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DI-BSCCO

DI-BSCCO®
The practical HTS wire

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Outline

1. Background to develop stronger Type HT
2. Mechanical properties
3. Transport properties
4. Discussion on practicability
5. Summary

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Lineup of DI-BSCCO

http://www.sei.co.jp/super/

Specifications of long-seller commercial products

	Type H High Current Density	Type HT-SS (Stainless Steel) Tough wire	Type HT-CA (Copper Alloy) Tough wire	Type G Ag-Au sheath
Width	4.3 ±0.3 mm	4.5±0.3 mm	4.5±0.3 mm	4.3 ±0.3 mm
Thickness	0.20 ±0.03 mm	0.30±0.04 mm	0.36±0.04 mm	0.23 ±0.03 mm
I_c (77K,Self Field)	180 A ~ 200 A	180 ~ 200 A	180 ~ 200 A	160 A ~ 200 A
Je (77K, Self Field)	210 ~ 230 A/mm^2	130 ~ 150 A/mm^2	110 ~ 125 A/mm^2	160 ~ 200 A/mm^2
Critical Tensile Stress(77K)	130 MPa	270 MPa	250 MPa	130 MPa
	Used for various fields	Used for coil	Used for power line cable	Used for current lead for SC magnet

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Demand for stronger Type HT

All lineups of DI-BSCCO except Type HT-SS
are supported by many customers.

Many of customers who are interested in Type HT-SS
need much stronger wire.

So we are developing stronger wire named Type HT-NX.

will be released in 2015

Goal of Type HT-NX :

Critical tensile strength 500 MPa

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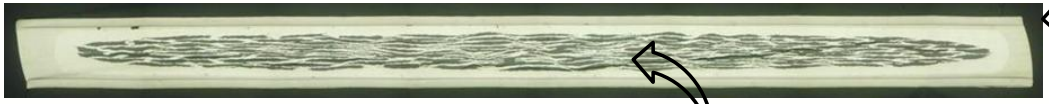
Strategy of Type HT-NX

500MPa should be achieved with keeping larger J_e from the view point of coil application.

Approaches to 500 MPa are…

- finding strong material for 3ply lamination
- adjusting lamination technique for HT-NX



Approaches to larger J_e is…

- use of thinner Type H

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Selection of reinforcement material

Demand for reinforcement material.

- ✓ high Modulus
- ✓ high Yield

NX tape		Stainless Steel
Modulus : >200GPa	>	Modulus : 180GPa
Yield : >1800MPa		Yield : 1200MPa

We have investigated adequate thickness from the view point of strength and high J_e.

Finally we have selected **30um** of NX tape.

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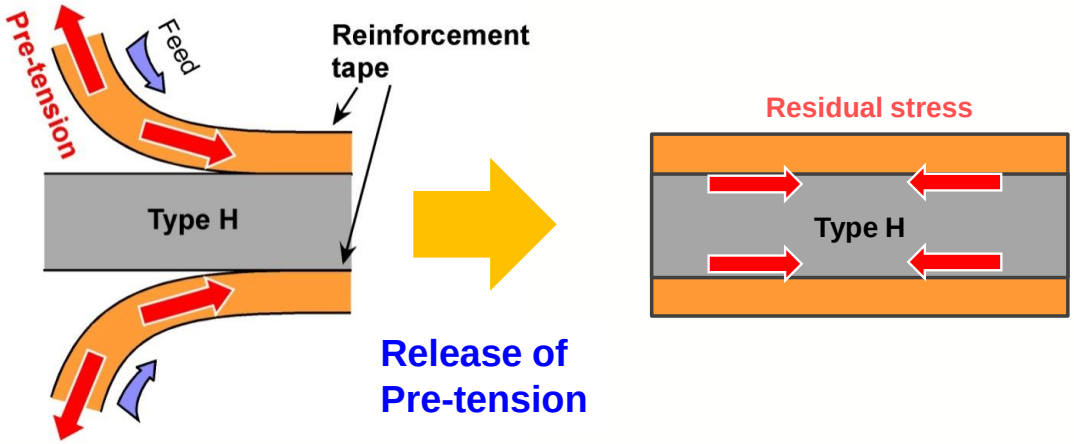
Lamination techniques

Adoption of pre-tension technique.



