PLD is 40 nm • m^2/hr
  - Current processing time to make 100-m-long, 3.5-mm-wide YBCO tape is ≈280 hr
  - Total processing time will be reduced to ≈40 hr in ≈2 yrs.
- ISD @ Munich
  - 35-m-long textured MgO (tape speed: 8 m/hr; 200-500 nm/min; 2 μm thick)
  - J_c = 0.8 MA/cm^2 (1.5 cm x 0.5 cm); 0.5 MA (10-cm x 0.8 cm); 0.1 MA (1-m x 0.8 cm).

Results of the European Program (cont.)

- Textured Ni-alloy tapes @ Dresden, Karlsruhe, Europa Metalli, THEVA, Munich, Cambridge
  - Controlled micro-alloying (0.1% Mo) prevents secondary recrystallization
  - High alloy concentration (13% Cr, 9% V) reduce grain boundary grooving but texture is imperfect
  - I_c = 60 A in 9-mm wide, 12-cm long and 1.4 μm thick YBCO ($J_c \approx 0.5 \times 10^6$ A/cm^2)
- Textured Ag-alloy tapes @ Geneva, Oxford
  - $J_c \approx 10^5$ A/cm^2 in short samples
- YBCO deposition
  - PLD, magnetron sputtering, LPE, MOCVD, thermal coevaporation, aerosol.

2001 Highlights – International

- 50-mm dia. YBCO films with $J_c \approx 11$ MA/cm^2 by TFA-MOD (ISTEC).
- 60-m long IBAD/$Gd_2Zr_2O_7$ tape (Fujikura).
  - 9.6-m long tape with end-to-end I_c=50A (J_c=0.4 MA/cm^2).
  - 8-cm long tape with I_c = 150 A (J_c = 1.2 MA/cm^2).
- 10-m long tape (by ISD) with $J_c = 10^5$ A/cm^2 (Sumitomo).
- 5-m long tape (clad-type, metallic substrates) with $J_c > 10^5$ A/cm^2 (Furukawa).
- 2-m long tape (by IBAD) with I_c=142 A (J_c = 1.23 MA/cm^2) (Göttingen).
  - 17.5 m long IBAD tape fabricated .
- 35-m long biaxially textured MgO layer by ISD (tape speed = 8 m/hr) on SS substrate (Munich).
- Korea had established a $146M/10-yr superconductivity initiative.

Summary

- Japan has a large, broad-based, multiorganization effort.
  - Consortia type arrangement
  - Developments are shared among companies; makes it easier for rapid technical progress
  - Achievable targets are set
  - Technical feasibility is most important compared to performance & cost effectiveness
- Impressive IBAD, ISD, and YBCO results are obtained in the European program.
- Small prototype devices using CCs have been demonstrated in Europe and Japan.

Results of the European Program (cont.)

- IBAD on stainless steel tape (strong, non-magnetic) @ Göttingen
  - Tape speed 8 cm/min; Dep. time 11 hr/m; Dep. window 6-cm x 12.5-cm; Volumetric dep. rate 14 nm • m^2/h
- PLD @ Göttingen
  - Volumetric dep. rate (present) 24 nm • m^2/h (future 43 nm • m^2/h)
  - J_c = 2.3 MA/cm^2 (23-cm x 1-cm); 0.6 MA (50-cm x 1-cm, I_c = 54 A); 0.4 MA (100-cm x 3.4 -cm)
  - Production rate < 0.3 m/h (conventional PLD); 9 m/h (HR-PLD @ present); > 20 m/h (in 2 years)
  - 20-mm thick YBCO target with an area of 300 cm^2 is sufficient to process 7 km long, 1-cm wide tape
- ISD/MgO @ TU Munich
  - Rate 200-500 nm/min; thickness ≈ 2 μm
  - J_c = 0.8 MA/cm^2 (1.5 cm x 0.5 cm); 0.5 MA (10-cm x 0.8 cm); 0.1 MA (1-m x 0.8 cm)

METI's FY'02 Budget Request for Superconductivity (mid-Aug '01)

	B-JYN
• AC Applications	1.45
• SC Generator	0.8
• Flywheel	0.35
• SMES	1.05
• Fundamental Technologies	3.5
– Coated Conductors	
– Bulk Materials	
– Industrial HTS Magnets	
– Electronics	
Total:	**7.15**

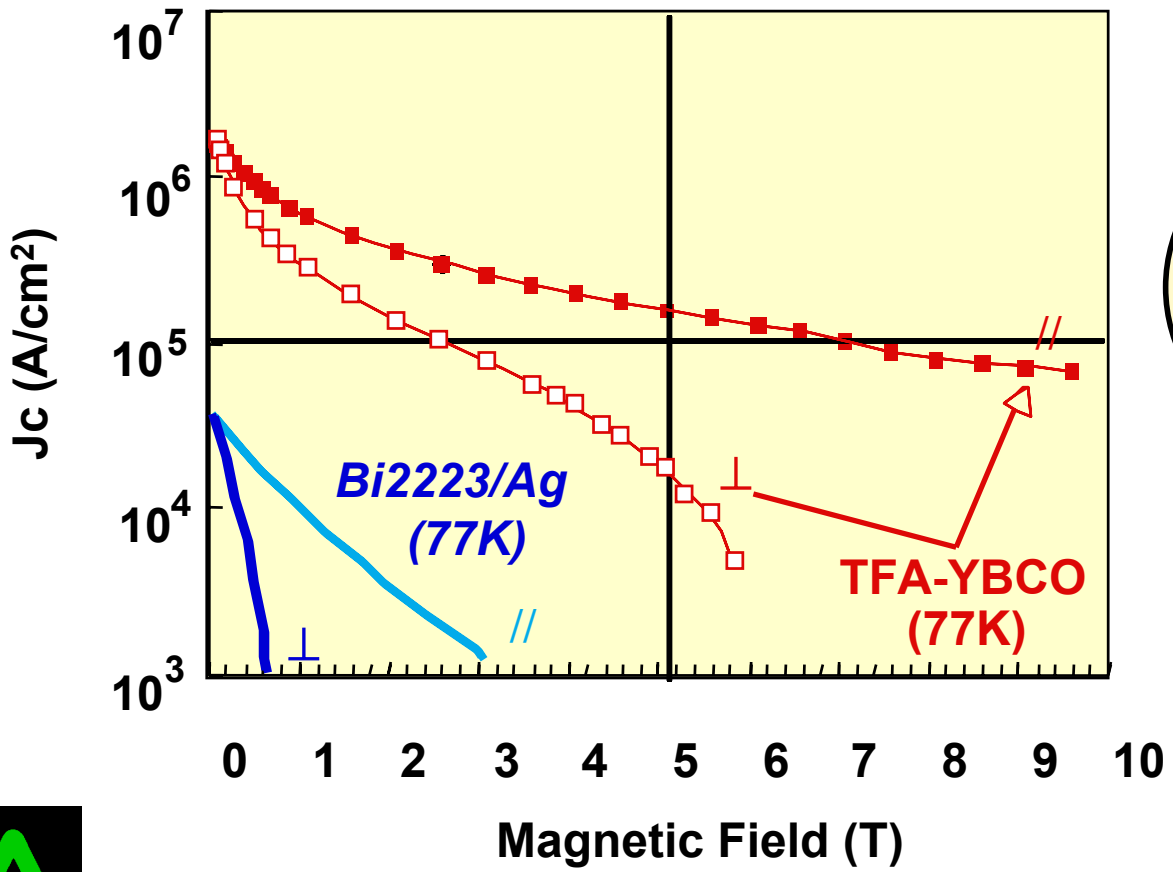
$59.39M @ 120.4 Yen = $1

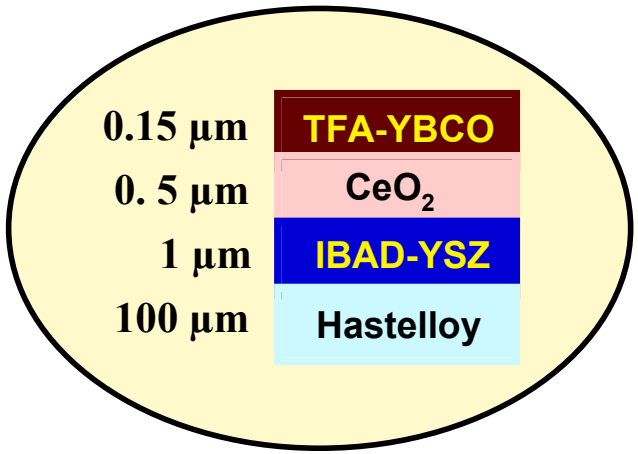
FY2002 Target for Development of Coated Conductor

- Critical Current Density
  - $J_c \geq 300$ kA/cm^2
    at 77K & 5T
    L > 20 cm
- Critical Current Density
  - $J_c \geq 10$ kA/cm^2
    at 77K & 0T
    L ≥ 50 m

Major Results

J_c-B Properties of YBCO Coated Conductor on IBAD Metallic Sub. Deposited by TFA-MOD Process





⊥; B⊥ ab-plane

//; B// ab-plane

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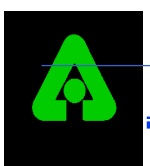
	✦ Power system application technologies	KERI



