June 24, 2004

Development of Ho-123 Coated Conductors by PLD Method

- for HTS Power Cable -

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Coated Conductor Project

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This work was supported by NEDO and Super-GM as Collaborative Research and Development of Fundamental Technology for Superconductivity applications.

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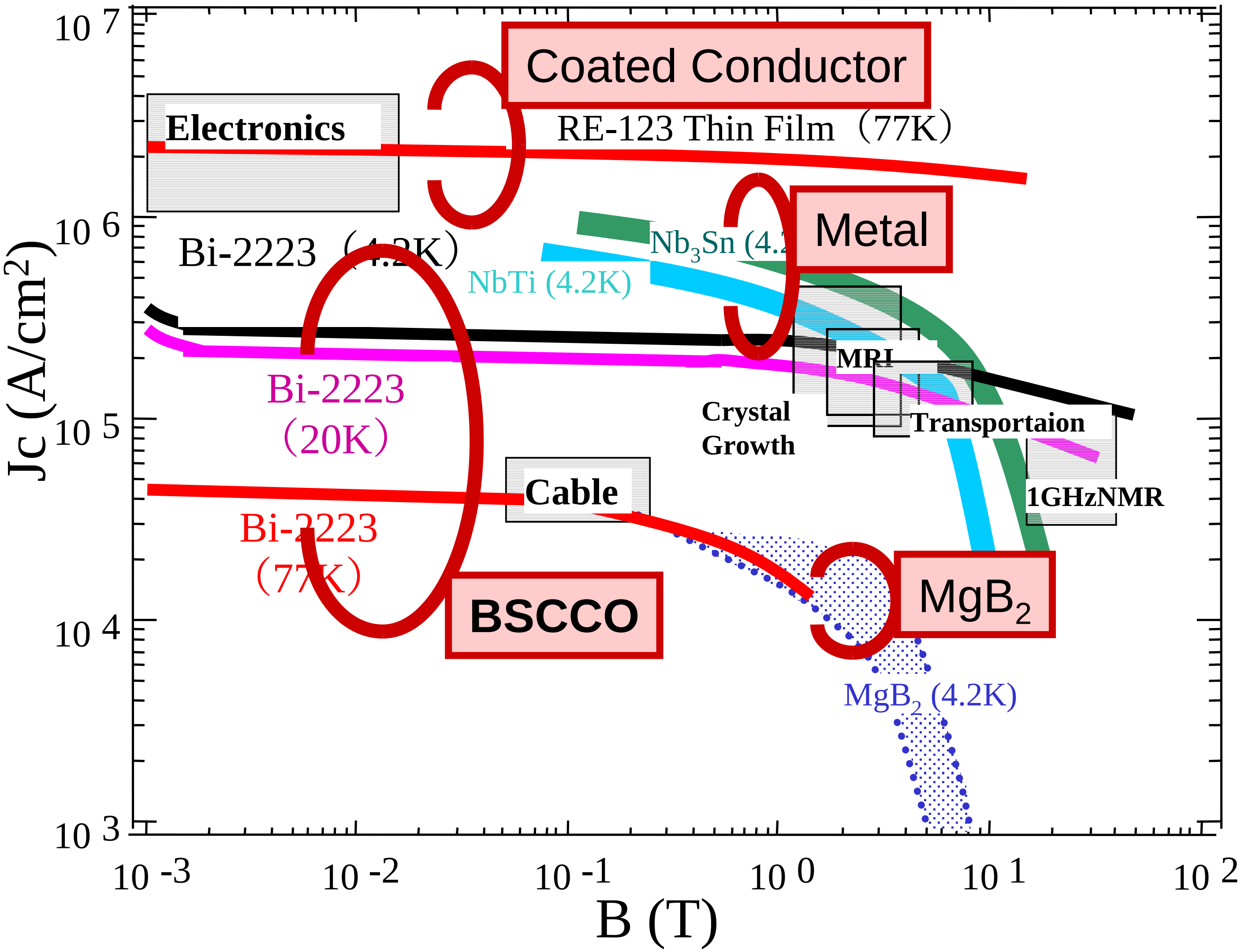
Present Status of Superconducting Wire



・Bi-2223 wires are widely applicable for various prototypes; cables, magnets, transformers, and FCLs

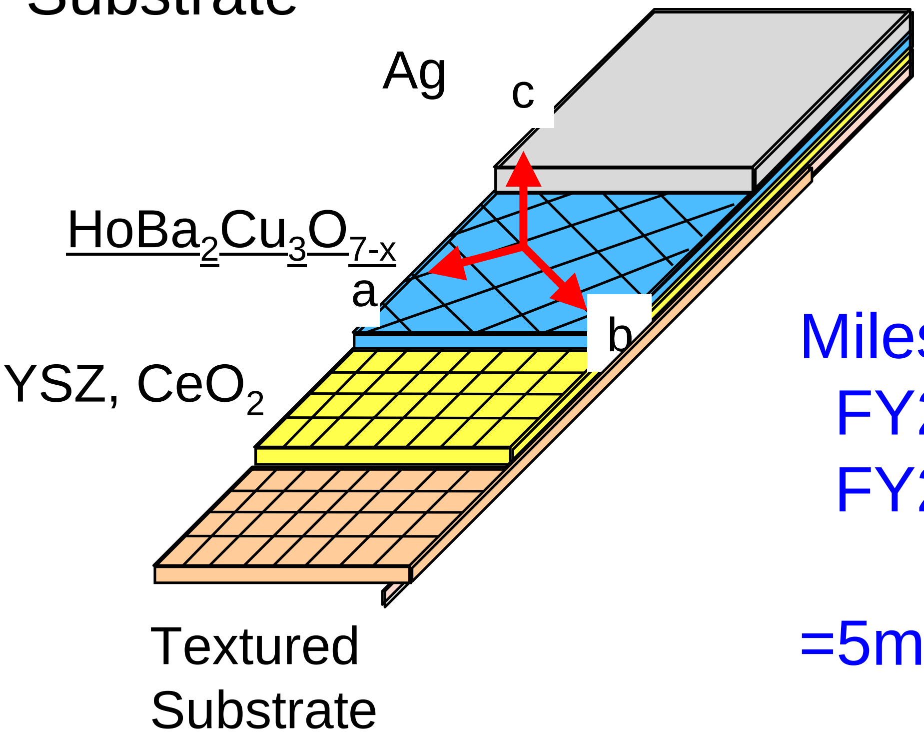
・RE123 Coated Conductors are under development

HoBaCuO Coated Conductor

Coated Conductor for National program (SEI)

・Phase I (FY1999-FY2002) : HoBCO on ISD Substrate

・Phase II(FY2003-FY2007) : HoBCO on Textured Substrate



Milestones

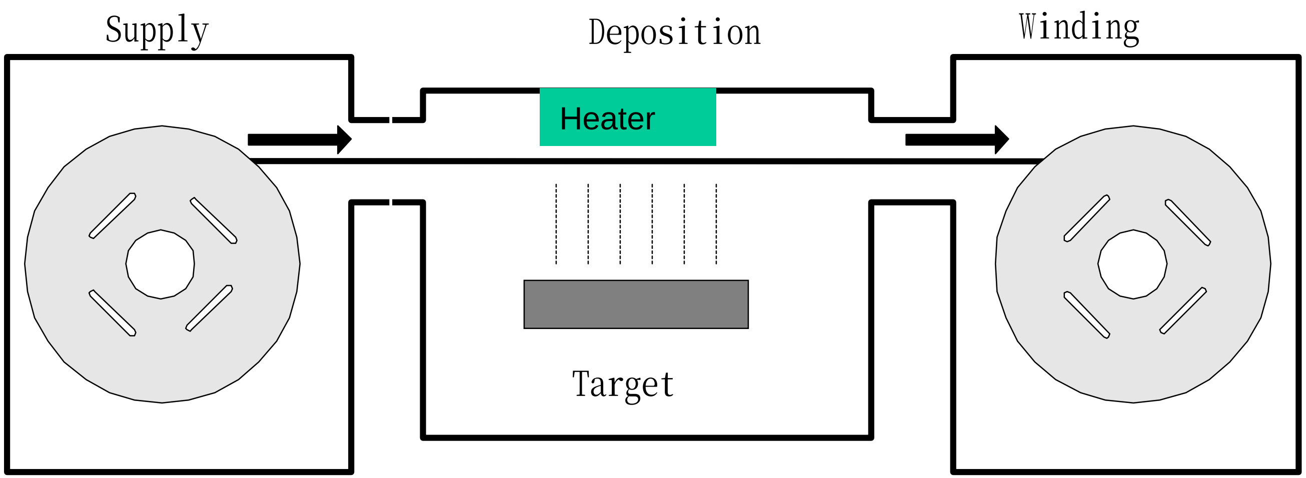
FY2005: ・200A-200m

FY2007: ・300A-500m

・Tape Speed =5m/H

・Cost =\8/Am

Deposition Process



Buffer

■Simple Oxides （CeO2,YZS, etc.）
Thin Film (<1 Micron)
Multi Layered Structure
Wide Deposition Condition
Large Area & Low Cost