During lamination : Large tensile stress is applied to reinforcement tape. ⬅ Pre-tension

After lamination : 3 plyed wire is released from applied tensile stress.

In the end : Compressive strain is applied to Type H wire.
Type H wire in center has advantage against tensile strain.

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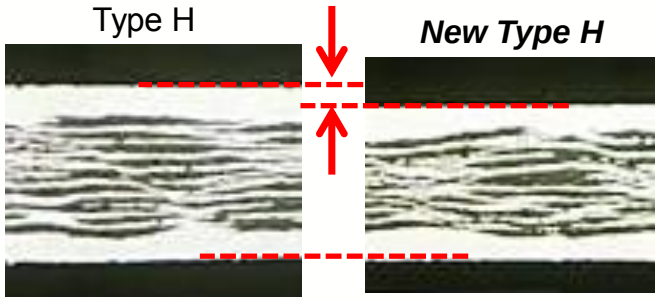
Use of thinner Type H

Wire Type (in production)	Type H	*New Type H*	
Reinforcement tape	-	-	
Width	4.3±0.3mm		
Thickness	0.23±0.03mm	0.20±0.03mm	↓13%
I_c (77 K, Self-Field)	180 A ,190A, 200 A		
J_e (77 K, Self-Field)	200 A/mm^2 (*)	230 A/mm^2 (*)	↑15%
Critical Tensile Stress (77 K)	130 MPa		

(*) in case of Ic=200A wire

Only the thickness is changed.



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Mechanical properties of TypeHT-NX

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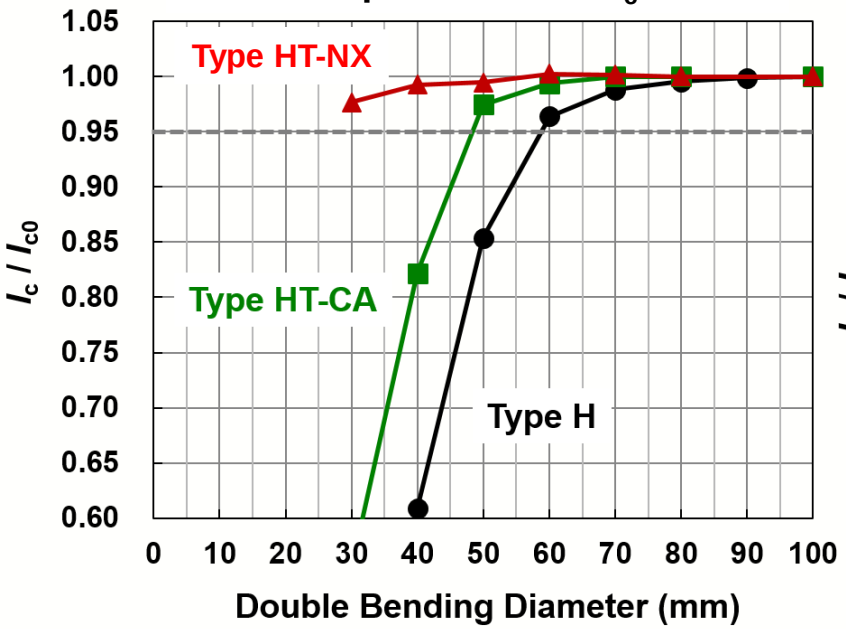
Mechanical properties at R.T.