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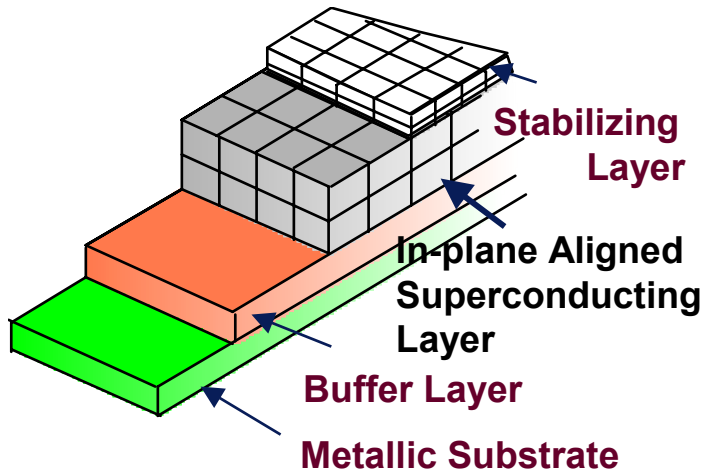
CAST

Objectives

Development of primary technologies for RE123 coated conductors in order to use under the high magnetic fields:

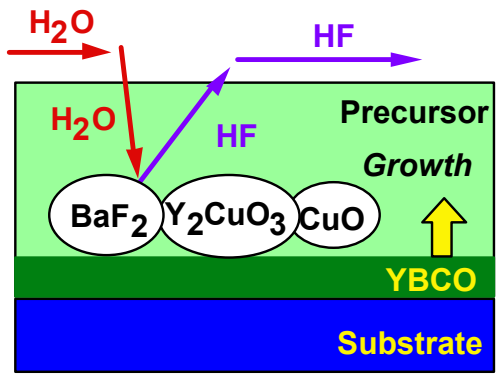
- Substrates, Buffer Layers
  - —Search for Appropriate New Materials
  - —Processing to obtain Textured Metallic High Strength Substrates
  - —High Speed Process for In-plane Aligned Buffer Layers
- Superconducting Layer
  - —High Speed Process for a Long Length, High Crystallinity & Thick Superconducting Layer



Innovative Process for Superconducting Layer

Approach

Metal Organic Deposition(MOD)



•Major Results

1. Technology for High Quality Film Deposition;

Achieved High Jc in Combination of IBAD & TFA-MOD

Jc=2.5 x10^6 A/cm^2(0T), 0.17 x 10^6 A/cm^2 (5T) @77K

2. Process for Thick Film Deposition; Improved Ic & Jc by means of Triple Coating (0.9-1μm) in TFA-MOD

on Single Crystal Sub. Ic*=280A/cm-width Jc=3.1 x10^6 A/cm^2

on Metal Sub.(IBAD) Ic*=153A/cm-w Jc=1.6 x10^6 A/cm^2

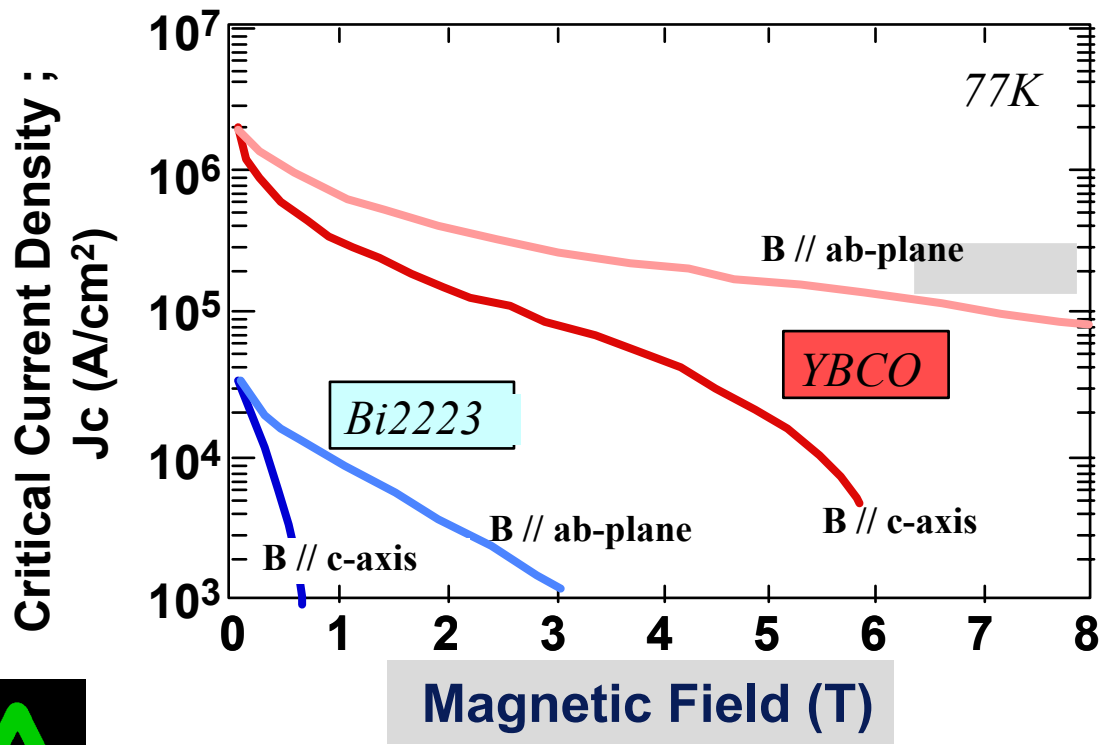
3. Technology for Long Length Production;

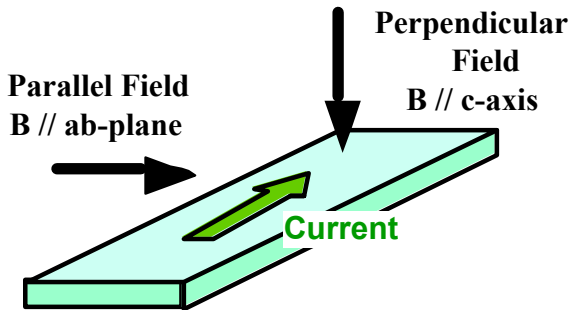
Deposition of 10cm Long Tape by Dip-coating & Beed-coating

Background

Comparison of Jc-B Properties between Bi-2223 & Y123 Tapes

< Effect of Direction of Applied Magnetic Field >





Approach

- Process for Textured Metallic Substrate
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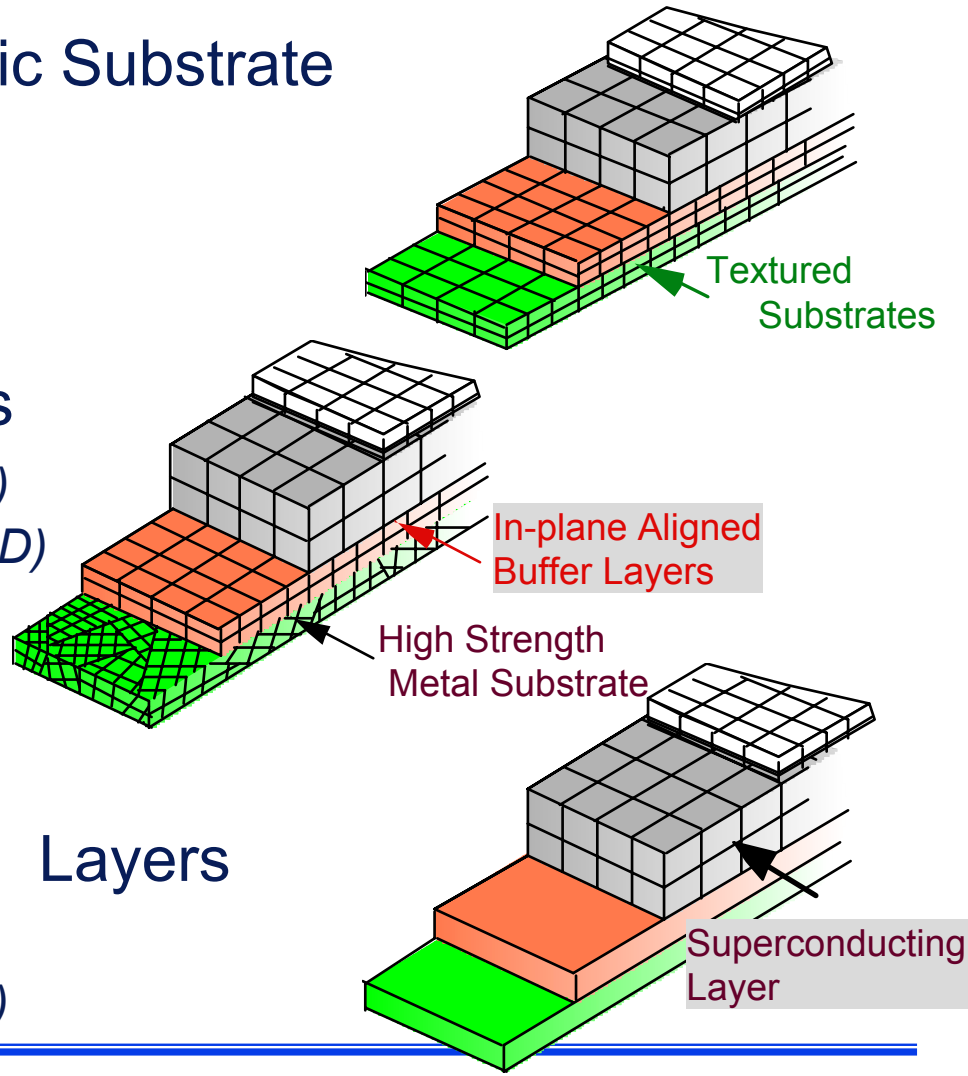
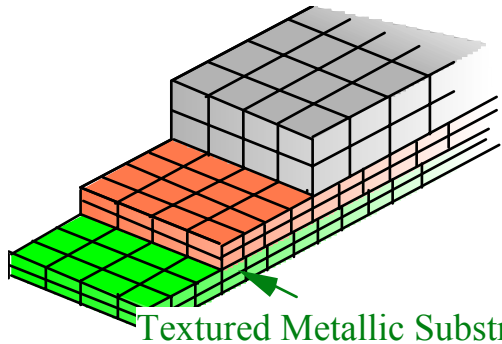
  - *SOE, Cute*
- Process for In-Plane Aligned Buffer Layers
  - *Incllined Substrate Deposition(ISD)*
  - *Ion Beam Assisted Deposition(IBAD)*
- Innovative Process for Superconducting Layers
  - *Liquid Phase Epitaxy (LPE)*
  - *Metal Organic Deposition(MOD)*



