Superconductor status and prospects

Peter J. Lee (Presenter)

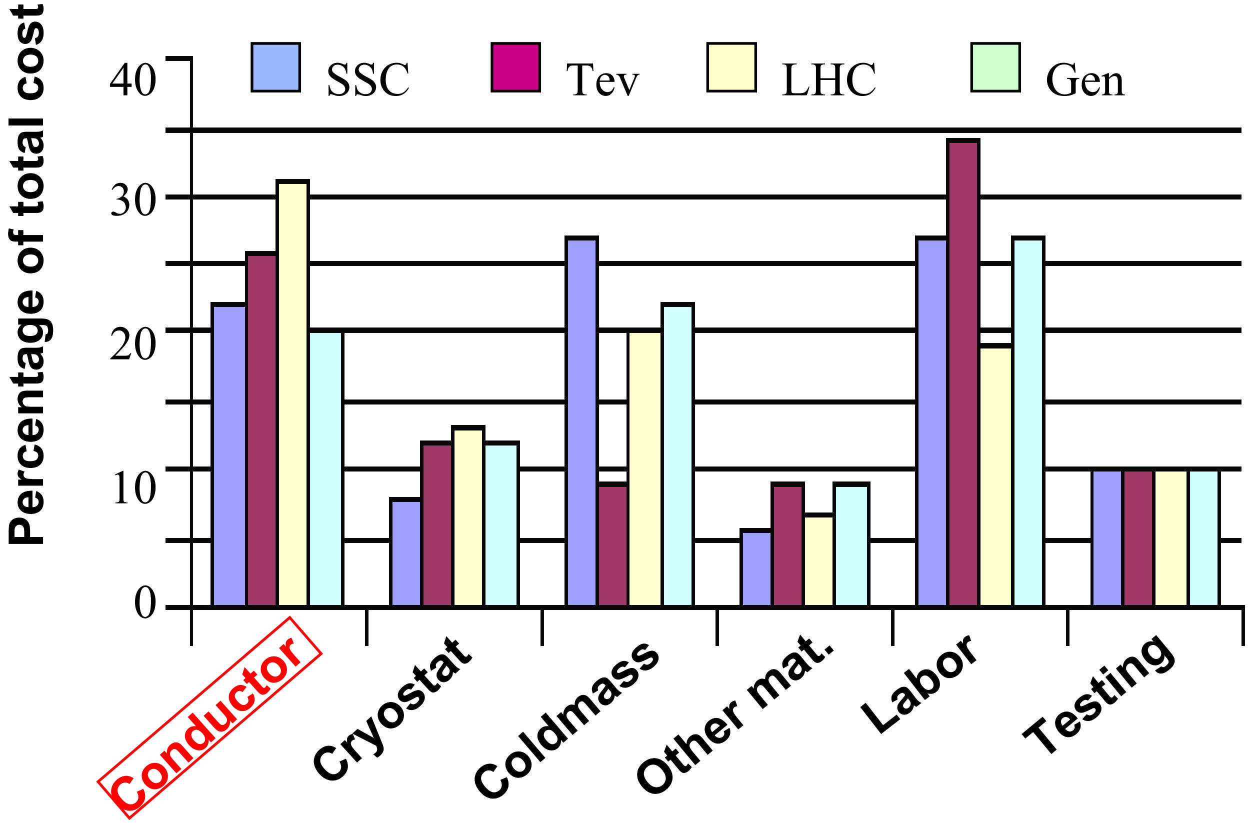
with lots of help from Ron Scanlan (LBNL), Rob Hentges et al. (OI-ST), Eric Gregory (IGC-AS), Bruce Zeitlin (Supergenics), Arup Ghosh (BNL), Takao Takeuchi (NRIM)

David C. Larbalestier, Christopher D. Hawes, Michael T. Naus and Alexander A. Squitieri (UW-Madison)

Very Large Hadron Collider

UW Work
Sponsored by:

Where to save $?
Start with the conductor

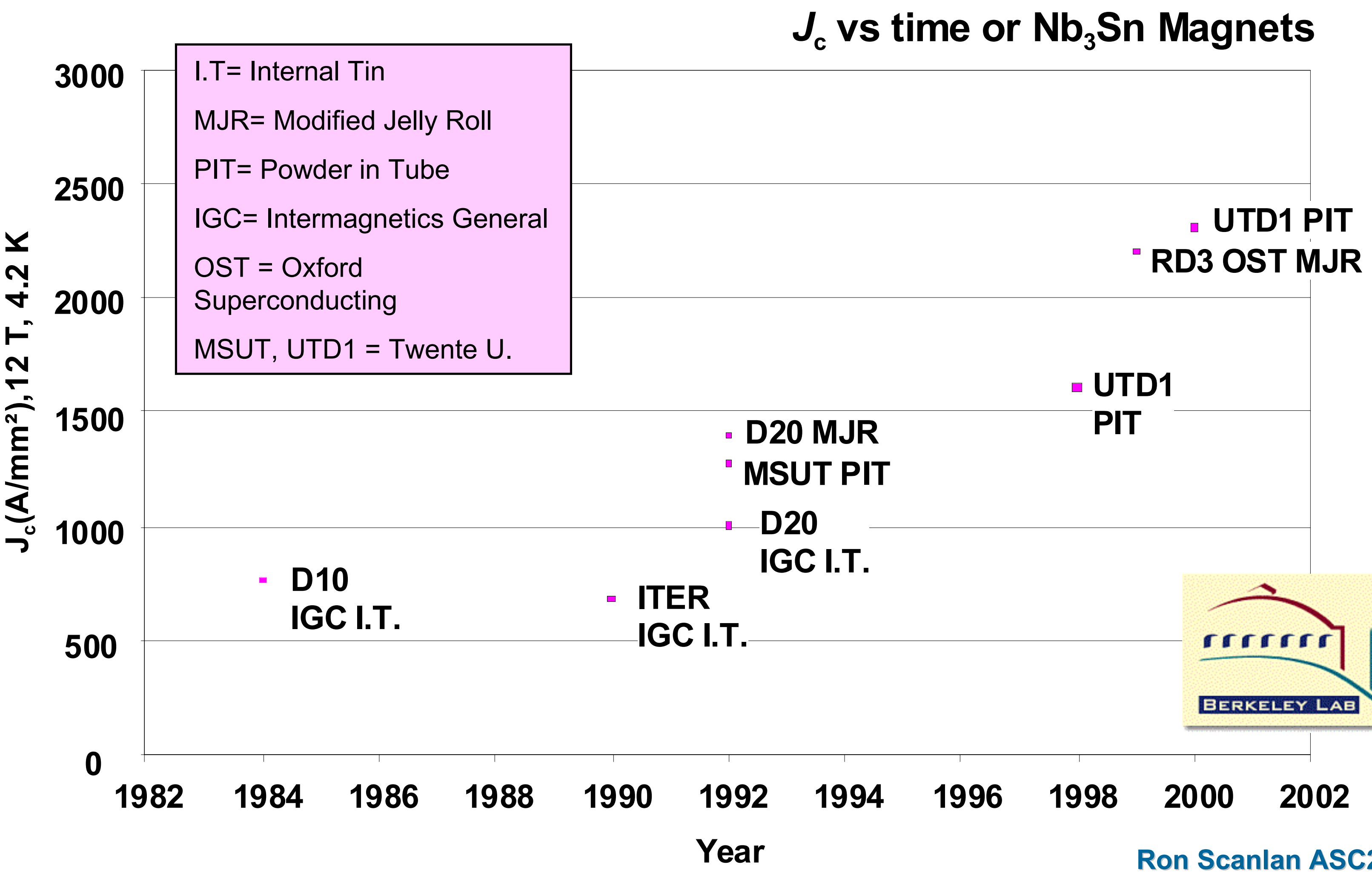


Steve Gourlay
chart via
Ron Scanlan
ASC2000

$$C_{dipole}(\$) = 3.2\pi B\rho 2560((r+0.5)/2)^{0.43}(0.25+0.55(8/L_d)^{0.6})(0.3+0.7(B/4.3))$$

RHIC scaling

Improvements in J_c for Nb_3Sn



J_c vs time or Nb_3Sn Magnets

I.T= Internal Tin

MJR= Modified Jelly Roll

PIT= Powder in Tube

IGC= Intermagnetics General

OST = Oxford Superconducting

MSUT, UTD1 = Twente U.