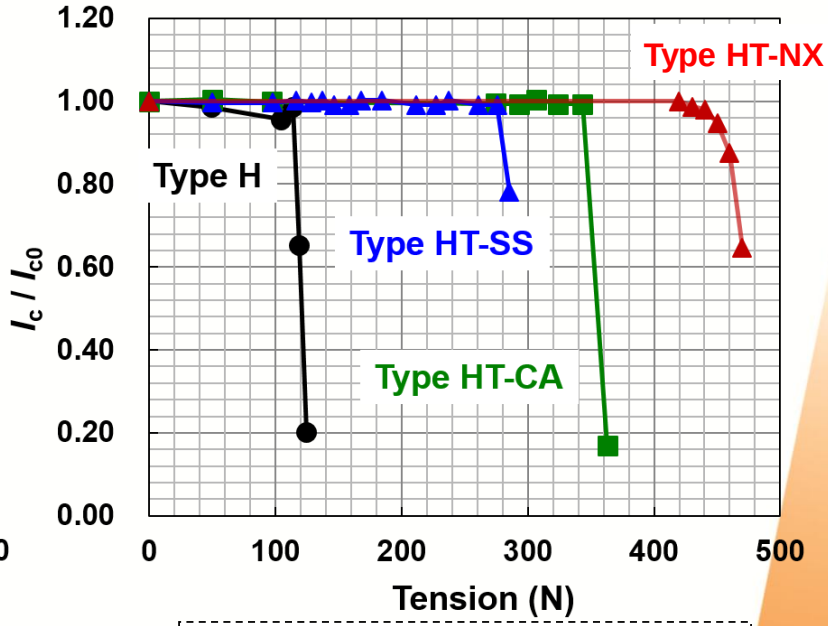
Double bending diameter at R.T. dependences of I_c



Critical diameter (@R.T.)

- ✓ **< 30 mm : Type HT-NX**
- ✓ 50 mm : Type HT-CA
- ✓ 60 mm : Type H

Tension at R.T. dependences of I_c



Critical tension (@R.T.)

- ✓ **449 N : Type HT-NX**
- ✓ 344 N : Type HT-CA
- ✓ 277 N : Type HT-SS
- ✓ 114 N : Type H

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Definition of "critical" is 95 % Ic retention in this paper.

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Transport properties of TypeHT-NX

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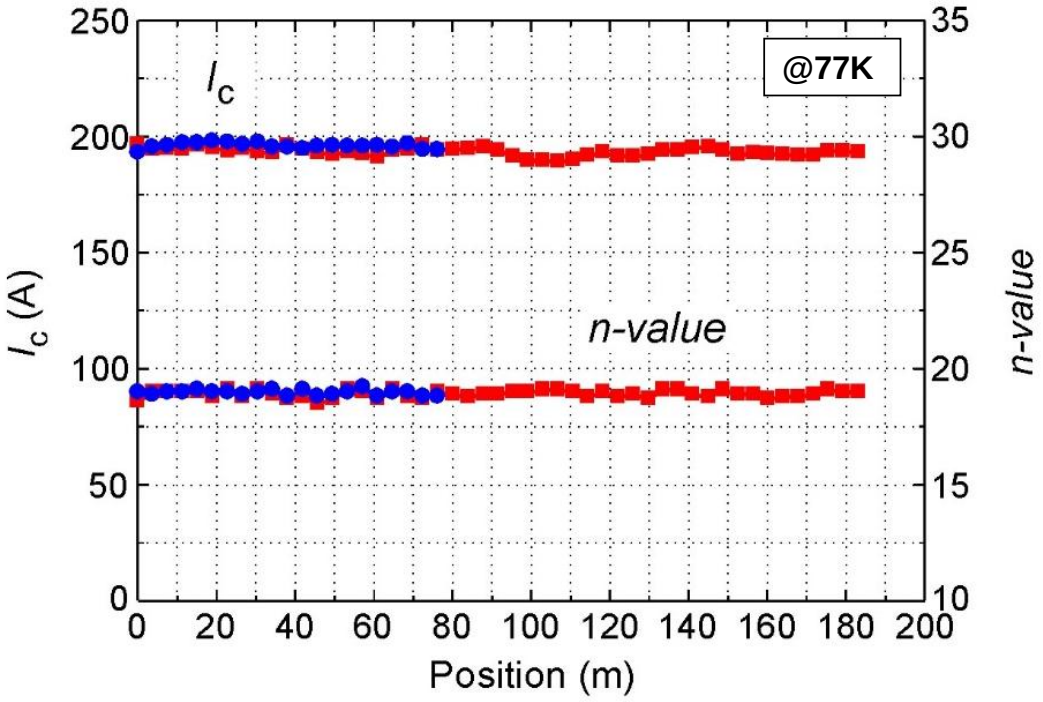
I_c distribution of Type HT-NX test production



- ✓ I_c performances at the range between 180A to 200A
- ✓ I_c and n-value are very uniform in long length
- ✓ **300 m-class wires** are being experimentally produced now

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Discussion

Can Type HT-NX really be used in practical condition?