→

■Conventional Large Area Deposition Process
・RF Sputter
・EB

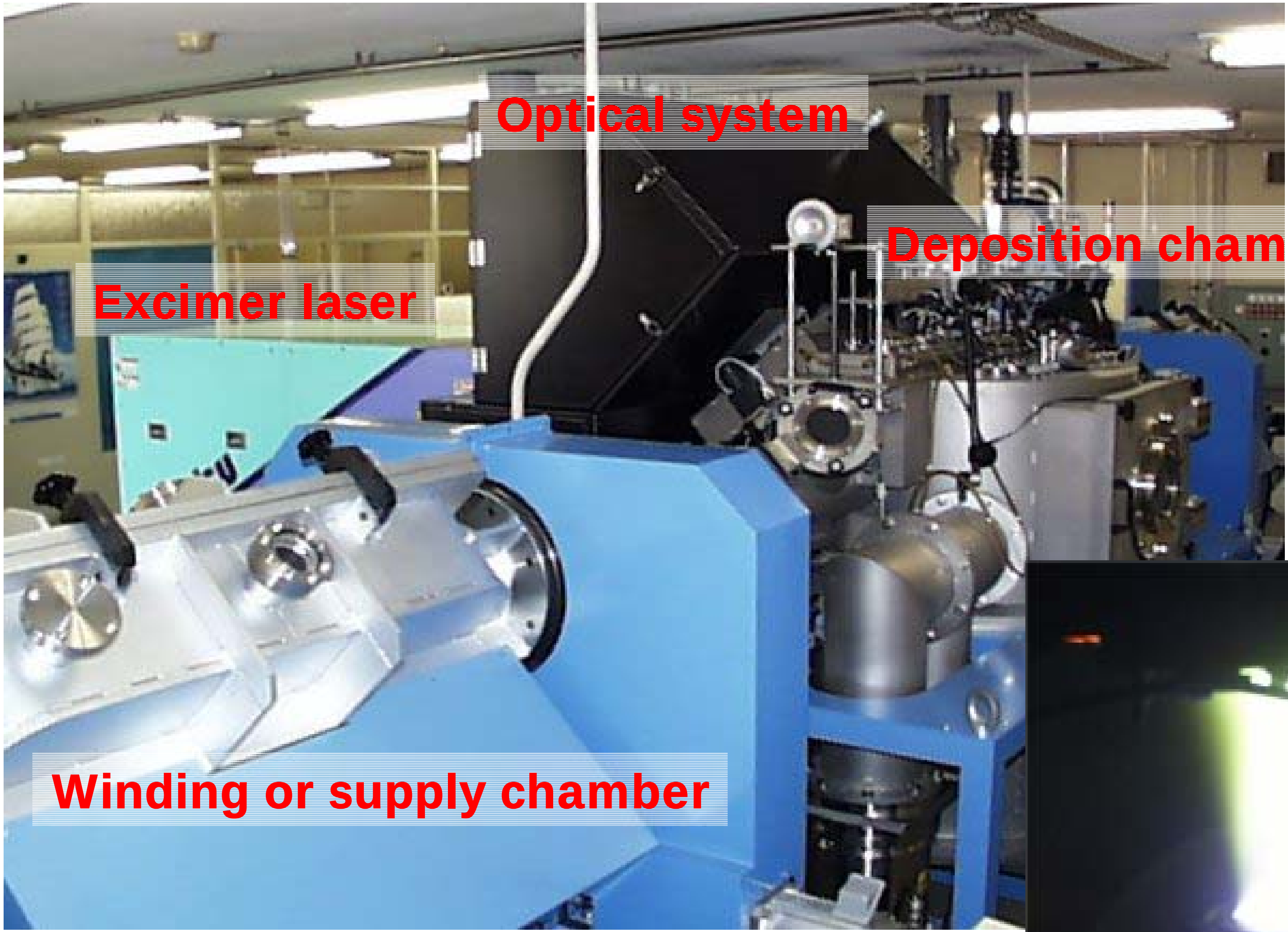
SC

■RE-123 Oxides （HoBCO）
Thick Film (>1 Micron)
High Jc & Ic

→

■Special Deposition Process
・PLD

PLD System for Long Wire



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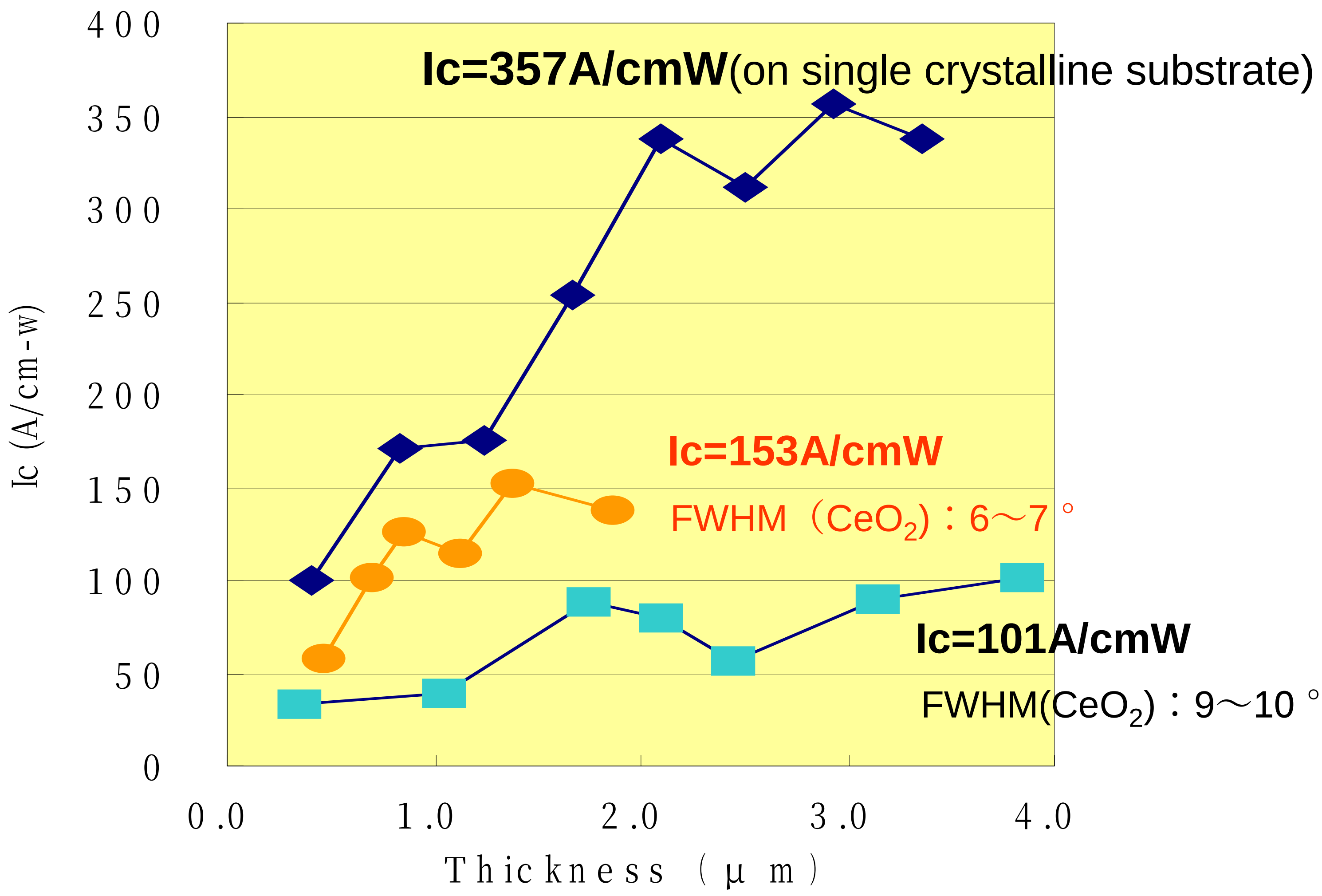
High Ic of HoBCO Layer



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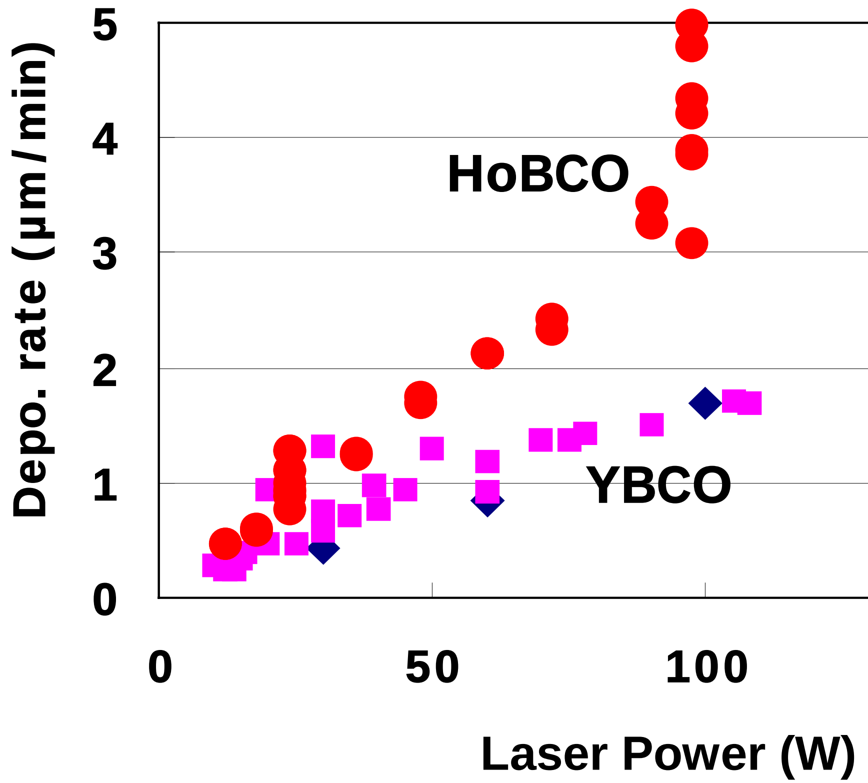
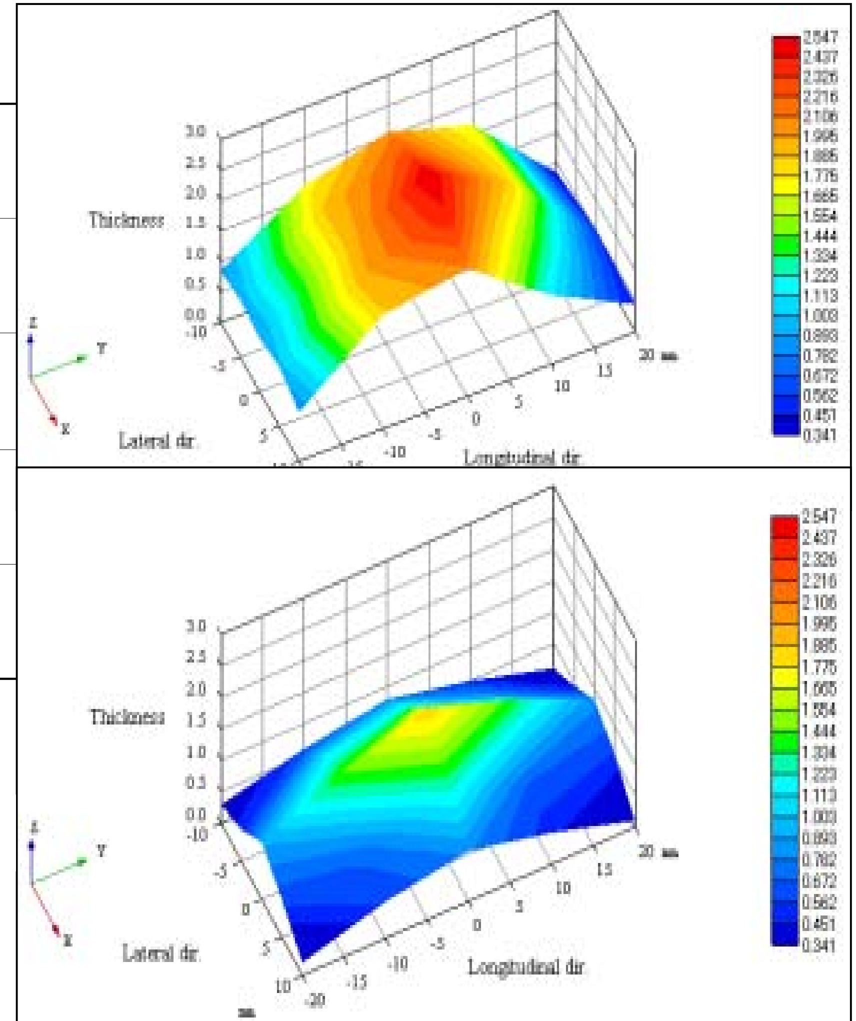
High Rate Deposition of HoBCO