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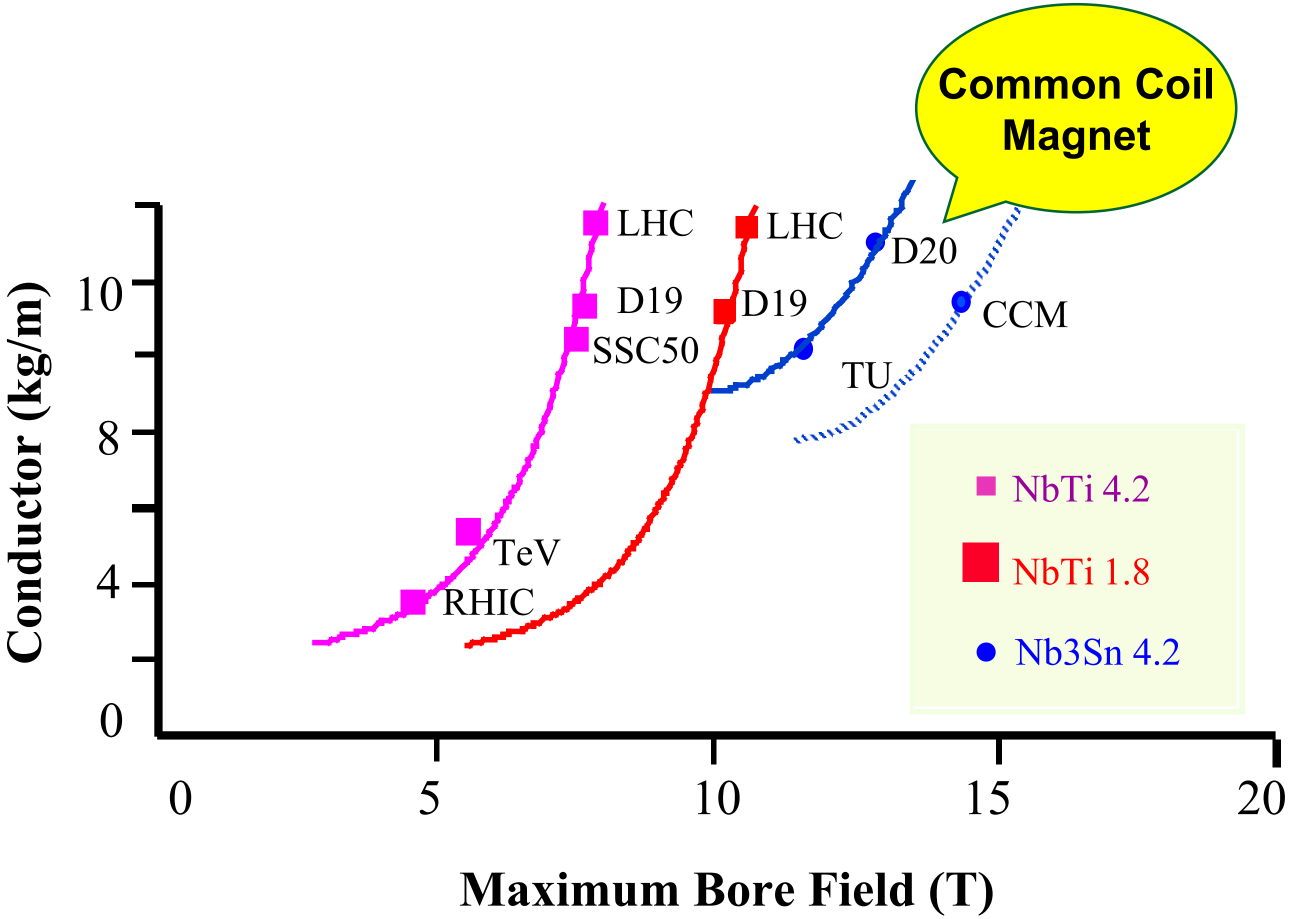
Better materials & simpler coil geometry reduce conductor use



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Major Development This Year: We now have a conductor development program that can fund industrial R&D outside SBIR box

- Funded programs at OI and IGC
- Improved Interaction with manufacturers
- Conductor progress in most areas