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Various problem in practical condition

We suppose Type HT-NX wire will be used in high field application for example MRI.

So we need to assess various properties assuming practical condition.

- Transport properties in low temperature
- Mechanical properties in low temperature
  In low temperature, Type H in Type HT is supposed to compressive strain caused by difference in CTE(coefficient of thermal expansion).
- Hoop stress test
  Of course, homogeneity in long length is needed.
- Fatigue test
  Wire must be robust.

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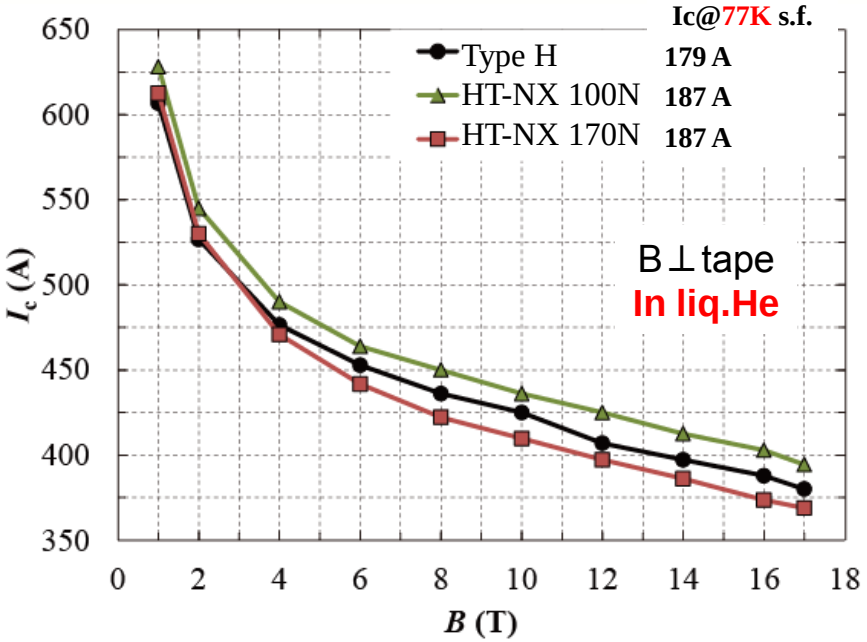
Degradation of I_c at 4.2 K



Measured by NIMS @ LNCMI/Grenoble

In liq. N_2 : Type HT-NX wire show no I_c degradation.
In liq. He : In case of 170N pre-tension, I_c slightly degraded.

⇩

We need to select adequate strength of pre-tension.