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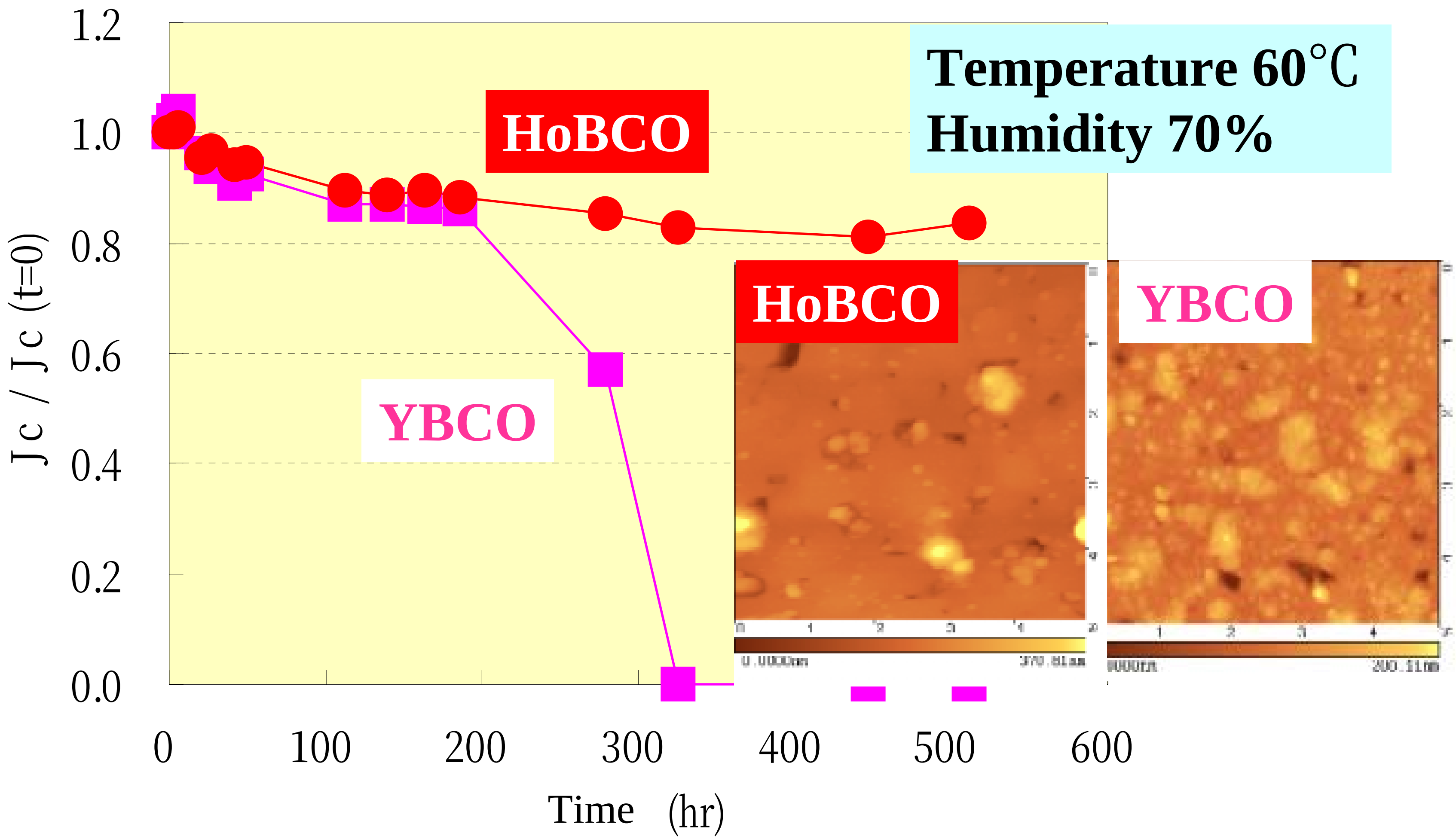
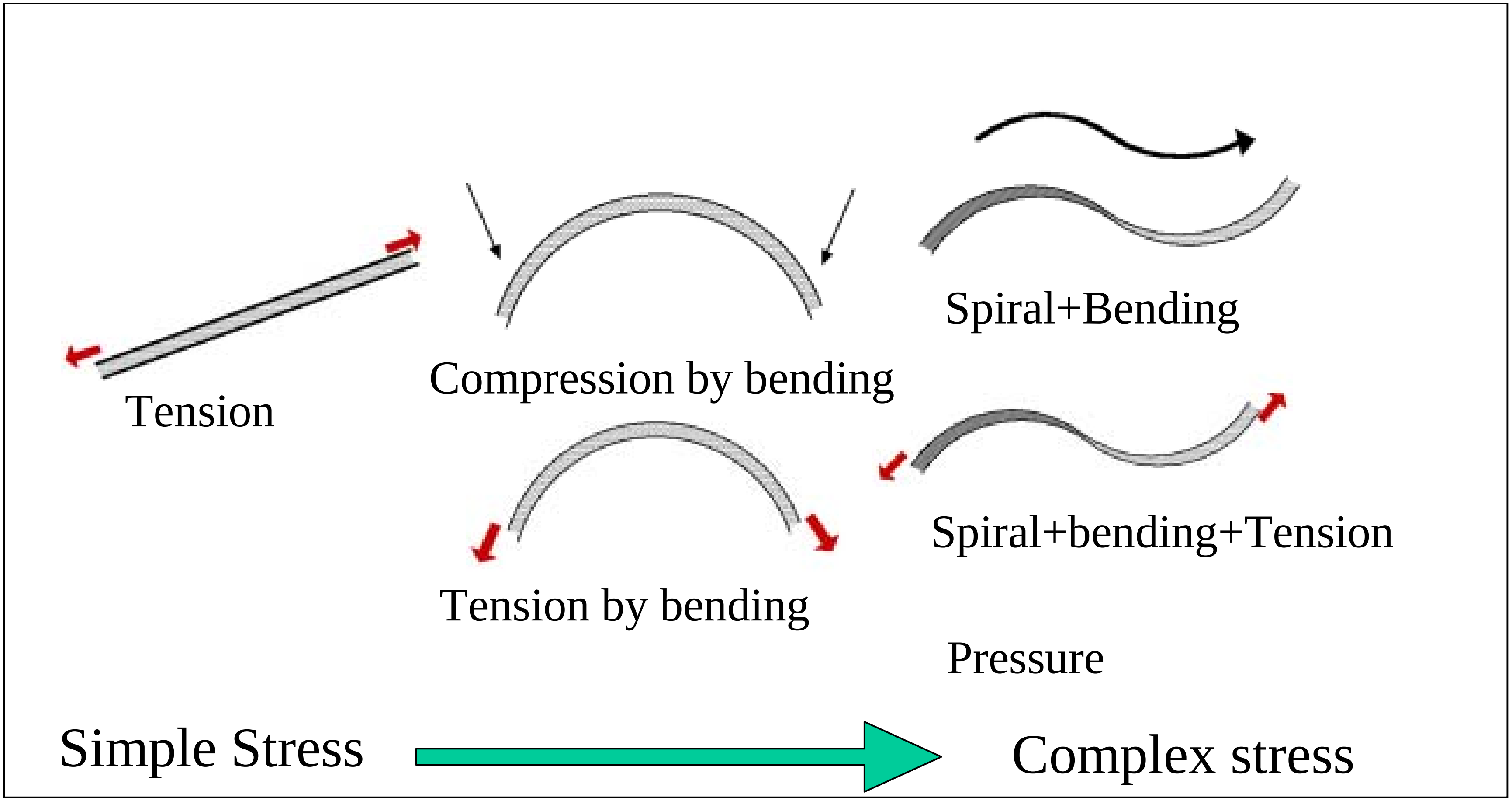
Deterioration of Jc under temperature and humidity