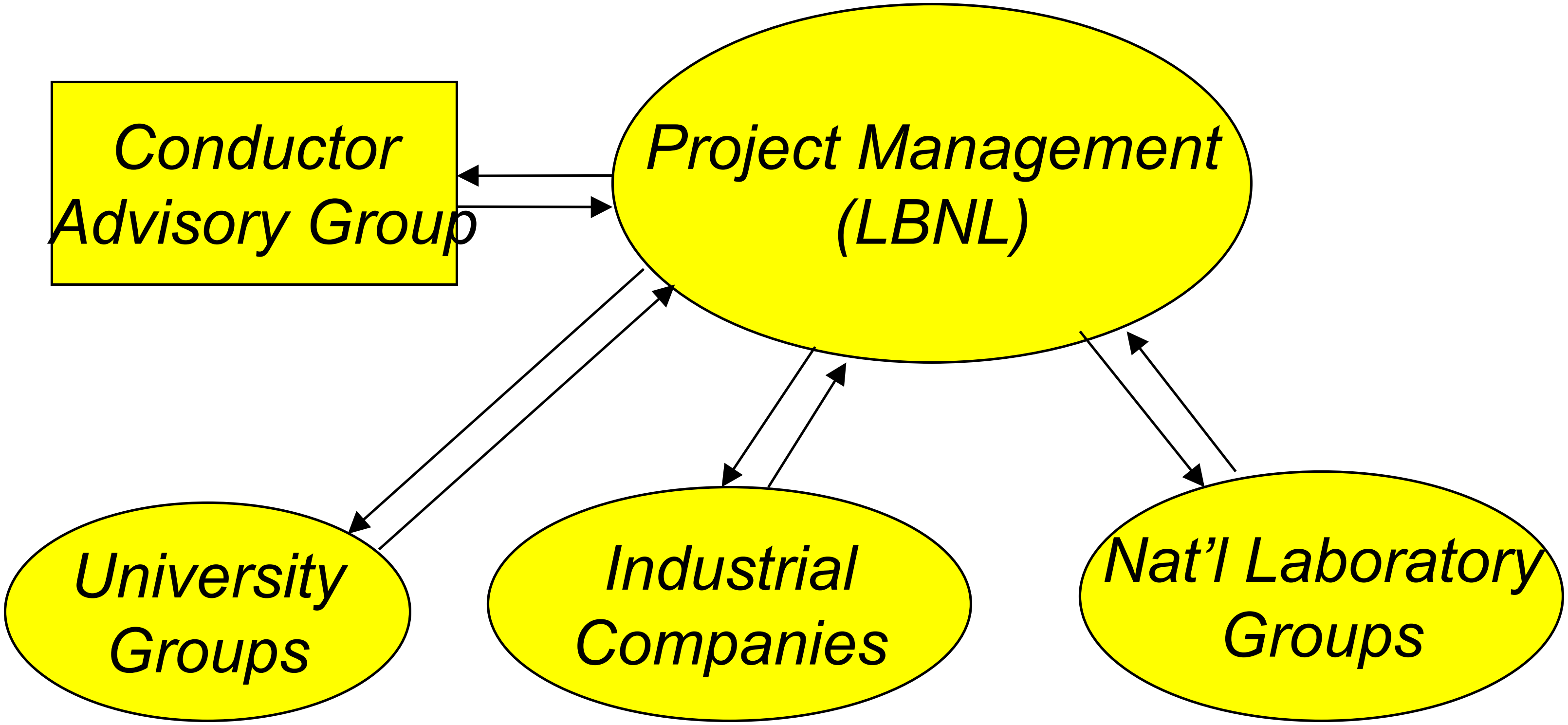
CDP Goals

- Provide a cost-effective, high-performance superconductor of qualities not yet achieved for the high-field magnets required for the next generation high-energy physics colliders
- Target specifications for the HEP conductor include:

J_c (non-Cu,12 T,4.2 K):	3000 A/mm^2
Effective filament size:	40 μm or less
Piece length:	Greater than 10,000 m in wire diam. of 0.3-1.0 mm
Wire cost:	Less than $1.50/kA-m (12 T,4.2 K)

From:
Ron Scanlan ASC2000

Conductor Development Program Organization



Conductor Advisory Group

Project Management (LBNL)

University Groups

Industrial Companies

Nat'l Laboratory Groups

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The CD Group provides

- Input to program plans and goals
- Technical support for the manufacturing R&D work
- Member organizations are BNL, FNAL, LBNL, OSU, TAMU, and U.Wisconsin-Madison

  -A. Ghosh(BNL)
  -P. Wanderer(BNL)
  -G. Ambrosio(FNAL)
  -P. Limon(FNAL)
  -D. Dietderich (LBNL)
  -R. Scanlan(LBNL)