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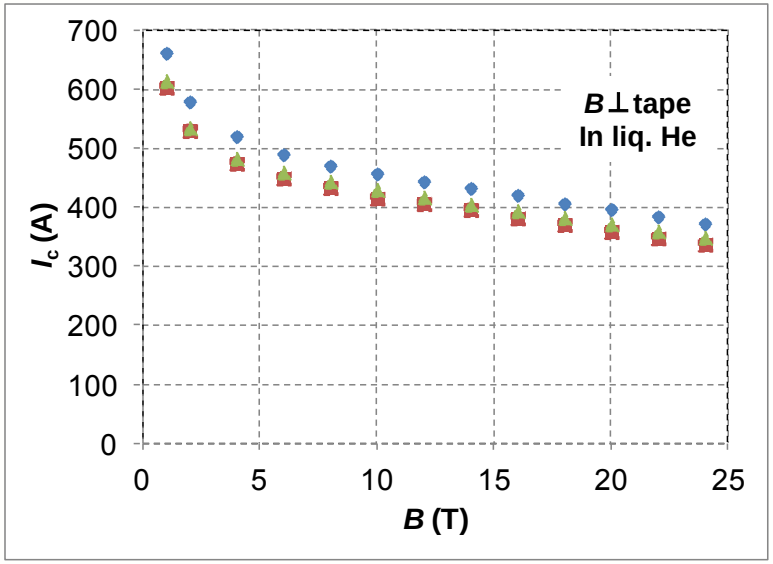
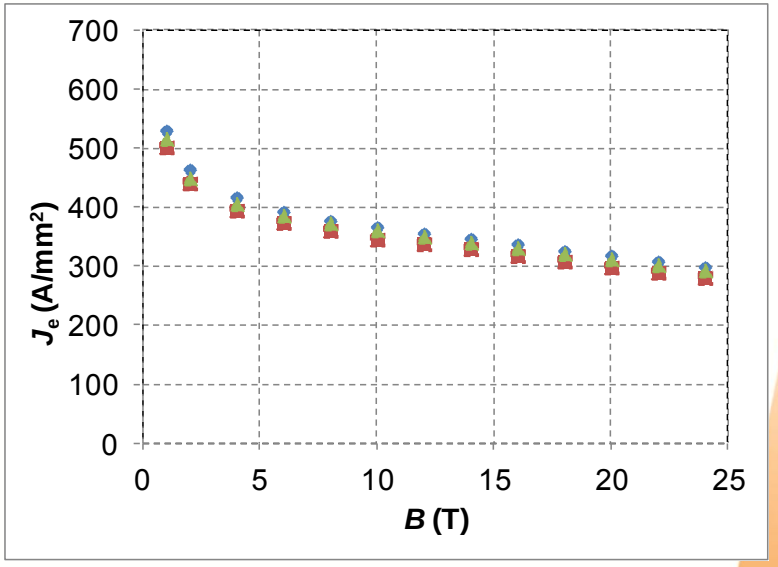
I_c dependency on B at 4.2 K

Measured by NIMS @ LNCMI/Grenoble





These 3 Type HT-NX wires were produced by adequately controlled pre-tension.

I_c(77.3 K, s.f.) ~ 190 A
I_c(4.2 K, 20 T) ~ 375 A
J_e(4.2 K, 20 T) ~ 300 A/mm²

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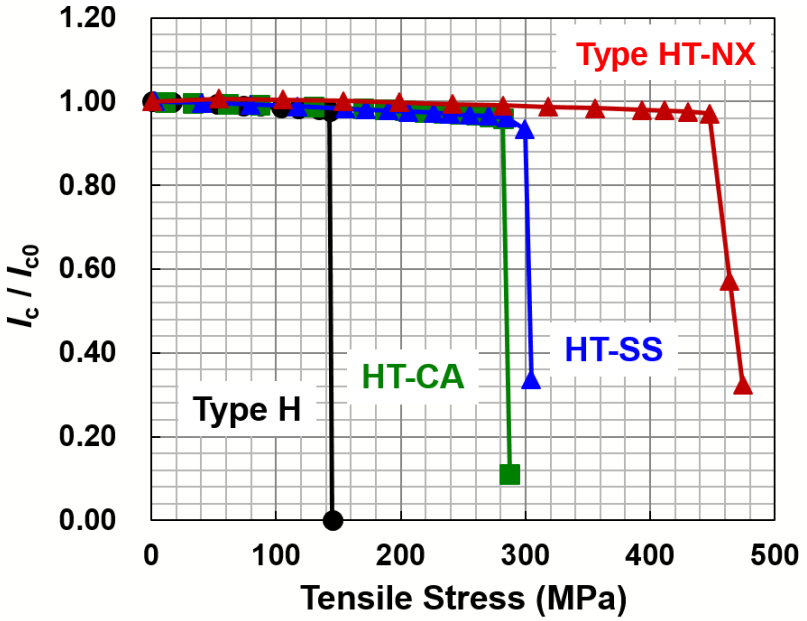
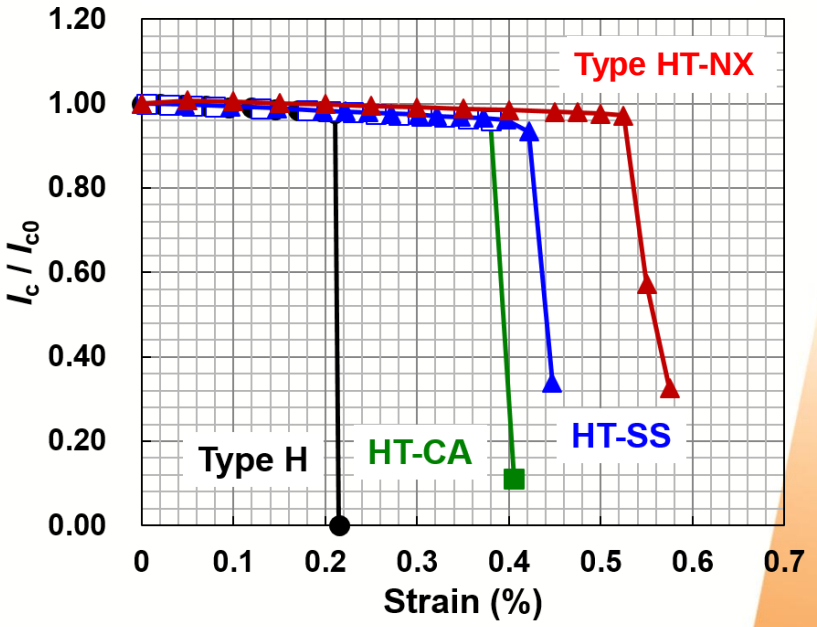
Mechanical properties at 77 K