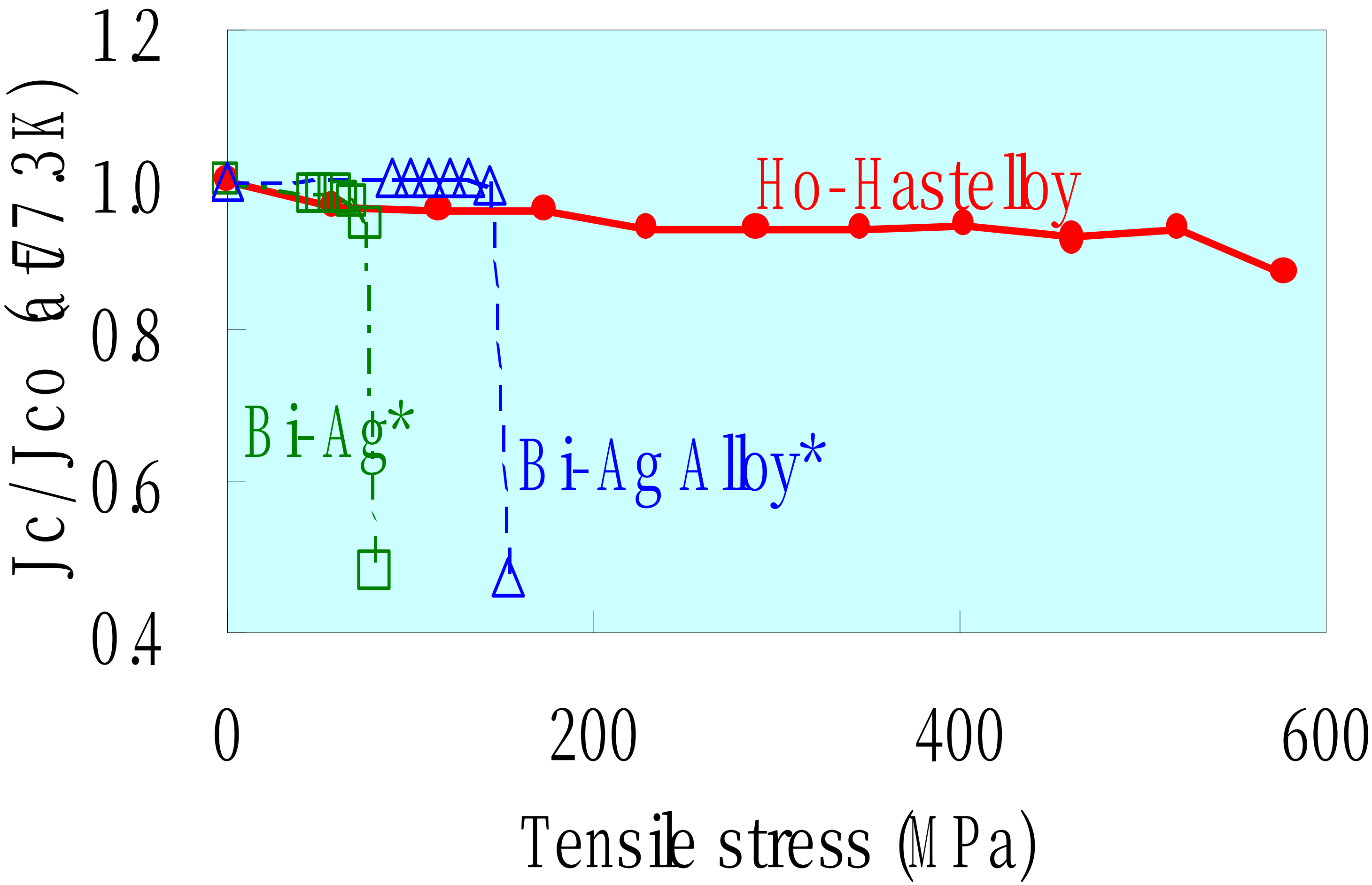


Elementary study for HTS Power Cable Conductor

Several complex stress is adopted in assembling process



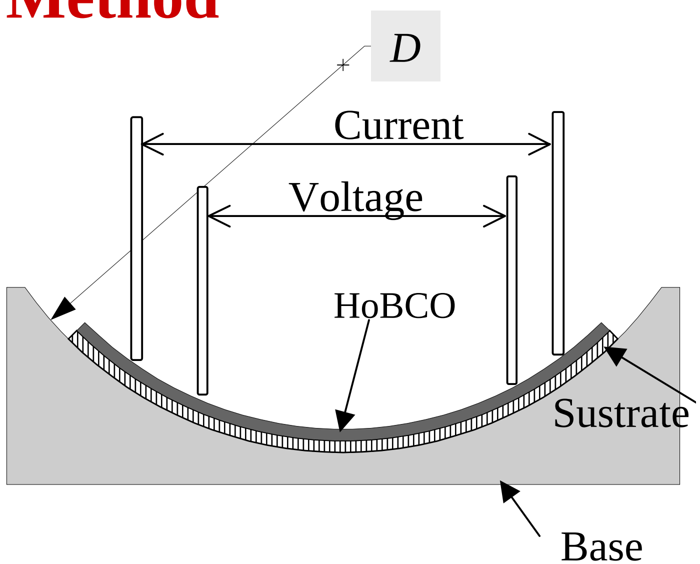
Tensile Stress on Jc of HoBCO Coated Conductor