  E. Collings(OSU)
  P. McIntyre(TAMU)
  P. Lee(U.Wisc.)
  D, Larbalestier(U.Wisc)
  B. Strauss(DOE)
- Other contributors include: conductor R&D teams at IGC(see ASC 2000 paper 4MK07) and OST(see ASC 2000 paper 4MK08)

Lab and University Support for FY00 is coming from base program funds

- BNL(Suenaga): Heat Treatment (HT)
- FNAL(Barzi): HT, I_c tests
- LBNL(Dietderich, Higley): HT, characterization, cable development
- OSU(Collings, Sumption): Magnetization measurements
- TAMU(McIntyre,students): HT
- U. Wisc(Lee, students): HT, characterization, I_c tests

Total new funding for FY00:

\$500K	direct DOE	(IGC+OST contracts)
\$1,500K	DOE SBIR	support for Nb_3Sn
\$1,100K	DOE SBIR	support for Nb_3Al

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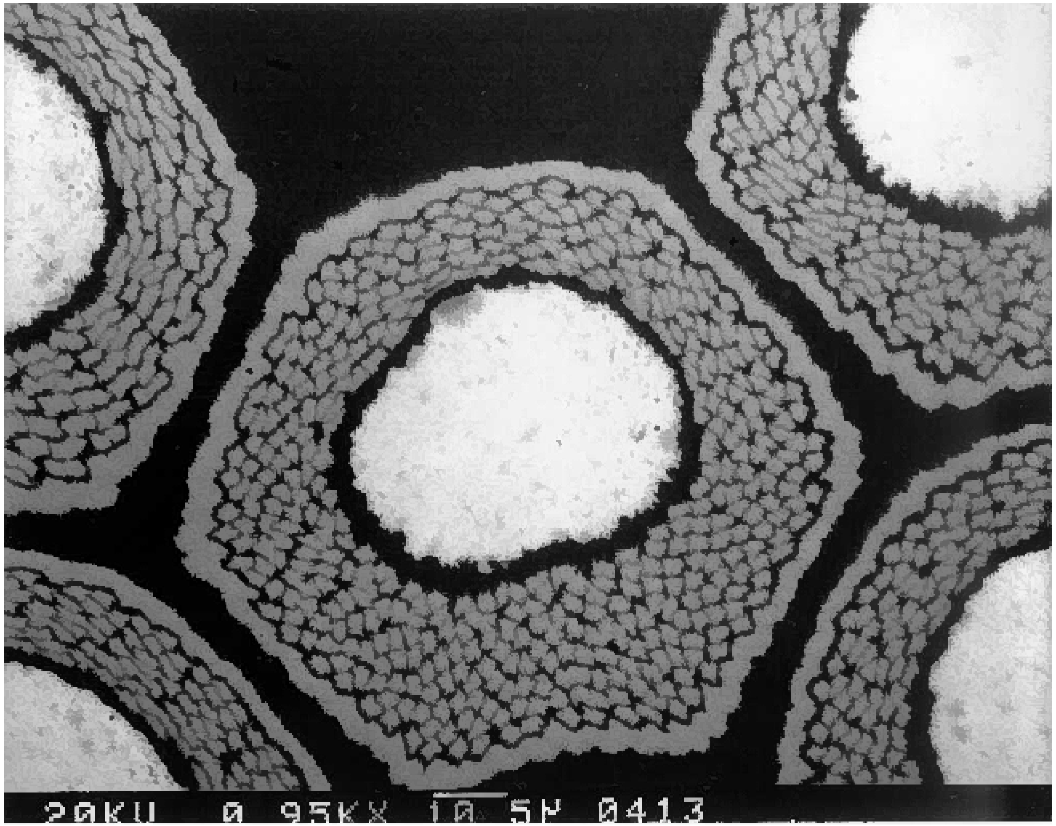
MJR Conductor used in LBNL Magnet RD-3