Tensile stress at 77 K dependences of I_c



Strain at 77 K dependences of I_c



Critical tensile stress (@77 K)

- ✓ **443 MPa : Type HT-NX**
- ✓ 287 MPa : Type HT-SS
- ✓ 283 MPa : Type HT-CA
- ✓ 131 MPa : Type H

Critical strain (@77 K)

- ✓ **0.53 % : Type HT-NX**
- ✓ 0.39 % : Type HT-SS
- ✓ 0.38 % : Type HT-CA
- ✓ 0.22 % : Type H

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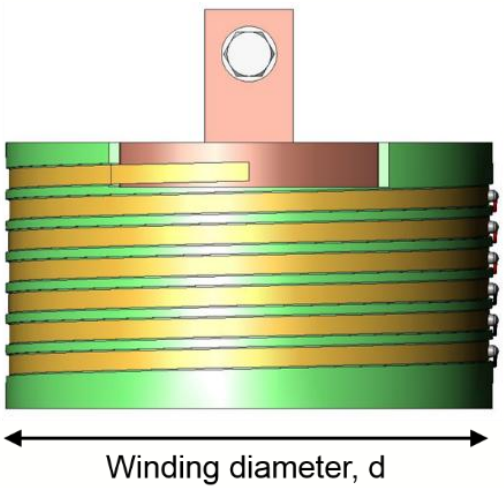
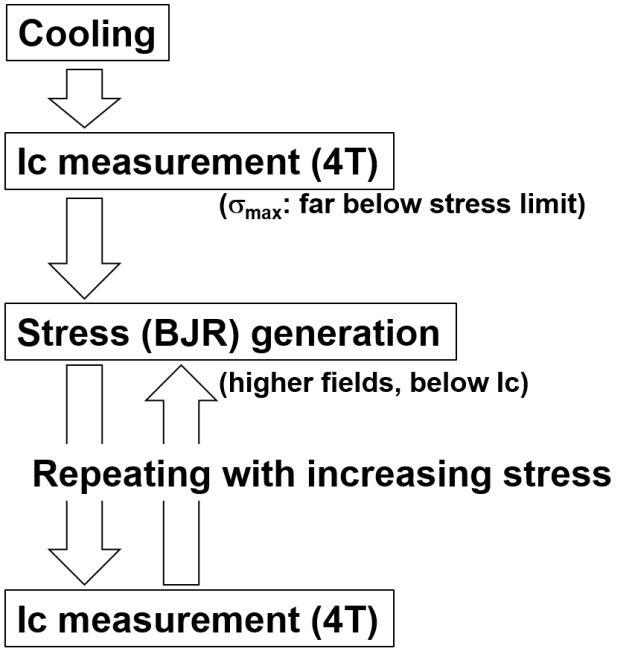
Hoop stress test of Type HT-NX



Using one layer coil specimen,
test was performed in LHe bath.