* N.Ayai : Advances in Superconductivity XII (1999), p631p

Bending Stress on Jc of HoBaCuO Coated Conductor

Method

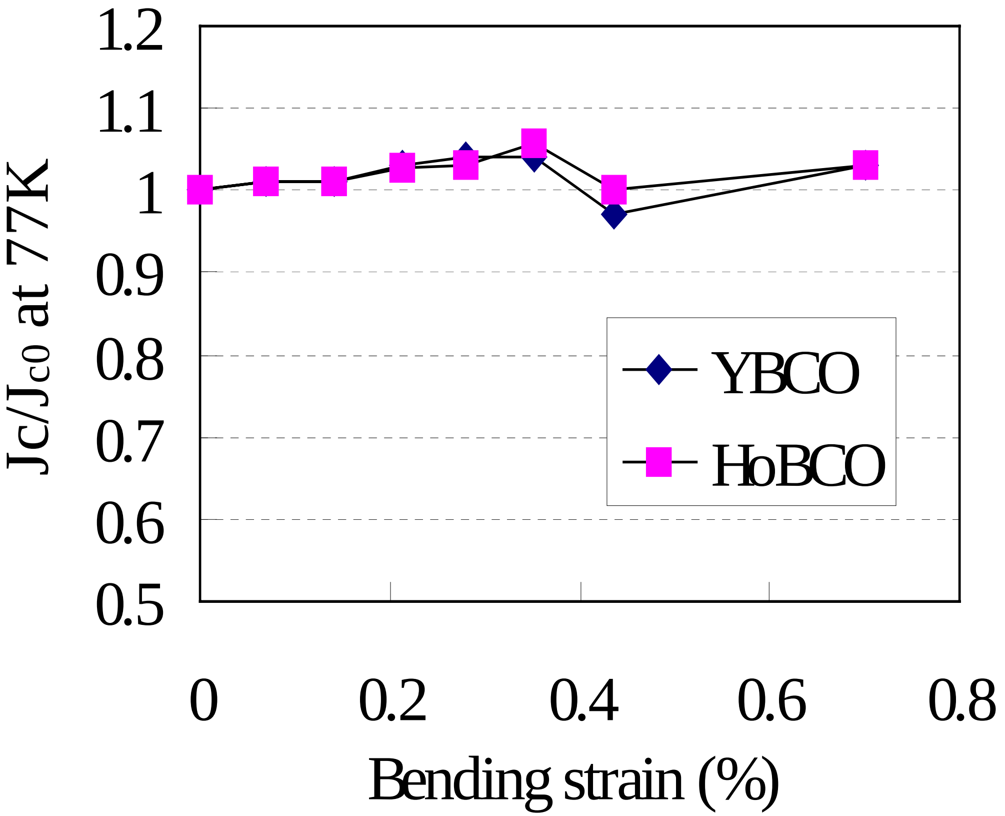


Compressive bending strain

$$\varepsilon(\%) = \frac{t}{D} \times 100$$

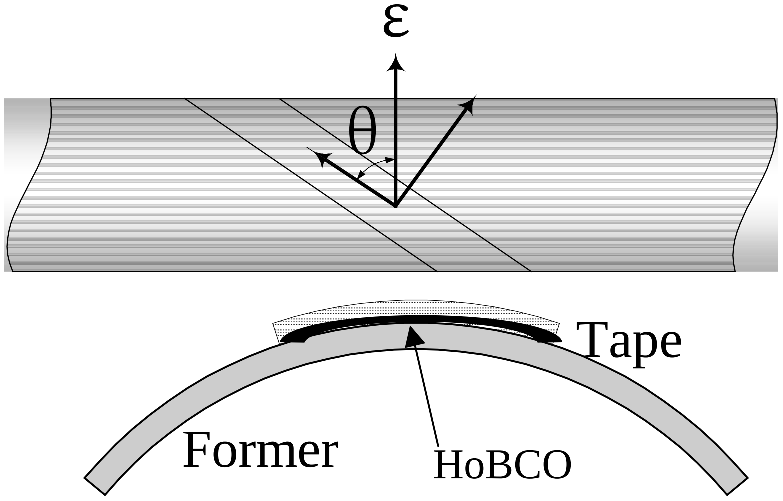
D : diameter of bending

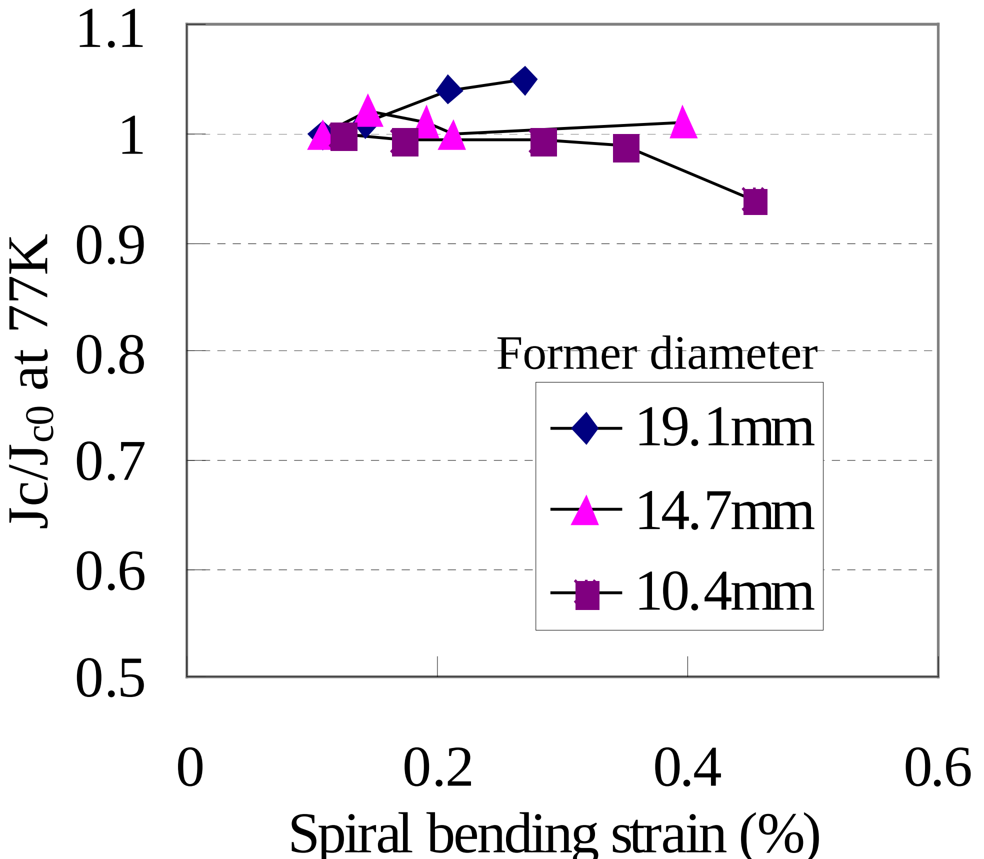
t : thickness of tape



Spiral Bending Stress on Jc of HoBaCuO Coated Conductor

Spiral bending





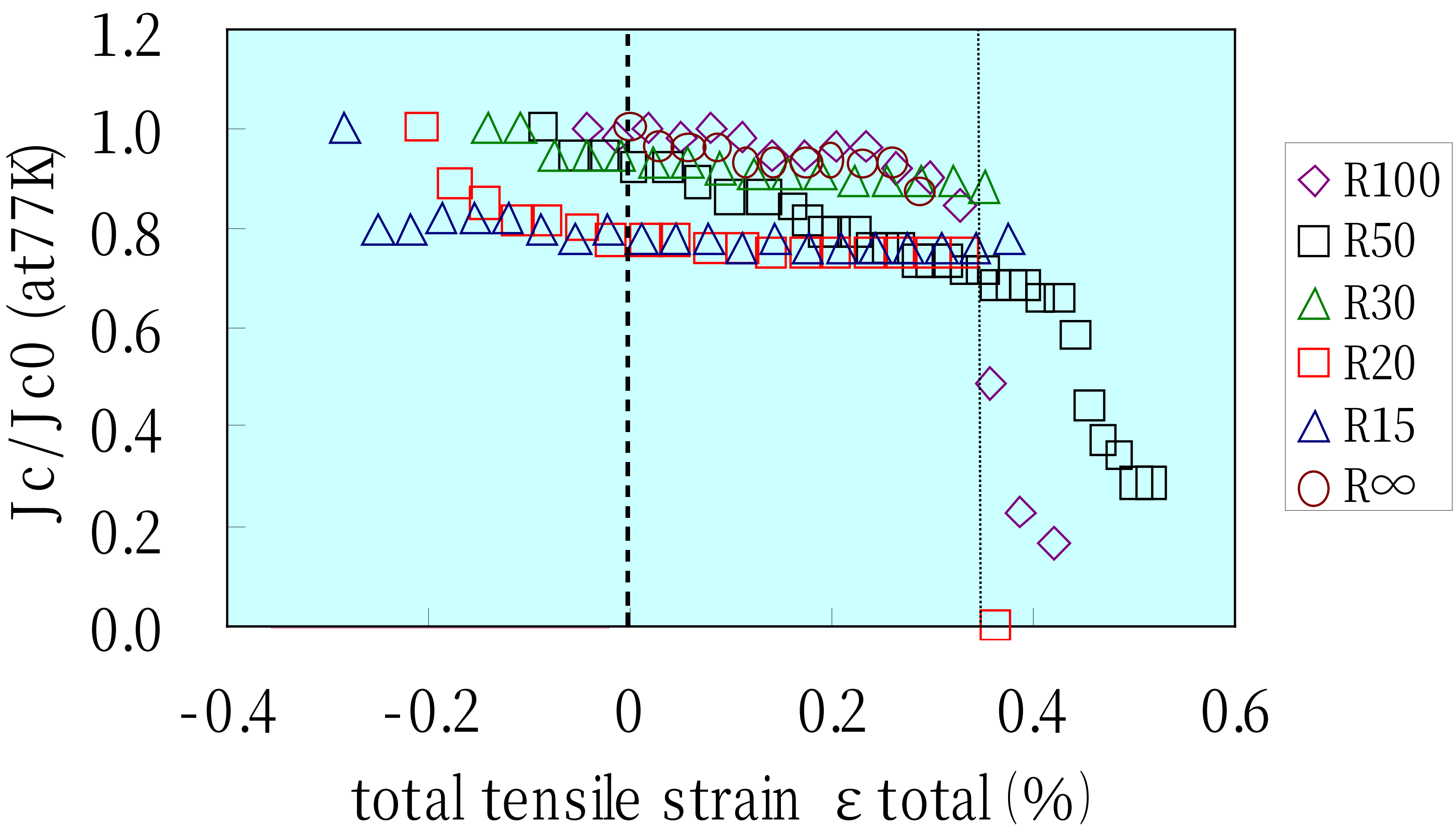
Compressive spiral-bending st

$$\varepsilon(\%) = \frac{t}{D} \times \cos\theta \times 100$$

$$\theta = \tan^{-1}\left(\frac{P}{\pi D}\right)$$

D : diameter of bending
t : thickness of tape
P : pitch of winding

Jc vs Strain(Bending + Tension) of HoBaCuO Coated Conductor

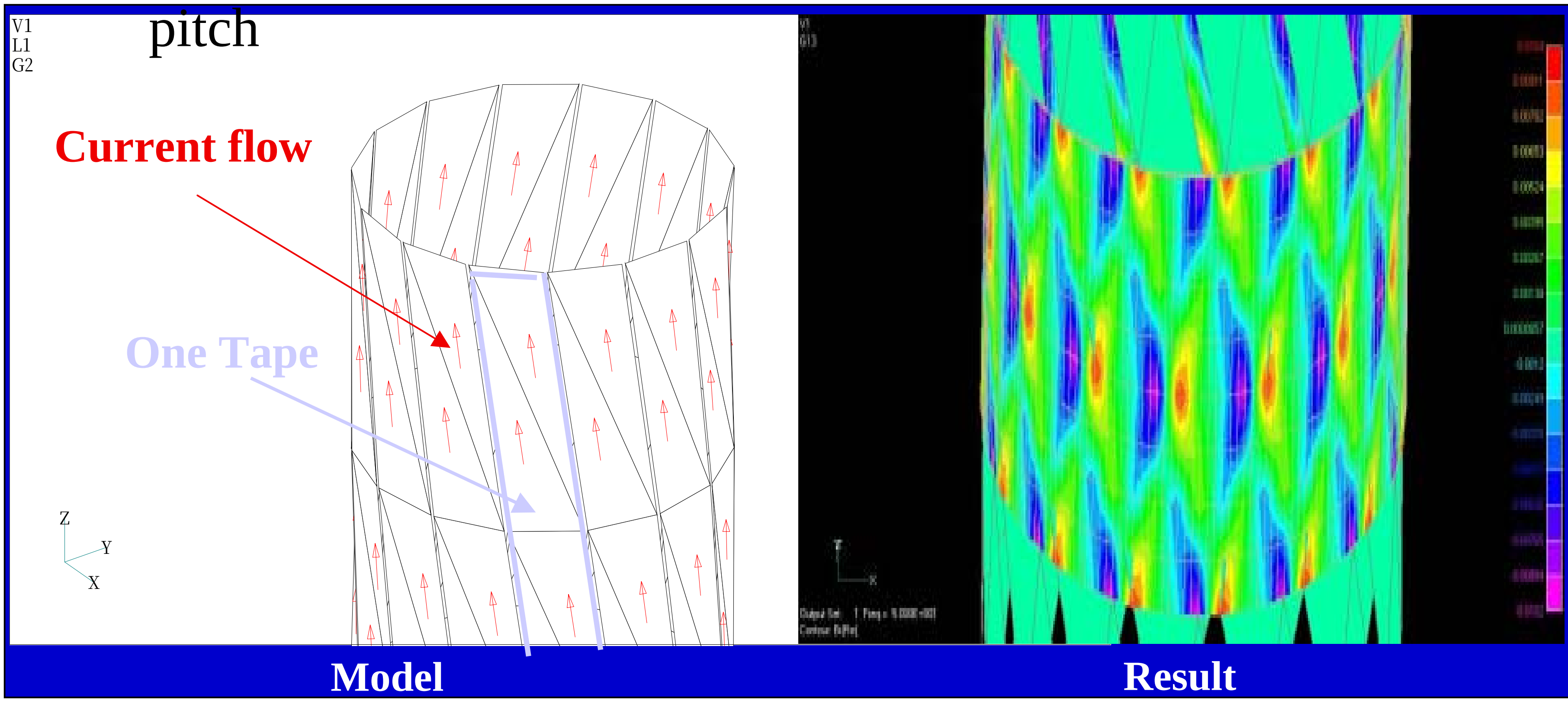


(Total tensile strain=Tensile strain-Bending strain)