Major Results
Process for Textured Metallic Substrate

□Approach□

RABiTS (Ni&Ag)&
Surface Oxidation Epitaxy(SOE)



□Major Results□

1. Development of Long Length SOE Tape□

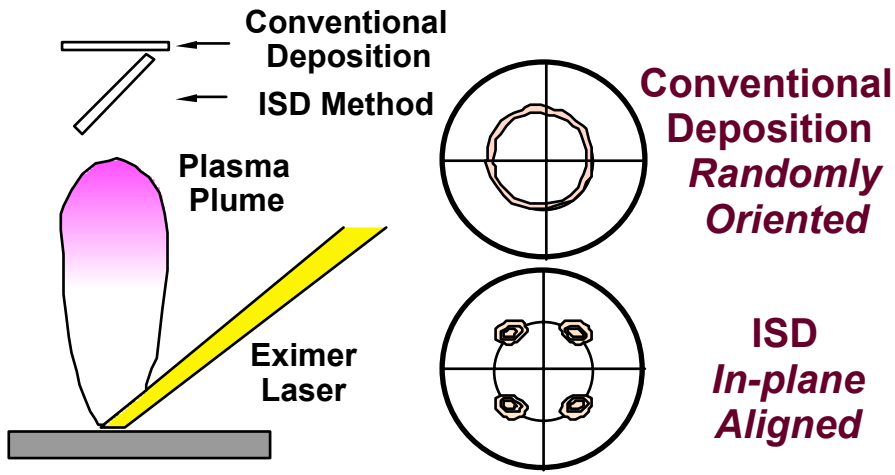
□□□□□□□□□□□□□□□□50m SOE-NiO/Textured Ni

2. High Strength & Low Magnetic Substrates using
   Clad-Type Metallic Substrete□SOE-NiO/Ni/Ni-Cr (30m)
3. Jc=3x10^5 A/cm^2 (@77K,0T) YBCO on SOE
4. Jc> 10^5 A/cm^2 & L=5m YBCO/Ag-Cu/Ag-Ni

Process for In-plane Aligned Buffer Layer (Inclined Substrate Deposition)

□Approach□

Inclined Substrate Deposition(ISD)



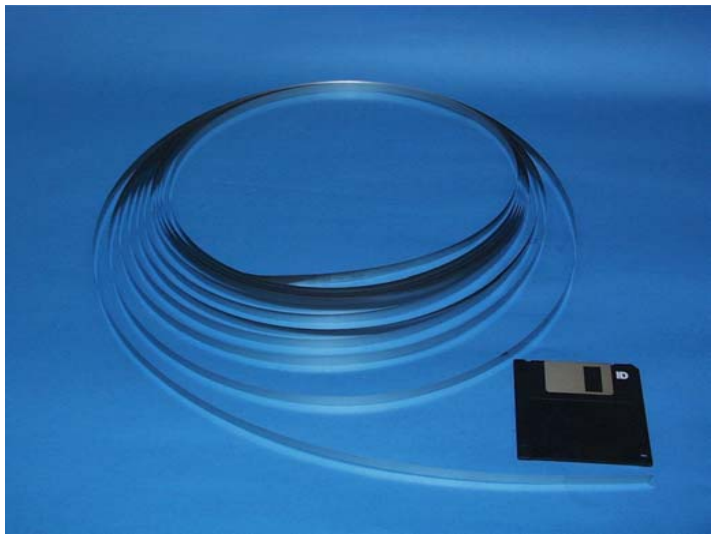
□Major Results□

1. Technology for Stable Long Length Tape Production; 200W Industrial Laser & Large Chamber Stable Oscillation >100hrs
2. Production of Long Length Coated Conductor; L=10m Jc=10^5 A/cm^2 (@77K,0T)

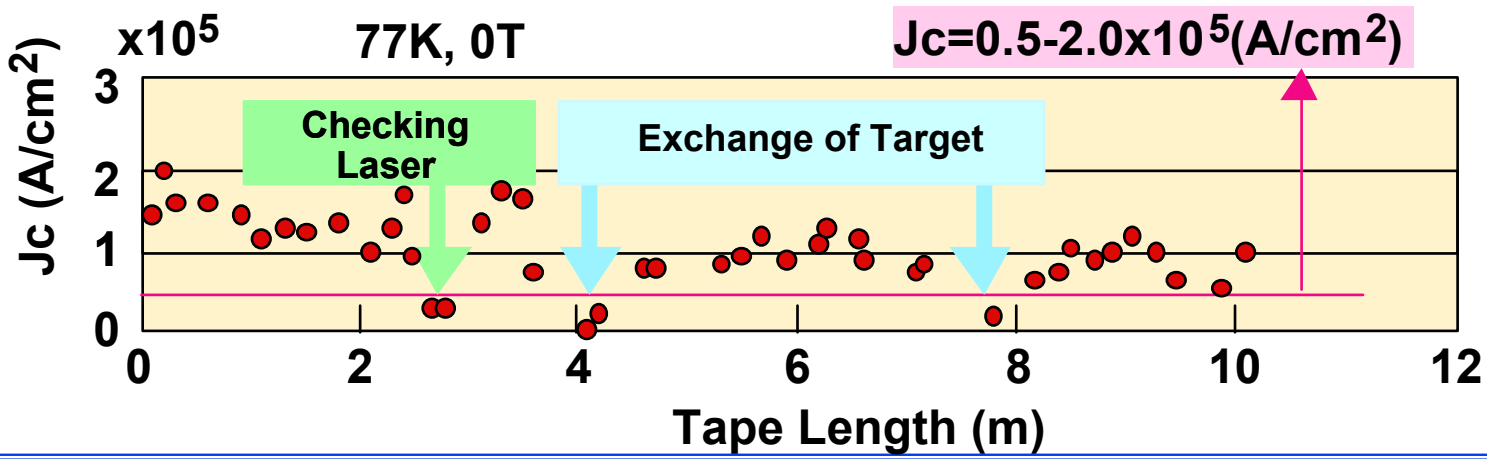
□□ YBCO/ISD-YSZ/Hastelloy

Achieved in 50m Long CeO_2 Buffer Layer Deposition

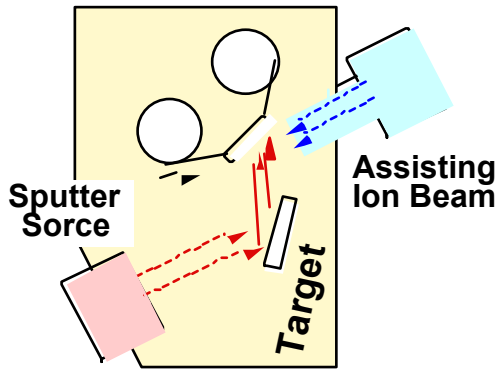
Major Results



YBCO (PLD)
YSZ(ISD □
Hastelloy



Process for In-plane Aligned Buffer Layer (Ion Beam Assisted Deposition)



Approach

Ion Beam Assisted Deposition(IBAD)