O.D. = 108 mm
Wire length = 2 m
Voltage tap spacing V1 = **0.340 m**
V2 = **1.021 m**
V3 = **1.701 m**



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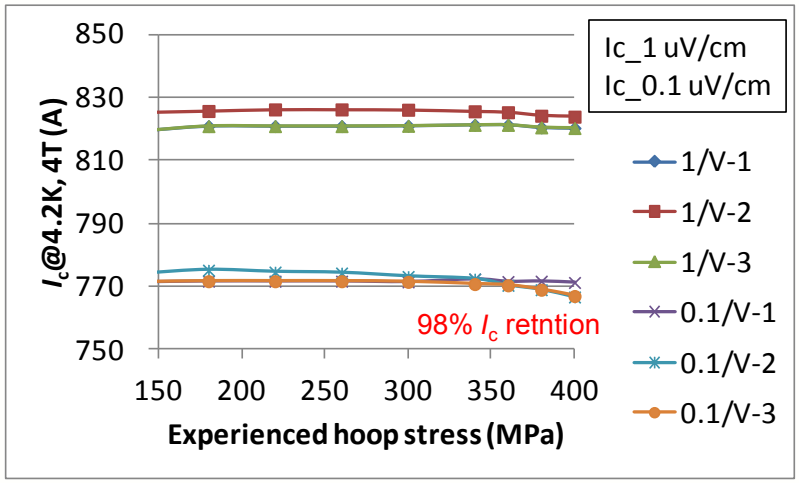
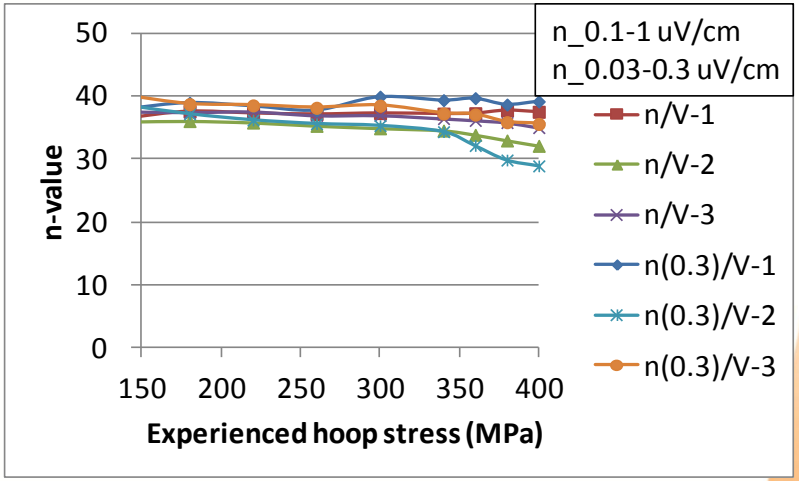
Hoop stress test of Type HT-NX

Measured by NIMS @ LNCMI/Grenoble





* Production condition of wire used in this test is slightly different from latest one.
  But applied compressive strain on Type H wire is almost same.
* Effect of wire bending is not considered in x-axis.

Using 2 m wire, homogeneous strength of Type HT-NX wire is observed.

Same test using Type HT-NX of latest design is now under planning.