Self Field Analysis of 4-Layer conductor

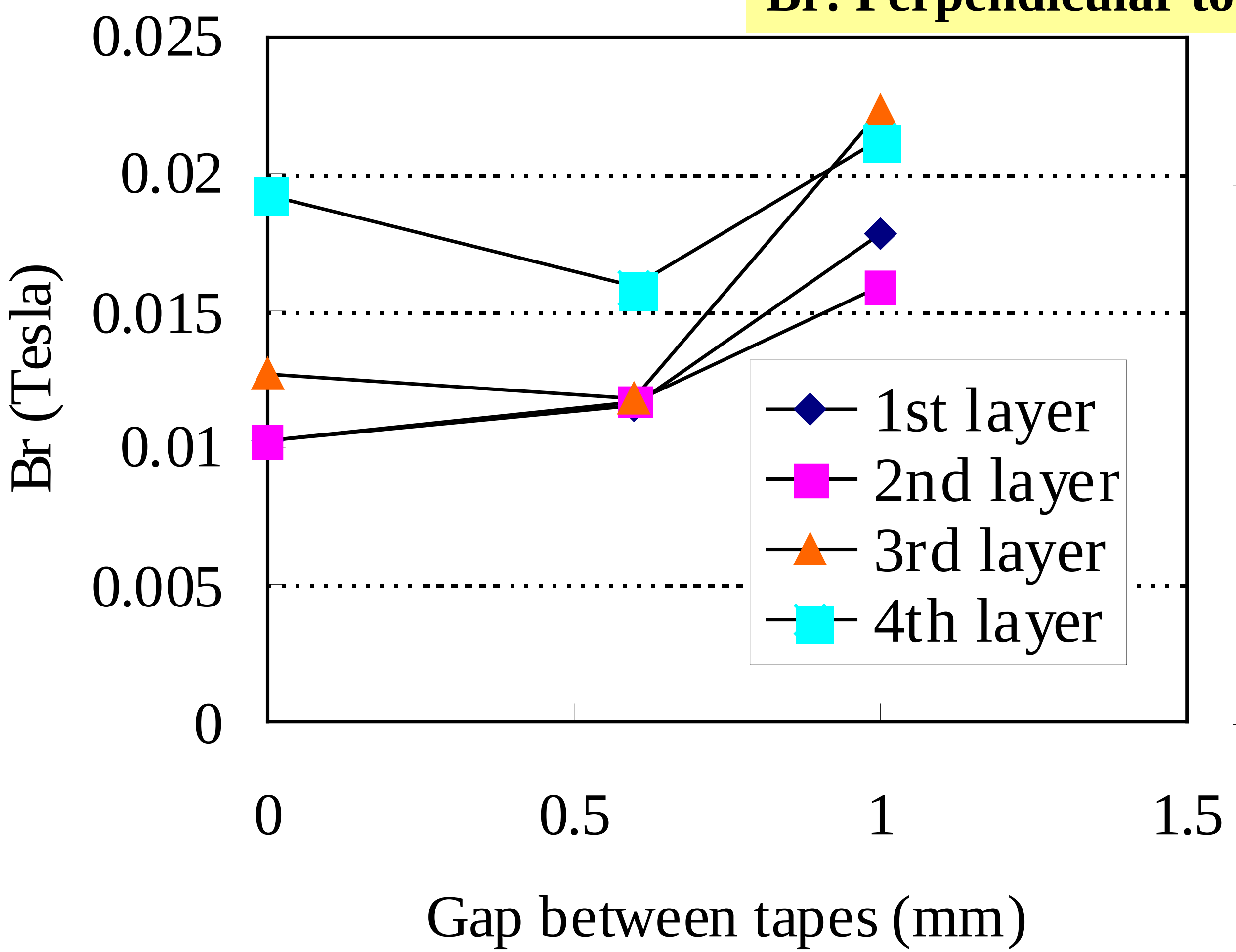
Self field analysis of 4-layer conductor

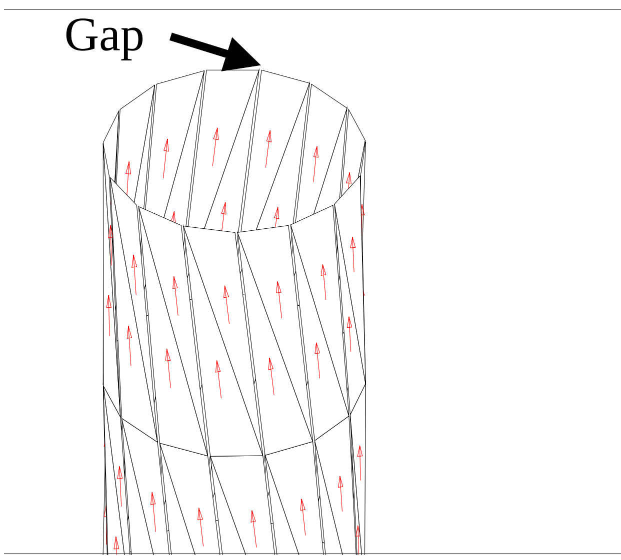
- ϕ19mm former,15tapes/layer, SSZZ, 3kA capacity
- Uniform current distribution by adjusting assembling pitch



Self Field Analysis of 4-Layer Conductor

Br: Perpendicular to HoBCO tape surface





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AC loss Calculation of 4-layer Conductor by Self Field

Parallel to HoBCO tape surface (Bz, Bt)

$$W = 2\mu_0 J_c d f H \left(1 - \frac{2}{3}\frac{J_c d}{H}\right) \quad (H > Jcd)$$

$$W = \frac{2}{3}\mu_0 f \frac{H^3}{J_c d} \quad (H < Jcd)$$

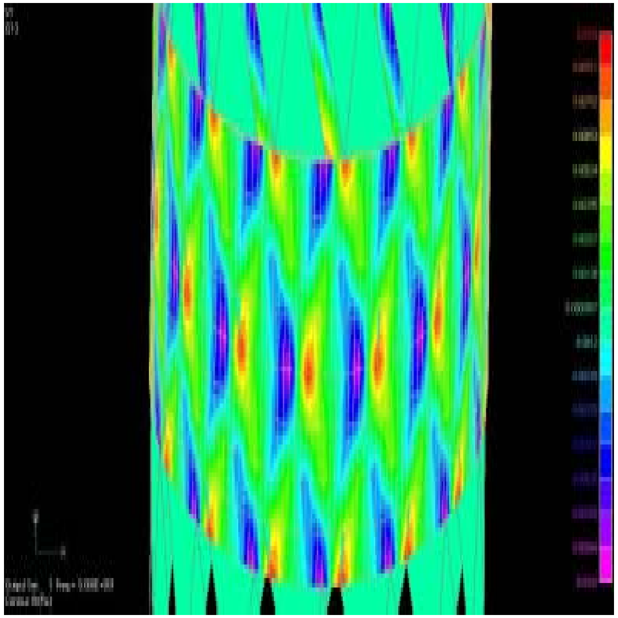
Perpendicular to HoBCO tape surface (Br)