- $J_c > 2000\ A/mm^2$ (12 T, 4.2 K)
- $D_{eff} = 70\ \mu m$
- RRR=3-15

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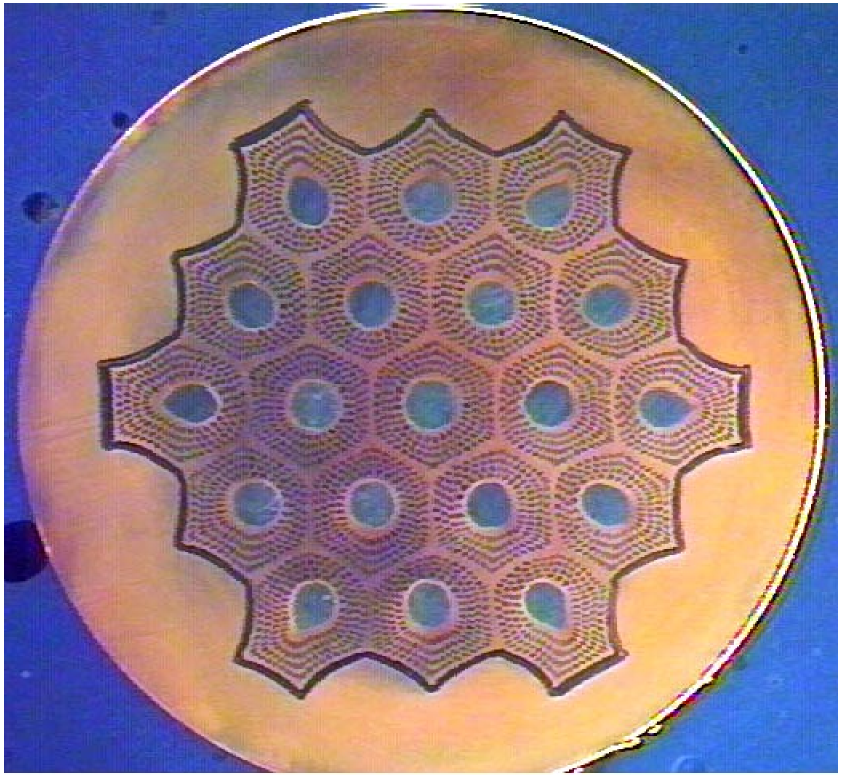
OI-ST Goals

- Develop the Hot Extruded Rod (HER) process as a new, cost-effective alternative to their MJR process
- Determine J_c vs filament size relationship for HER process
- Optimize composition to give maximum J_c



HER process billet after extrusion, before salt is removed from cores

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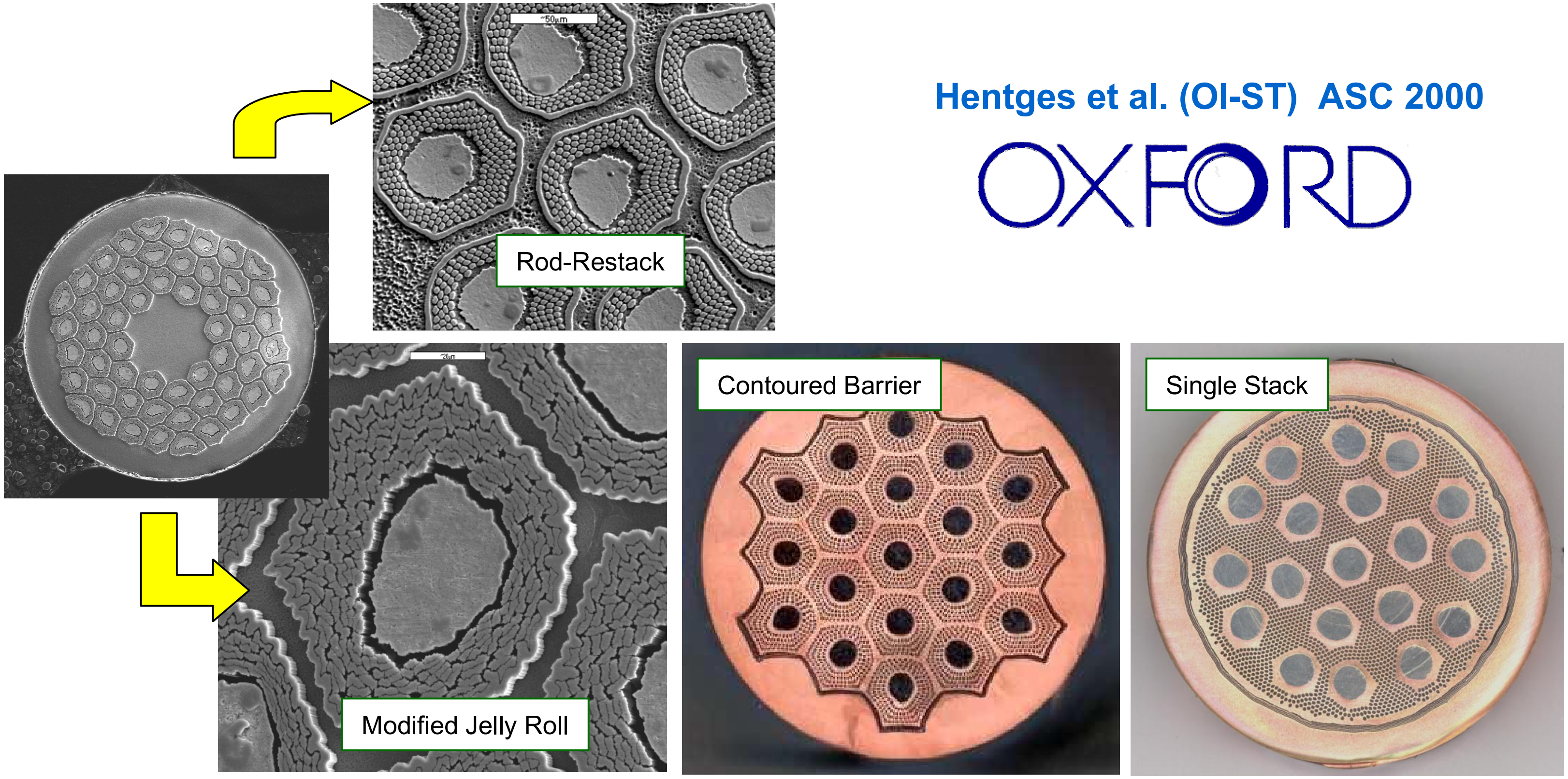
OI-ST Internal Sn designs seeking lower cost and higher performance