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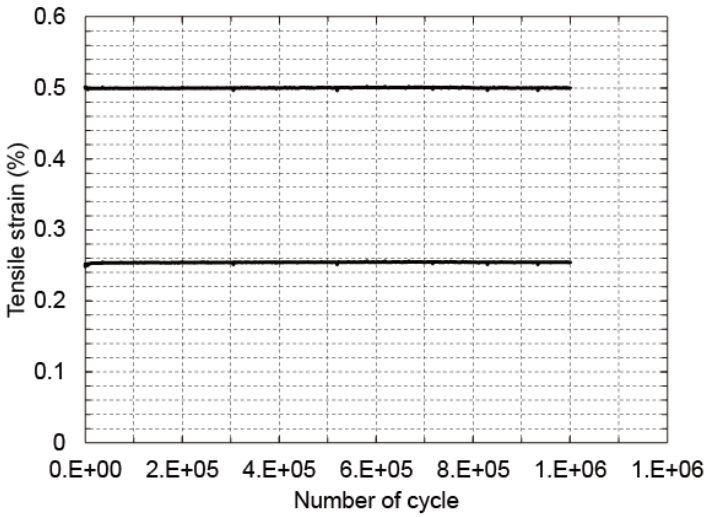
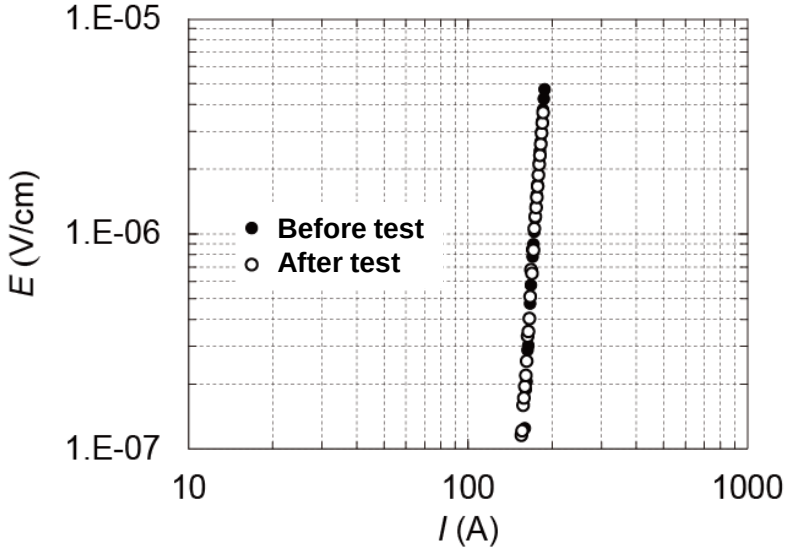
Fatigue test of Type HT-NX

Test condition

Wire: HT-NX (0.035mm^t) with New Type H
Max.Stress: 485MPa (=Max. Strain: 0.48%)
Min. Stress: 170MPa
Temperature: 77K
Number of Cycles: 1,000,000 cycles

	Before	After
I_c(1μV/cm)	174 A	173 A
I_c(0.1μV/cm)	166 A	165 A





No degradation of Ic and n-value until 10^6cycles.

Also no degradation of solder

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Summary

Wire Type	Type H	*New Type H*	*Type HT-NX*
Status	Commercial	Gradually released	
Reinforcement tape	-	-	Ni-alloy (0.030 mm^t)
Width (±0.3 mm)	4.3 mm	4.3 mm	*4.5* mm
Thickness (±0.04 mm)	0.23 mm	*0.20* mm	*0.28* mm
I_c (77 K, s.f.)	200 A	200 A	200 A
I_c (4.2 K, 17 T)	400 A	400 A	400 A
J_e (4.2 K, 17 T)	400 A/mm^2	460 A/mm^2	*310* A/mm^2
Critical Tensile Stress (77 K)	130 MPa	*130* MPa	*430* MPa
Critical D. B. Diameter (R.T.)	70 mm	*70* mm	*40* mm

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Summary

- Various mechanical properties of TypeHT-NX are shown to have satisfactory values for high field application.
  Critical tensile stress > 400MPa (almost 450MPa)
  ⇨ need further development

- Various test assuming practical condition are shown.
  Through those tests we are convinced that
  Type HT-NX wire can be used in high field application.

<u>Sumitomo's plan for mass-production in the near future:</u>

✓ Bare Type H wire : Already have released
(keep producing conventional Type H)

✓ Type HT-NX(30 μm^t) : We are preparing
for official release in 2015.