$$Q = \frac{4\mu_0 a \ \ JcH}{S} g\left(\frac{H}{Hc}\right)$$

$$g(x) = (2/x)\ln\cosh x - \tanh x$$

+

Self field analysis



3kA-single conductor: AC loss (gap:0mm) =0.46W/m

AC loss (gap:0.6mm) =0.36W/m

AC loss (gap:1.0mm) =0.88W/m

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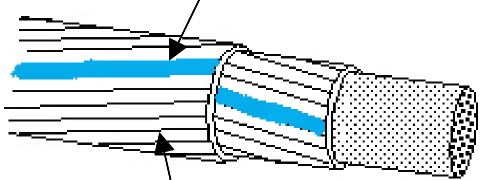
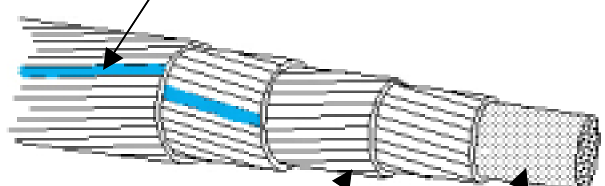
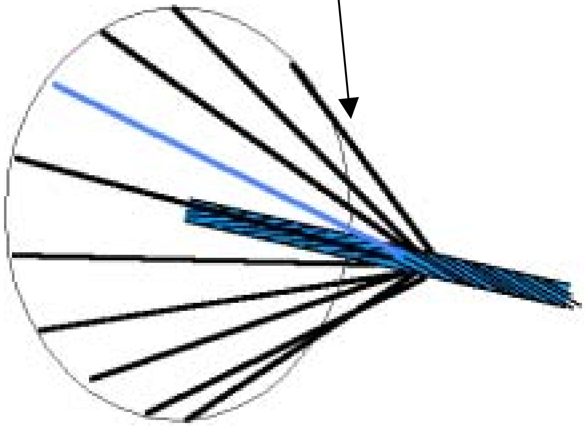
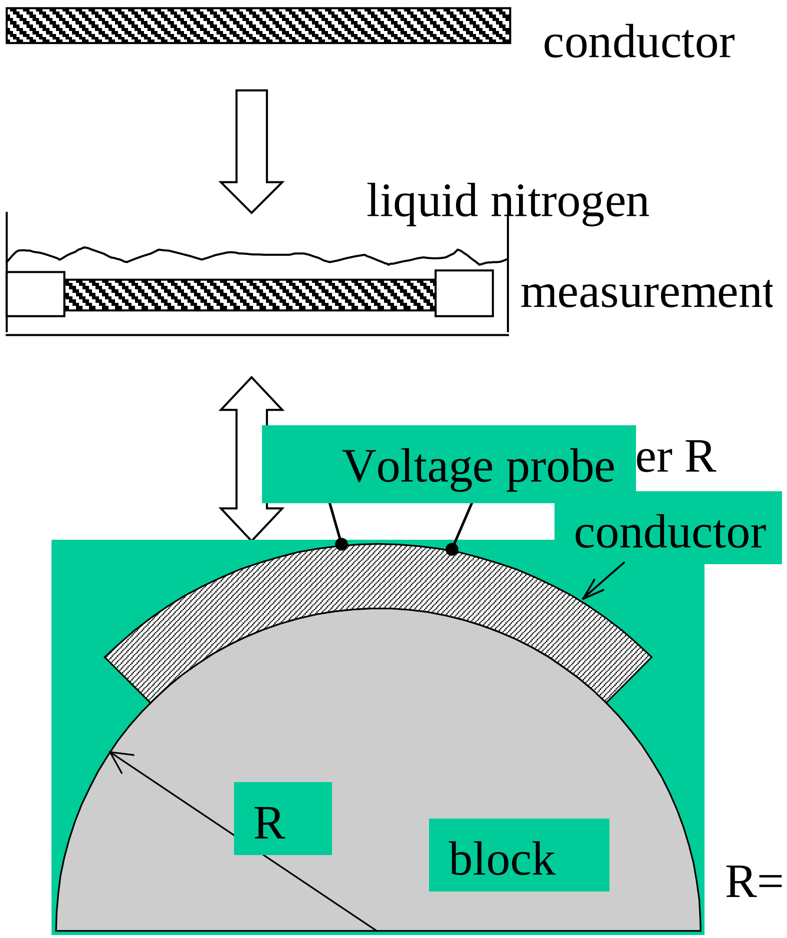
Assembling for Cable Conductor

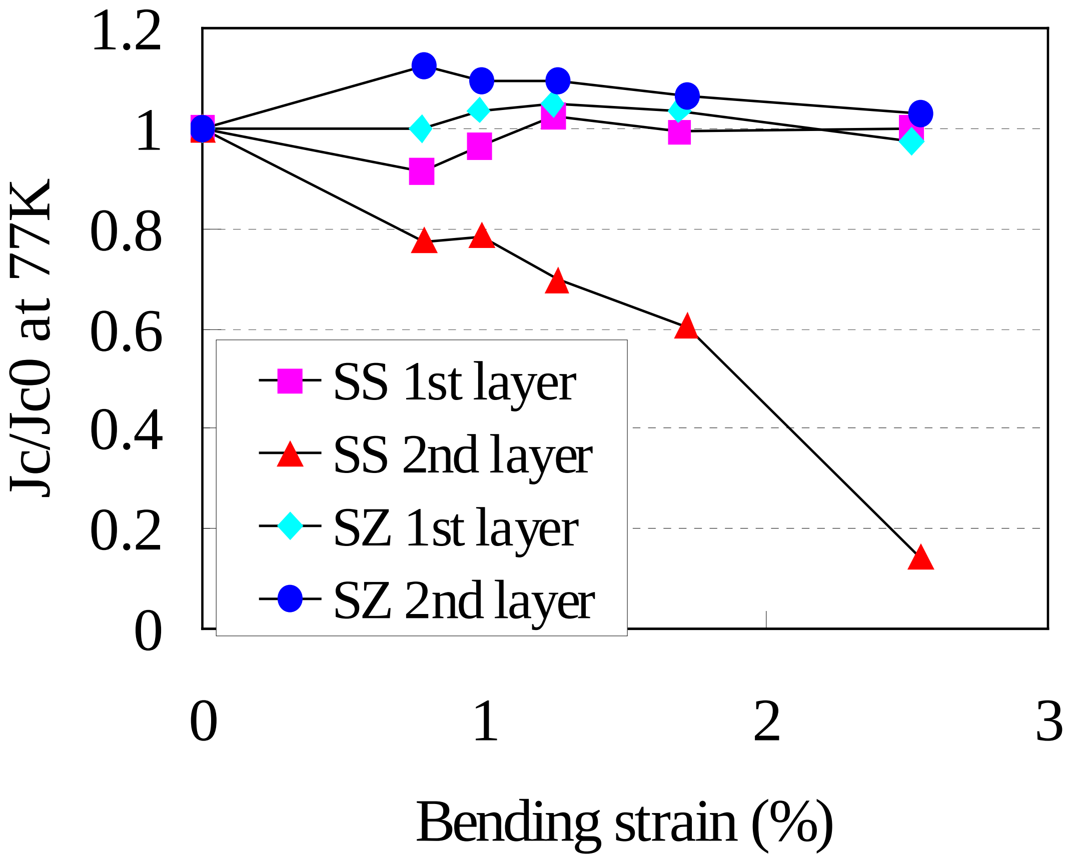
2-layer, 1m (hand winding)	4-layer, 1m (hand winding)	4-layer, 7m (assembling machine)
SS,SZ spiral	SZSZ spiral	SSZZ spiral
HoBCO tape  dummy tape	HoBCO tape  dummy tape former	All dummy tape 

Parameter of 2-Layer Conductor

Item	Parameter
Cable	Size : 19mm x 21mm Former : Cu pipe Structure : 2 layer Length : 1m Spiral winding : SS, SZ SC tape : 1 (HoBCO layer is compressive) Dummy tape : 14
HoBCO tape	Size : 4mm x 0.08mm Substrate : Hastelloy Buffer : YSZ Jc : 10^5A/cm^2(77K,0T)

Bending Properties of 2-Layer Conductor

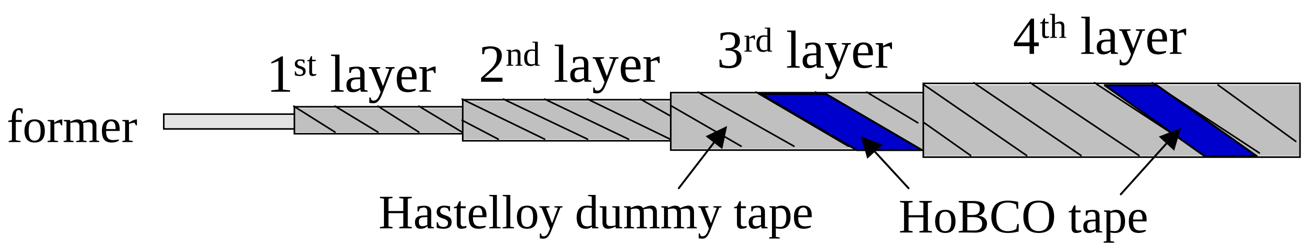




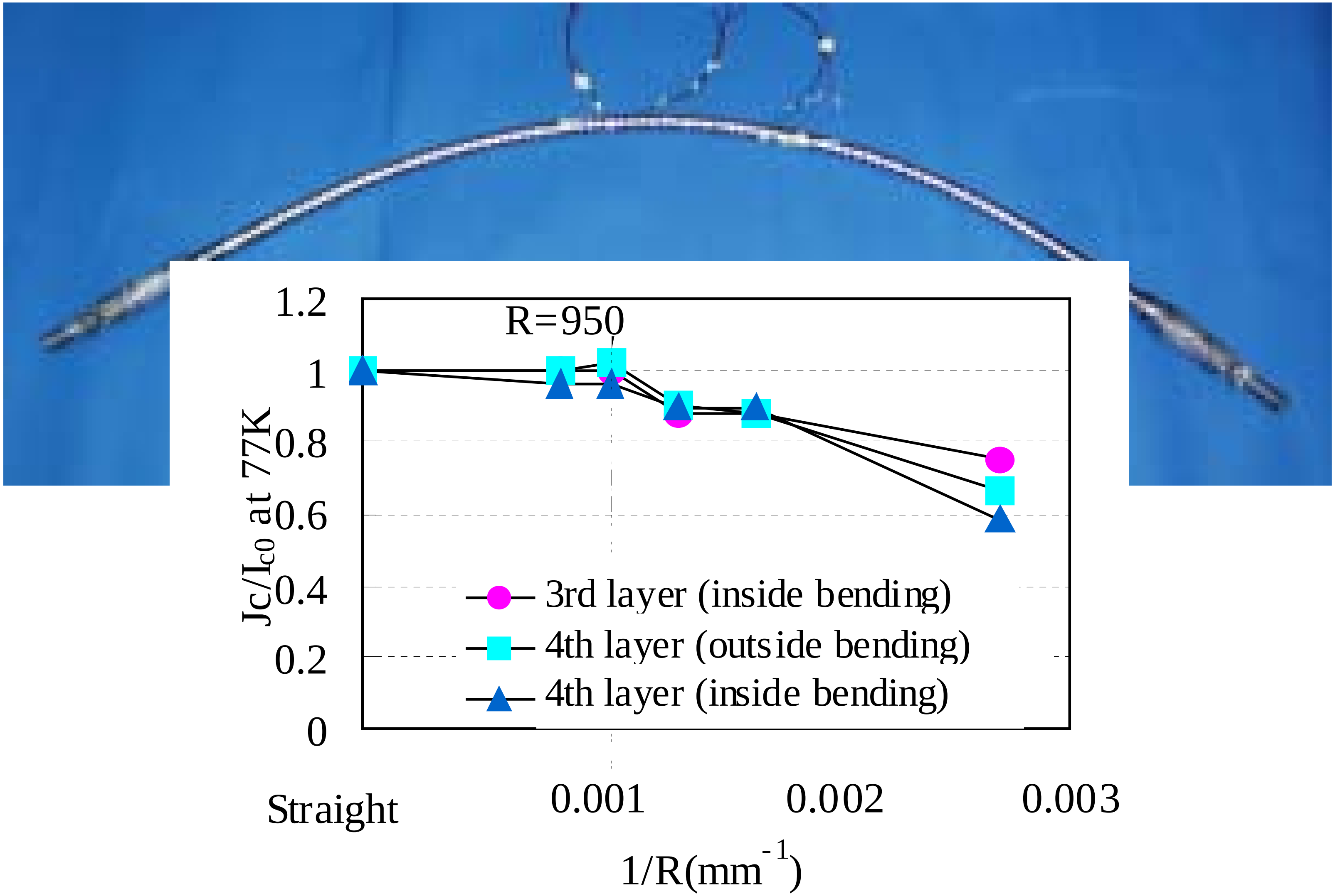
R=1200mm, 950mm, 750mm, 550mm, 370mm

Parameter of 4-Layer Conductor

Item	Parameter	
Cable	Size	: 19mm x 21mm x 1m
	Former	: Cu pipe
	Structure	: 4 layer, SZSZ winding
	SC tape	: 1 (HoBCO layer is compressive)
	Dummy tape	: 14
HoBCO tape	Size	: 4mm x 0.08mm
	Substrate	: Hastelloy
	Jc	: 10^5A/cm^2 (77K,0T)