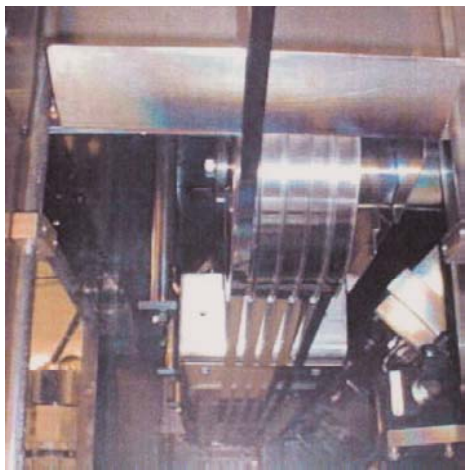
Major Results

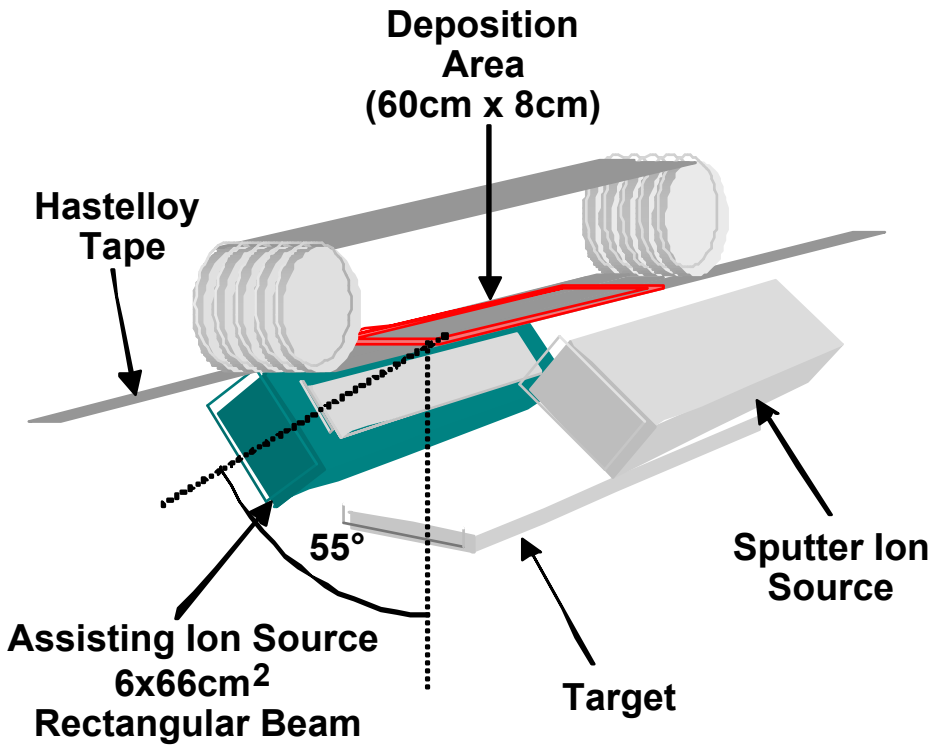
1. Technology for Stable Long Length Tape Production; Enlargement of IBAD System (Rectangular Ion Souce) Deposition Time > 500 hrs
2. Technology for High Speed & High Crystallinity Buffer Layer Deposition; Discovery of New Buffer Material ($Zr_2Gd_2O_7$)
3. Production of Long Length Coated Conductor;
   L=10m (Production Rate=1m/h) Jc=$4x10^5$ A/cm^2 (@77K,0T)
   YBCO/IBAD- $Zr_2Gd_2O_7$ /Hastelloy

Achieved in 60m Long $Zr_2Gd_2O_7$ Buffer Layer Deposition

Major Results

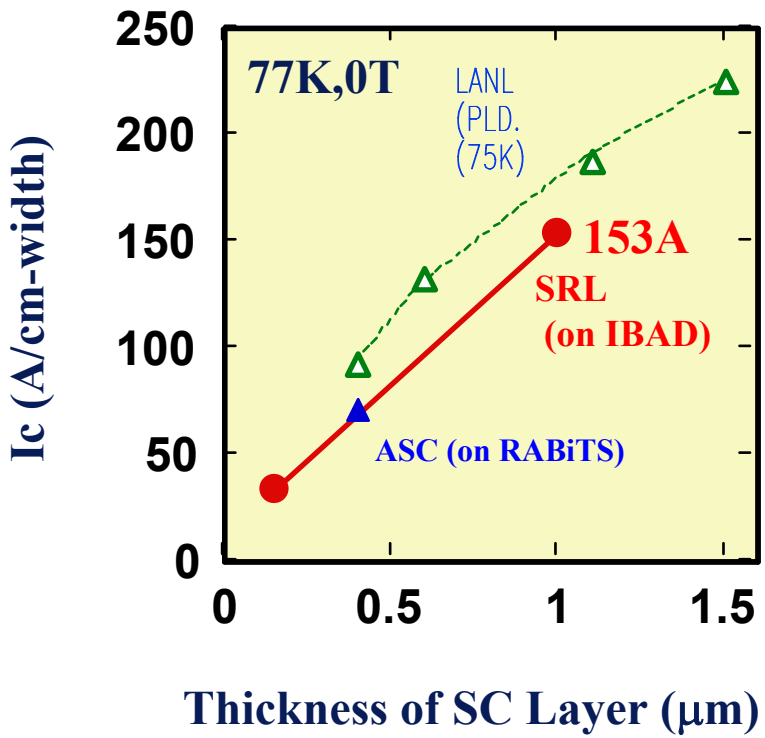
Large IBAD System

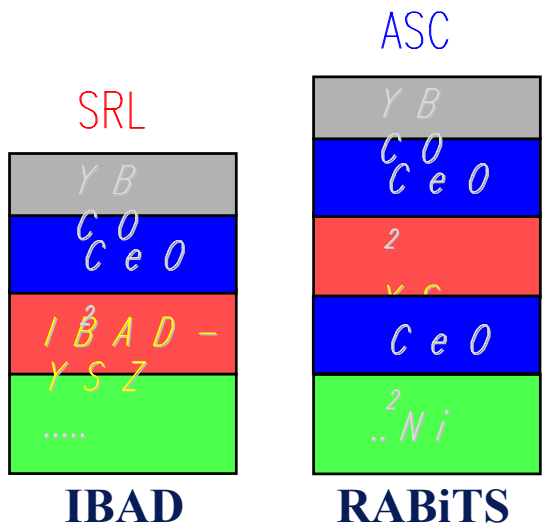




Major Results

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





Structure of Coated Conductor Deposited by TFA-MOD Process

Current Status & Future Prospect

Present Status□FY2001□	Goal of This Project□FY2002□
□Long Length Production□ □1.Length□□□□□□□10m □2. Jc□77K, 0T): □10 5 A/□ 3.□Production Rate: 1m/h □Innovative Processing□ □1.Length□□□□□□□10□ □2.Jc□ □□ Jc□77K, 0T□□2.5x10 6 A/□ Jc□77K, 5T□□1.7x10 5 A/□	□Long Length Production□ □1. Length □ □□□□□50m □2. Jc□77K, 0T): □10 4 A/□ □3. Production Rate: □1m/h □4.SC Thickness□ □100μ□□ □Innovative Processing□ □1.Length□□□□□□1m □2. Jc □ □Jc□77K, 0T□□10 6 A/□ □□□□□□□□□□L□20□□ □ □Jc□77K, 5T□□3x10 5 A/□ □□□□□□□□□□L□20□□ □

FY2001 Budget for Superconductivity-related R&D in five Ministries and Agencies (Requested Budget)

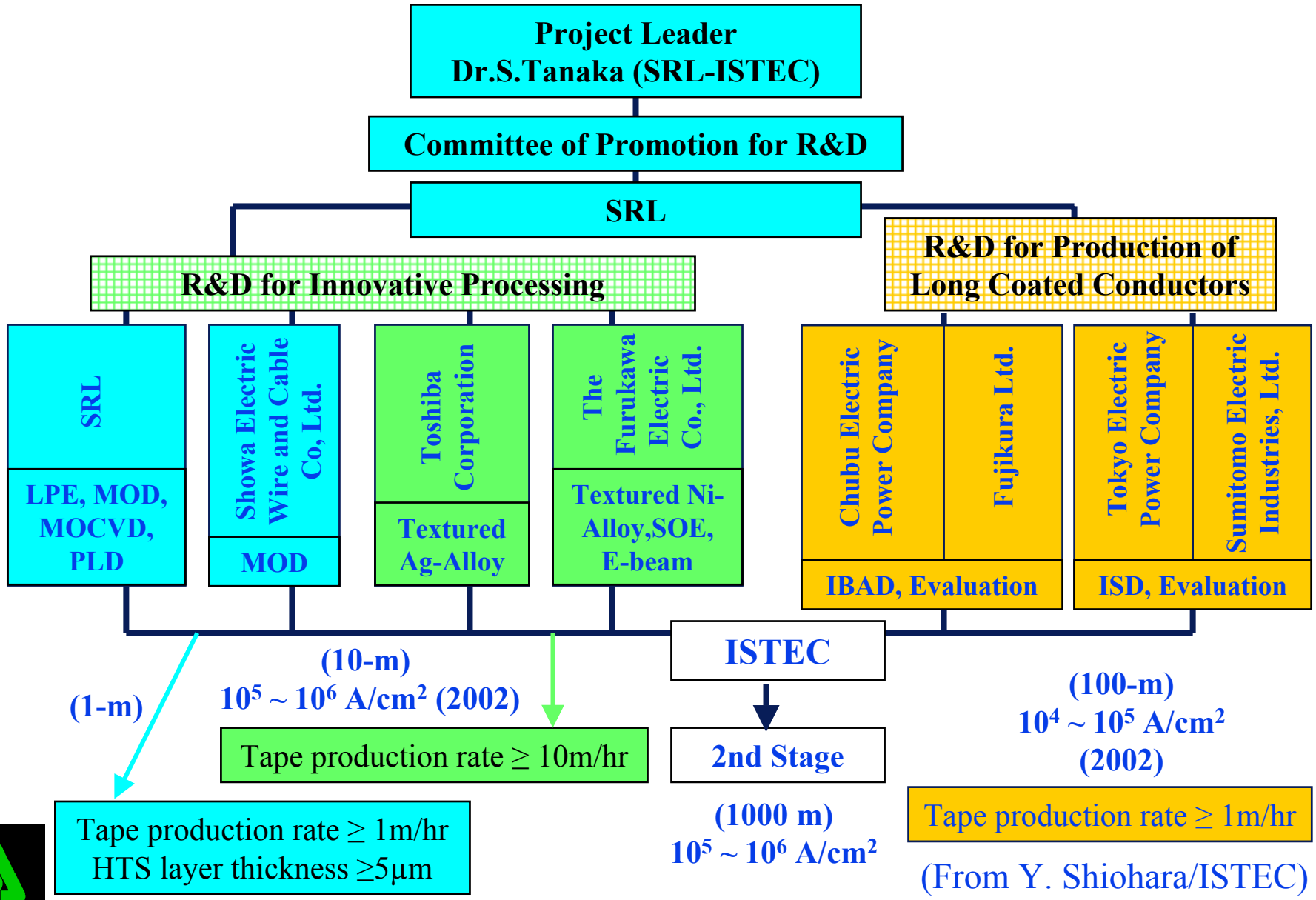
(Unit: million yen)

Item / Name of Ministry or Agency	Themes	FY 2000 Budget (Note 1)	FY2001 Requested Budget	Remarks
Ministry of International Trade and Industry (Ministry of Economy, Trade and Industry)	R & D on superconducting generators, flywheel electric power storage systems, SMES systems, and R&D on fundamental technologies for superconducting applications	8,025	9,093	
Science and Technology Agency (Ministry of Education, Science and Technology)	Multi-core project for superconducting material studies, nuclear fusion, etc.	2,746	2,731	
Ministry of Education (Ministry of Education, Science and Technology)	Consolidation of superconductivity-related research and educational systems	529	530	
Ministry of Transport (Ministry of National Land and Transportation)	Subsidy for technical development of superconducting magnetically levitated railroads	1,184	1,380	
Ministry of Posts and Telecommunications (Ministry of Public Management, Home Affairs, Posts andTelecommunications)	Grant to run an independent administrative corporation named General Research Institute of Communication "Research on Ultrahigh Frequency and High-speed Circuit Technology Using Superconducting Devices" as part of the "Research on New functions and Ultimate Technologies for Information and Communication Devices" program	111	Budget within 19,184	
	Total	12,594	13,733*	

Information Sources

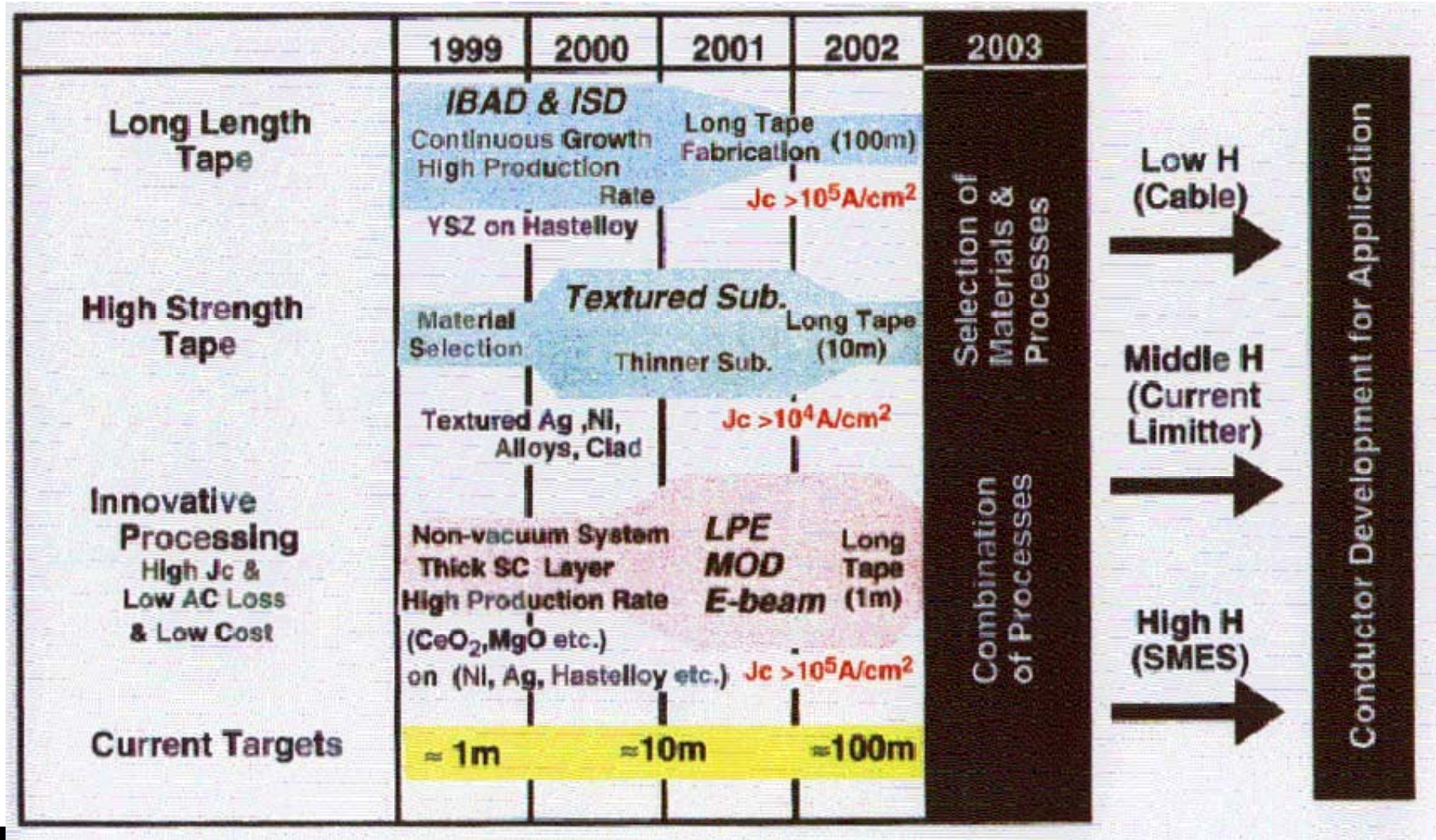
- SCENET - Superconductivity European Network Workshop on coated conductors, Göttingen, May 2000.
- ASC 2000 - Applied Superconductivity Conference, Virginia Beach, Sept. 2000.
- 9th ISIS - International Superconductivity Industry Summit, Copenhagen, Oct. 2000.
- ISS 2000 - International Symposium on Superconductivity, Tokyo, Oct. 2000.
- Fall 2000 MRS - Materials Research Society, Boston, Dec. 2000.
- Journal articles.

Organization for Development of Coated Conductor



(From Y. Shiohara/ISTEC)

Road-map for Development of Coated Conductors



Ref: Y. Shiohara, ISTEC

Japanese Coated Conductor Program Goals

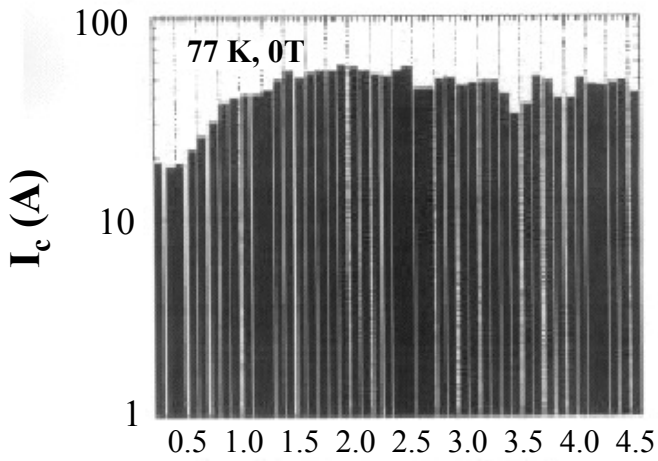
Developmental Targets

Item	**Length (m)**	**Thickness of substrate (μm)**	**J_c (A/cm^2)**	**Thickness of superconducting layer (μm)**	**Manufacturing speed (m/h)**
Textured substrate wire	10 ~ 100	[2] 100	$10^5 \sim 10^6$		10
Aligned buffer layer wire	100 ~ 1000	[2] 100	$10^5 \sim 10^6$		1
Rapid-growth superconducting layer wire	1 ~ 10	[2] 100	$10^5 \sim 10^6$	[3] 5	1