Bending properties of 4-Layer Conductor



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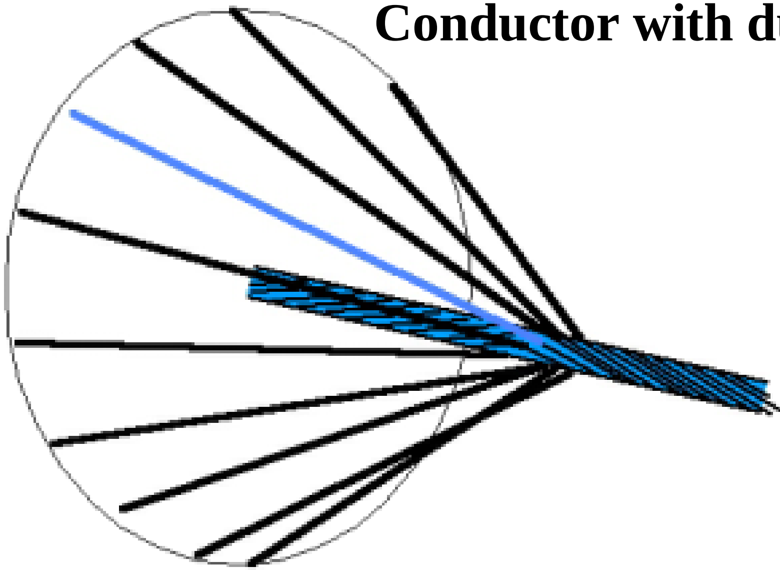
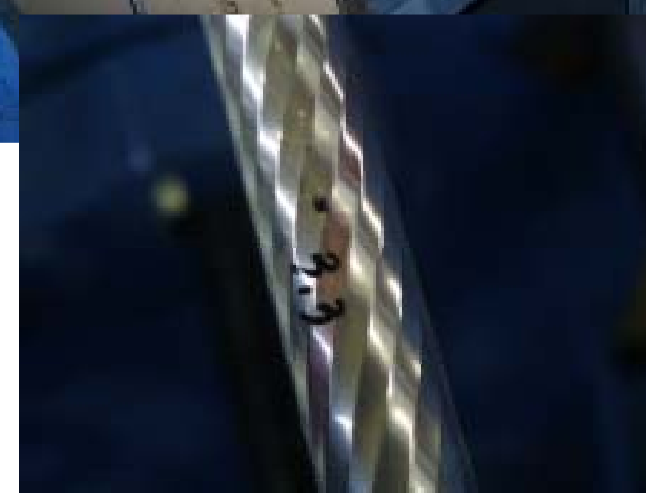
4-Layer, 7m Cable Conductor



Conductor with dummy tape by using assembling machine



Parameter
Tape : 4mm x 0.08mm hastelloy
Former :Cu stranded flexible cable
Strand number :15 for each layer
1st layer :OD=19.5mm, Pitch=300mm, S
2nd layer :OD=19.9mm, Pitch=470mm, S
3rd layer :OD=20.9mm, Pitch=380mm, Z
4th layer :OD=21.4mm, Pitch=170mm, Z

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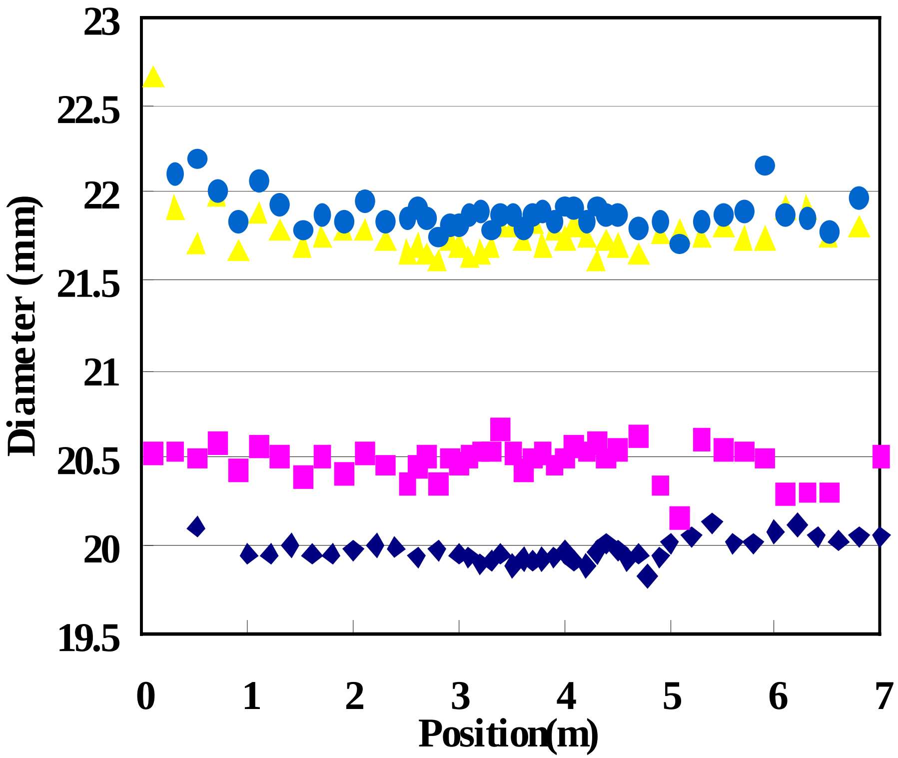
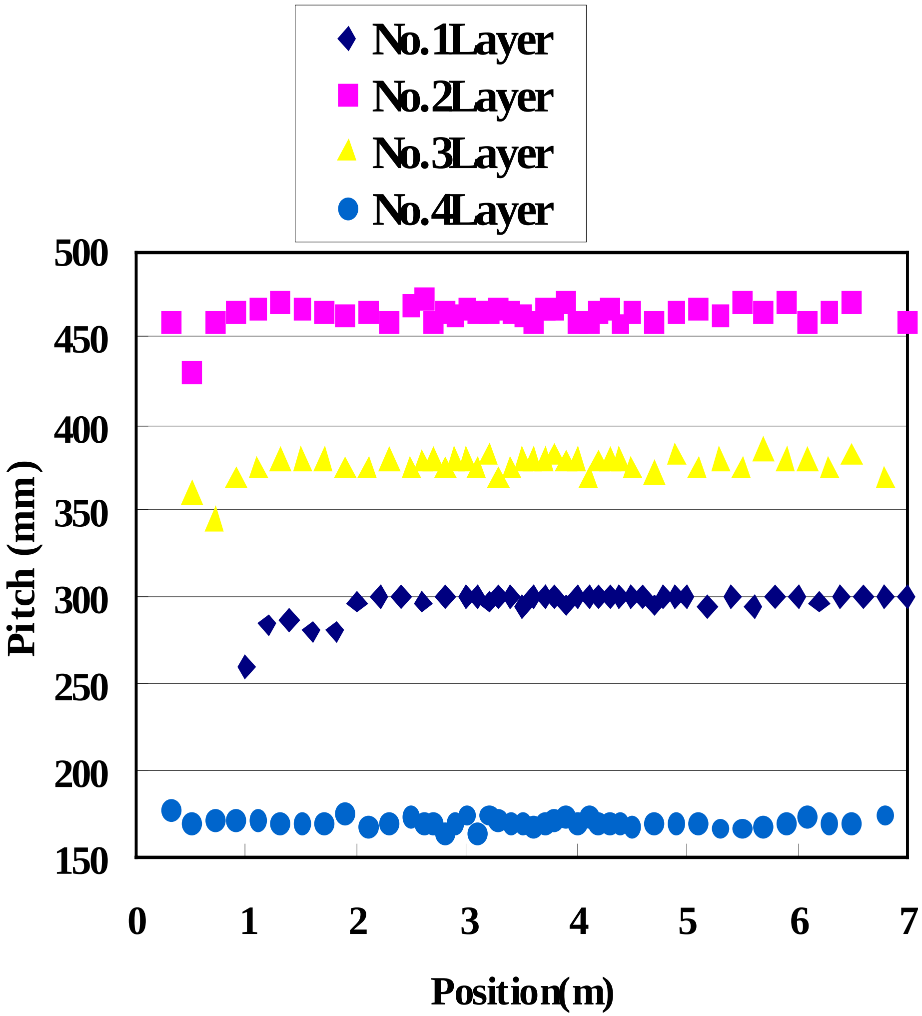
Distribution of Diameter and Pitch





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Conclusion

Several Bi-based HTS Cable Demonstrations in the world (EU, US, Japan, Korea, China, etc.) were successfully implemented.

RE-123 (HoBCO) coated conductor has been in progress rapidly.

HTS Cables with Large Transmission Capacity and Low AC Loss are Indispensable for 21st Century's Power Grid.