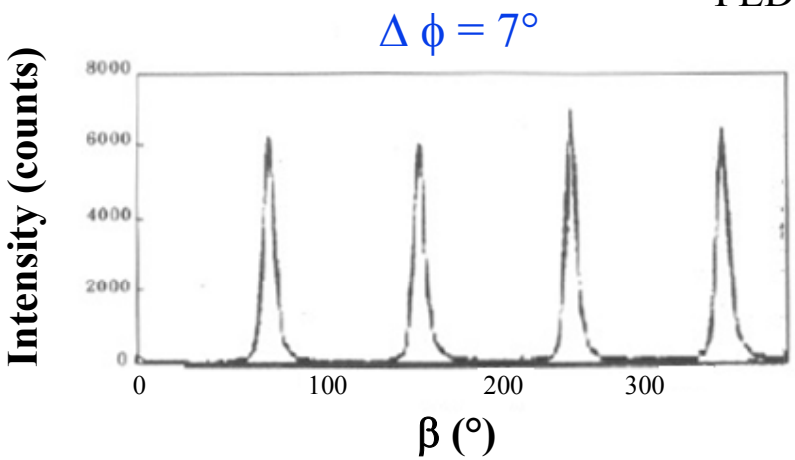
Ref: ISTEC Journal Vol. 13 no. 3 2000

IBAD YSZ/YBCO (Fujikura) (Y. Shiohara, Fall 2000 MRS)

IBAD YSZ
Tape speed: 0.1 m/h
Thickness: 1.0 μm
Length: 5.6 m
Time: 60 h
FWHM: 12°-13°
1-m section I_c: 54 A (3.8 x 10^5 A/cm^2)
4.6-m section I_c = 35 A (2.5 x 10^5 A/cm^2)

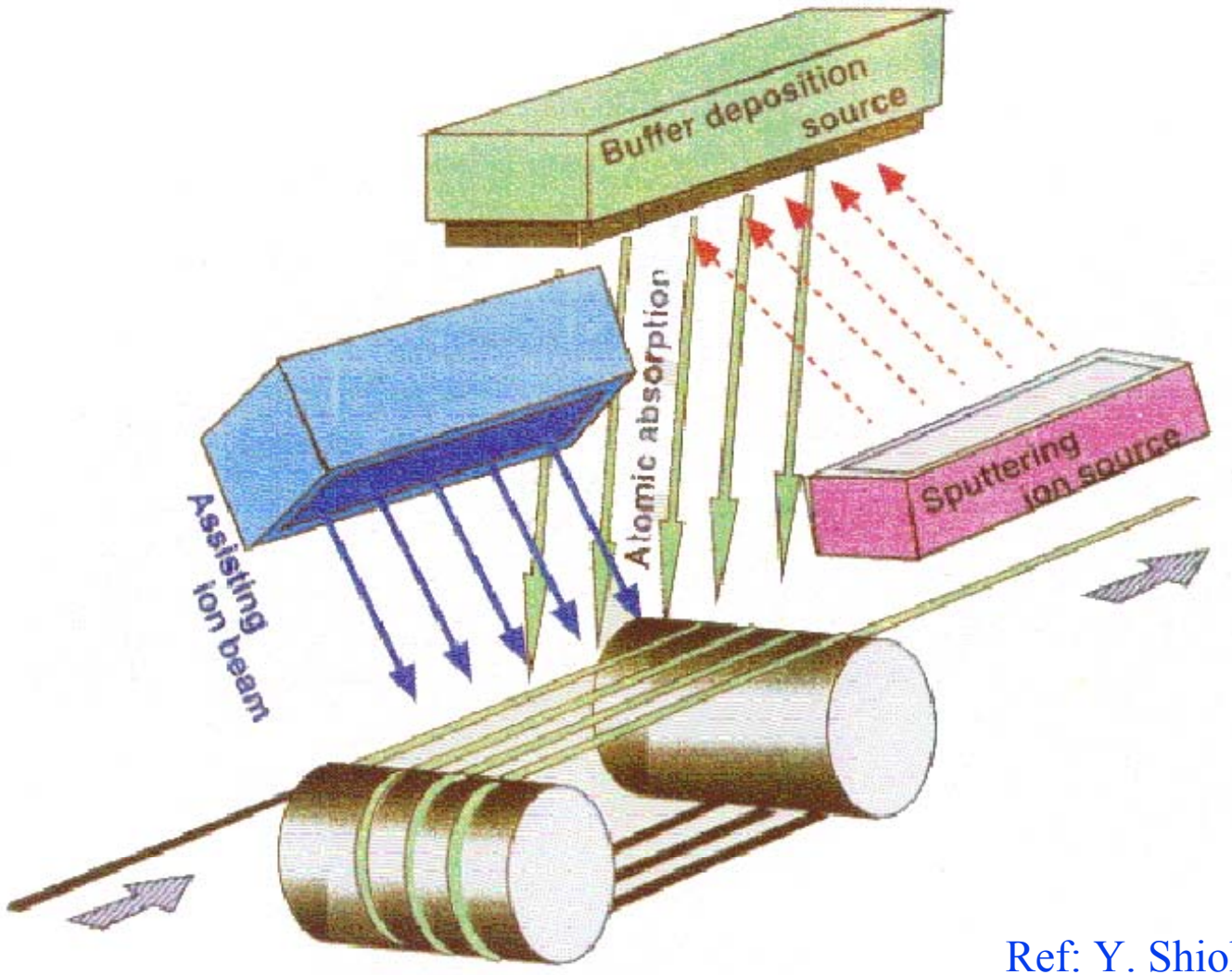


I_c of 4.6m IBAD/PLD YBCO tape
PLD tape speed: ≈ 1m/h



X-ray scans of YBCO on Zr-X-O IBAD layer

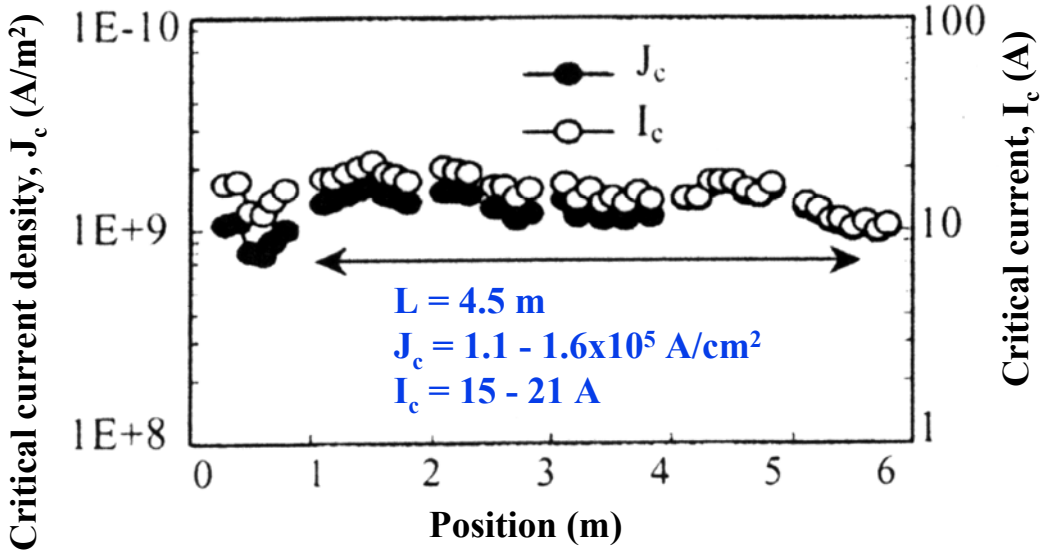
Schematic of Continuous IBAD Deposition Process (Fujikura)



Ref: Y. Shiohara, ISTEC

Inclined Substrate Deposition
(Ref: Y. Sato, et al. Applied Supercond. Conf, 2000.)
Sumitomo & TEPCO

Old laser:
YSZ/ISD@ tape speed of 0.6 m/h (≈0.6 µm/min)
YBCO @ tape speed of 0.2 m/h (≈1.5 µm/min)

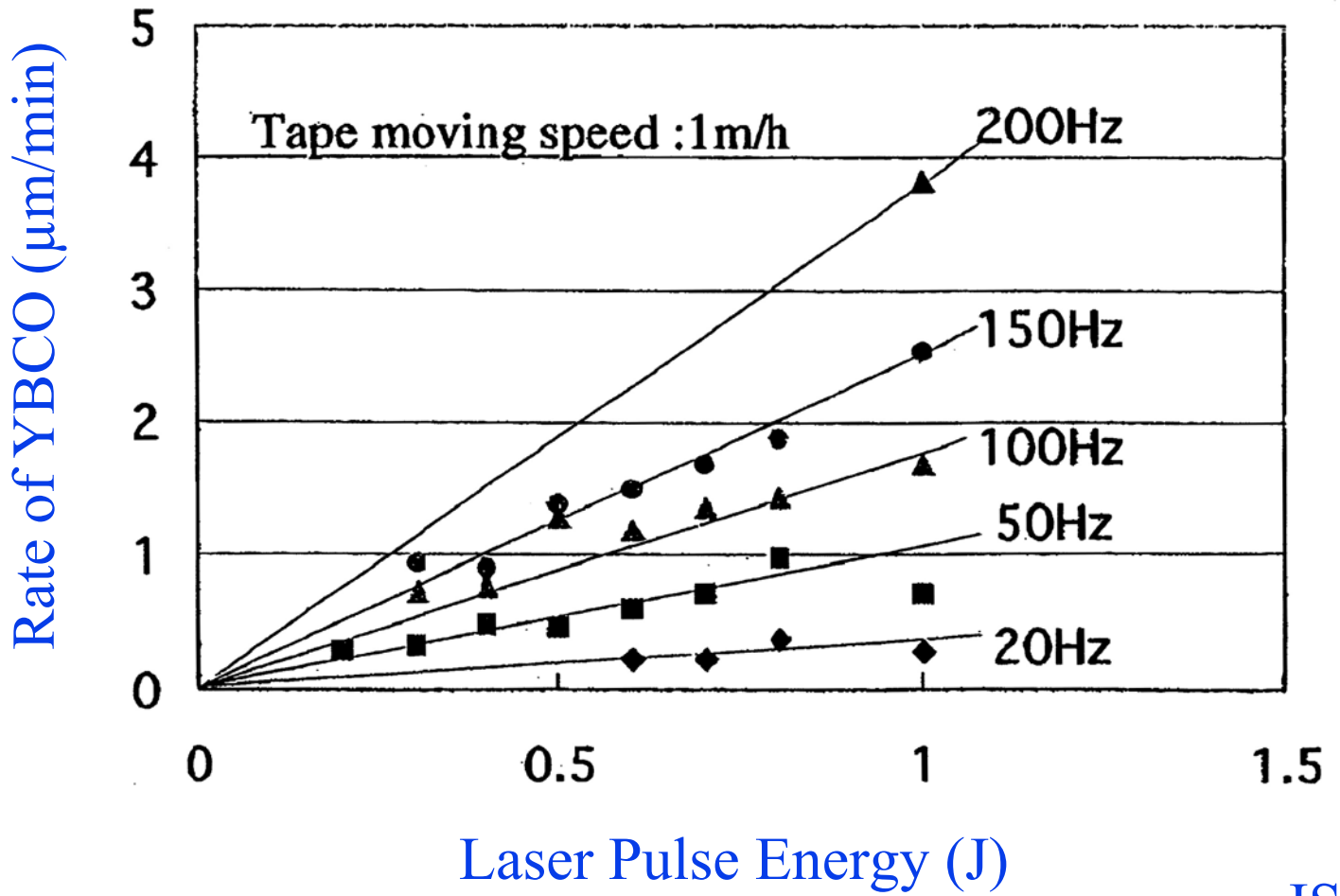


Longitudinal distribution of I_c and J_c for a 6 m-long and 1-cm wide tape.

New laser:
200 Hz/200 W laser: YSZ/ISD rate 1 µm/min
YBCO rate ≈4 µm/min

10-m long tape with 1 µm thick YBCO had J_c of 0.5 - 2 x10⁵ A/cm²

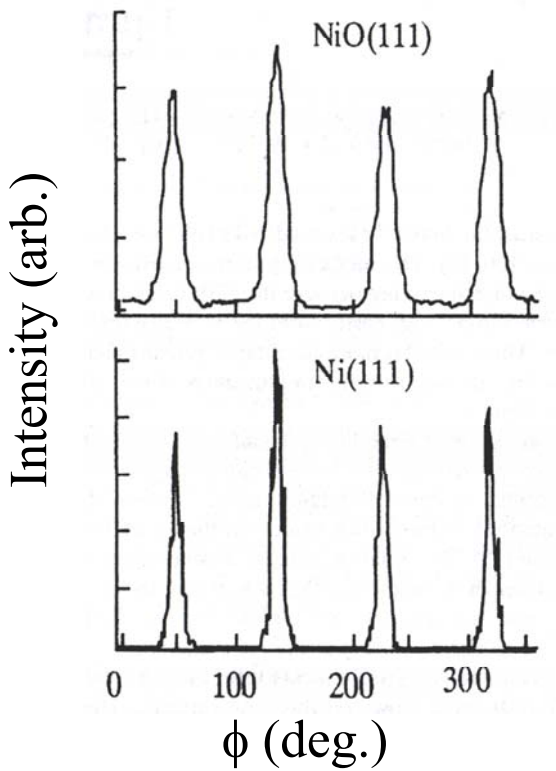
Deposition Rate of YBCO (Sumitomo/ISTEC/TEPCO result)



Surface Oxidation Epitaxy (SOE) Method (Furukawa/ ISTEC)

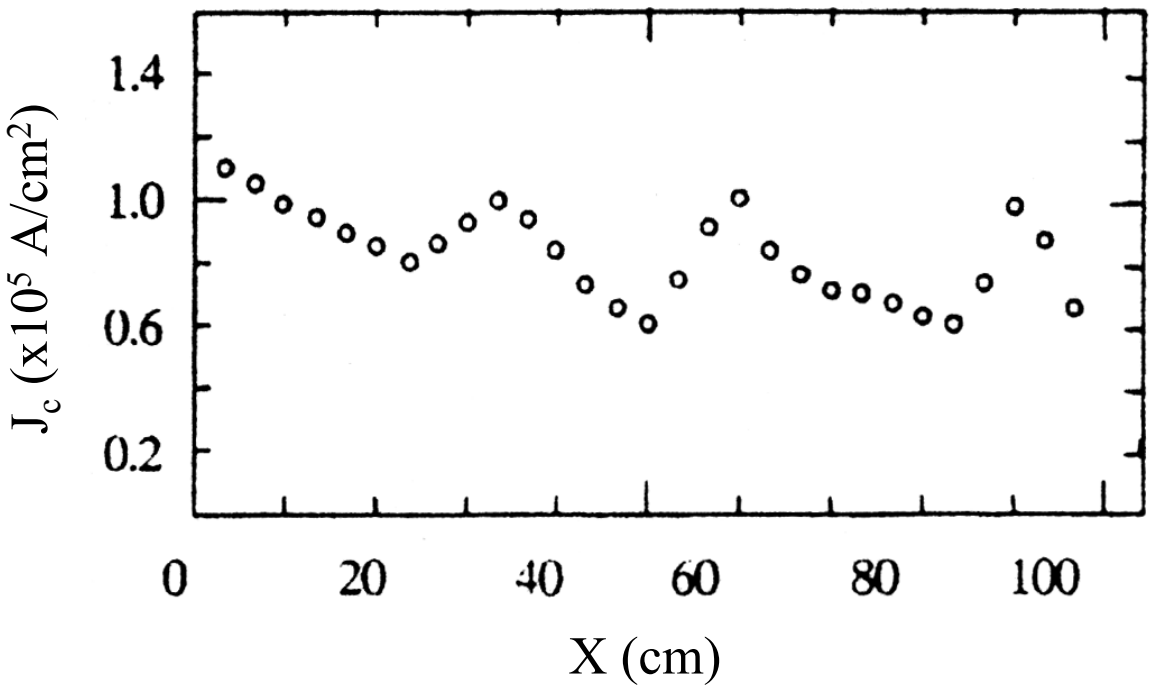
- 50-m long Ni tape with SOE NiO was produced

X-ray ϕ scans
FWHM ≈ 12°



- Short sample J_c of 3 x 10^5 A/cm^2 obtained on Ni/NiO/MgO/YBCO architecture.

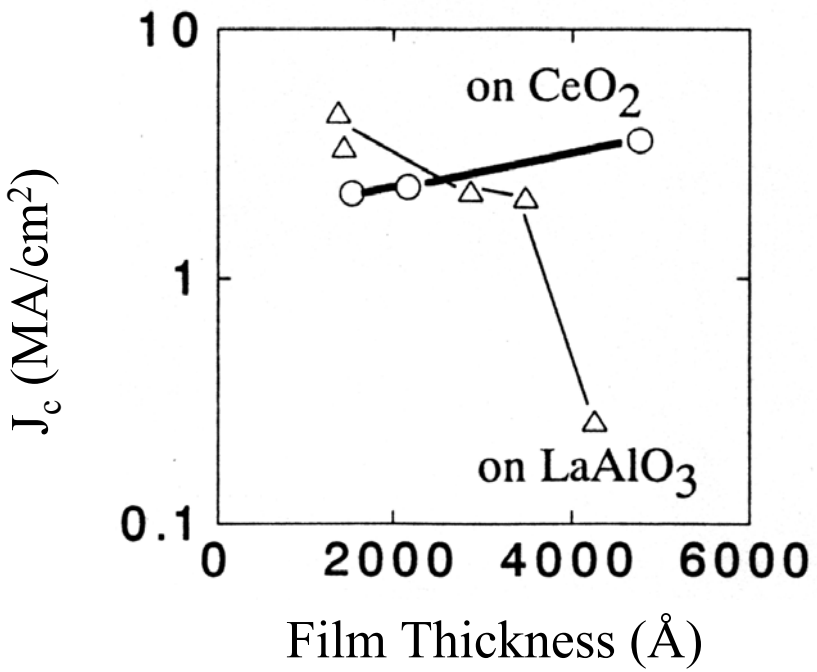
YBCO on Rolled Ag Tape (Toshiba Corp)



J_c distribution of a Y-123 film deposited (PLD) on rolling textured Ag tape with a length of 1 m.

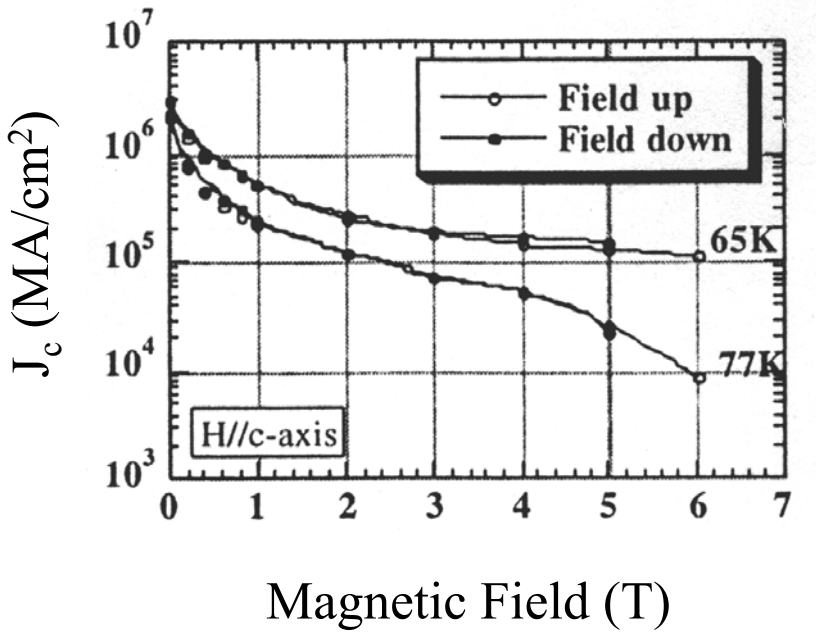
Ref: Y. Iijima and K. Matsumoto, Supercond. Sci. Technol. 13 (2000) 68-81.

TFA - Metalorganic Deposition (MOD) - ISTEC



- 5-cm dia. Substrates
- $J_c \approx 7 \times 10^6$ A/cm^2

Ref: ISTEC Journal vol. 13, no. 3, 2000.



- $J_c = 2.2 \times 10^6$ A/cm^2
- HC/IBAD-YSZ/CeO_2/YBCO

Ref: Y. Shiohara, Fall 2000 MRS

Liquid-Phase Epitaxy (LPE) - ISTEC

- $J_c \approx 2 \times 10^6$ A/cm^2 on MgO single crystals (YBCO ≈ 5 μm)
- LPE on metallic substrates are being tried

YBCO LPE film
(YBCO + MgO) LPE film
YBCO seed
MgO
Hastelloy
MgO
YBCO seed
(YBCO + MgO) LPE film
YBCO LPE film

Superconductivity Research at ISTEC
No. of Patent Applications

	Japanese applications			International applications			
F.Y.	**SRL-ISTEC**	**Entrusted**	**Total**	**SRL-ISTEC**	**Entrusted**	**Total**	**Grand Total**
1988	35	0	35	0	0	0	35
1989	52	10	62	3	0	3	65
1990	7	5	22	18	6	24	46
1991	12	18	30	19	1	20	50
1992	10	16	26	25	12	37	63
1993	8	30	38	8	15	23	61
1994	2	17	19	9	34	43	62
1995	0	24	24	0	19	19	43
1996	1	29	30	0	16	16	46
1997	1	18	19	1	20	21	40
1998	0	18	18	2	8	10	28
1999	0	23	23	0	19	19	42
Total	**138**	**208**	**349**	**85**	**150**	**235**	**581**

International applications include the total number of applications to USA,EPC, Korea and Canada.

Ref: ISTEC Journal Vol. 13 No. 3, Nov. 30, 2000

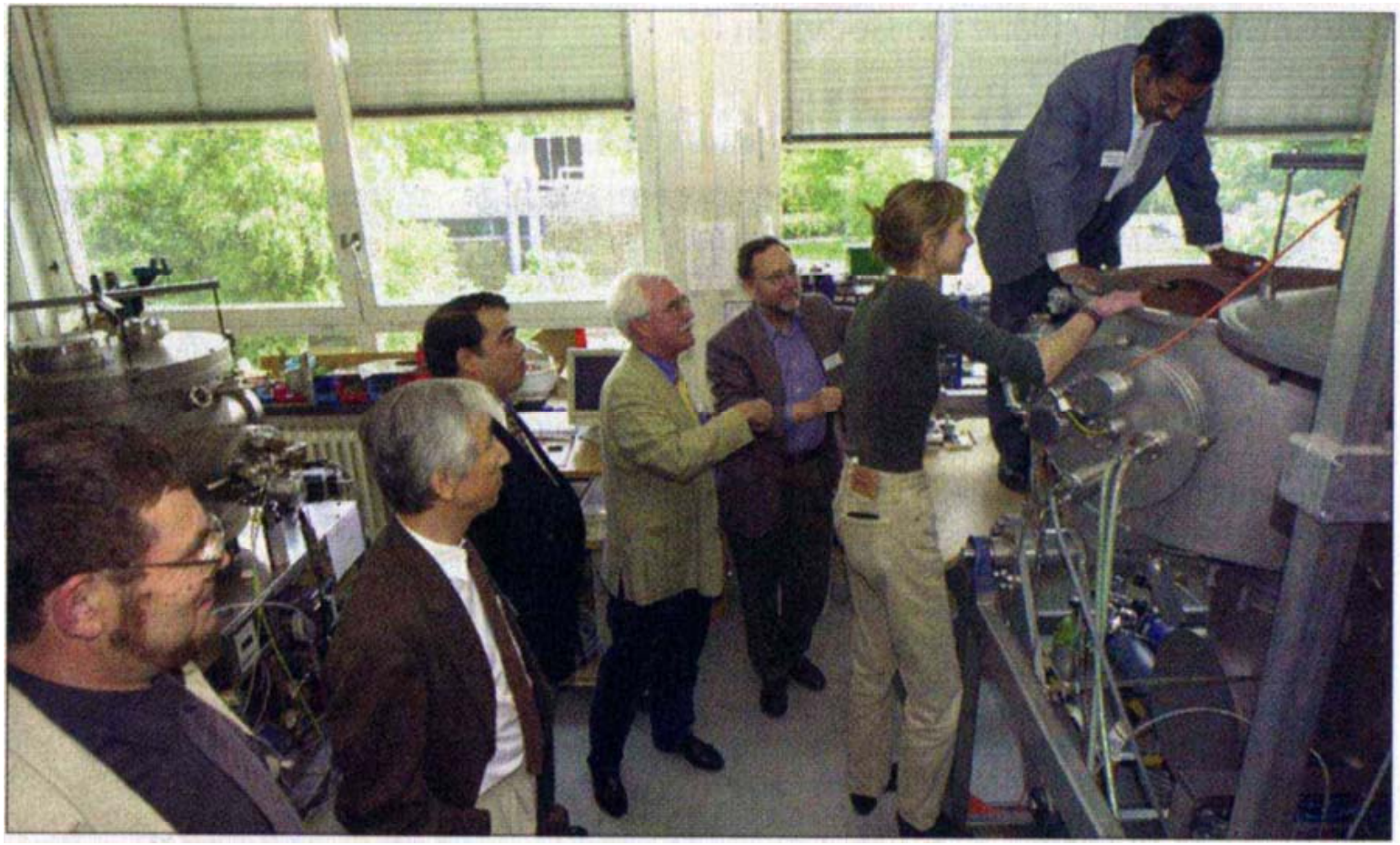
"Finally, the most important point in the practical application of Y-123-coated conductors is the manufacturing cost. It is expected that a truly practical high-temperature superconducting tape will be realized by the development and combination of various manufacturing methods described in this review."

Y. Iijima & K. Matsumoto, High-Temperature-Superconductor Coated Conductors: Technical Progress in Japan, Supercond. Sci. Technol. 13 (2000) 68-91.

EUROPEAN FRAMEWORK PROGRAM (Brite-Euram)

- MUST- Multifunctional Flexible High-Temperature Superconducting Tapes
- READY- Refrigerated Efficiency AC Conductor by (MOCVD) Deposition of YBCO
- CONTEXT- Consortium on Textured Substrates
- SUPERTEXT- Superconductor on Textured Substrates
- SUPERPOLI- Superconducting Power Link
- SHIFT- Superconducting High Field Coils for High Field Technology
- CONECTUS- Consortium of European Companies Determined to Use Superconductivity

Large IBAD Chamber @ Göttingen, Germany



Conductor Prices

- Copper
  - $10/kA-m (RL Hughey)
  - Very high volume and very mature
- Aluminum
  - $2/kA-m (RL Hughey)
  - Very high volume and very mature
- NbTi
  - $1/kA-m (Grant)
  - Mature
- $NbSn_3$
  - $8/kA-m (Grant)
  - Early production
- OPIT BSCCO
  - $500/kA-m (ASC)
  - Early production

Ref: 3M Corp./1999 wire workshop.

Comparison of Coated Conductor Manufacturing Cost Estimates in $/kA-m

- DOE goal- $10 price
- IGC- $20
- Chapman- $4.28
  - 18,000 km/yr
  - 7.2 million kA-m/yr
- Hammond- $7.40
  - 50,000 km/yr
  - 5 million kA-m/yr
- Grant- $1875
  - 10 km/yr
  - 4000 kA-m/yr
- 3M <$10
  - Very preliminary

Ref: 3M Corp./1999 wire workshop.