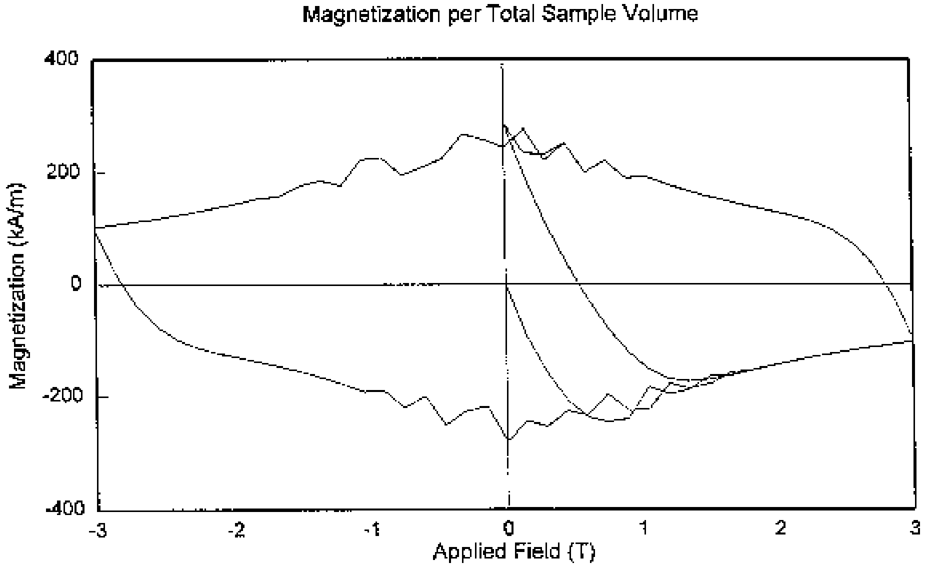
Hentges et al. (OI-ST) ASC 2000

OXFORD

Internal Tin

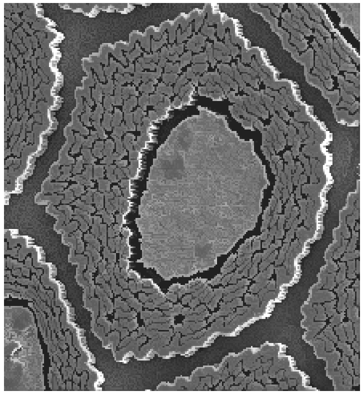


Magnetization of MJR



- Minor flux jumps <2 T
- D_{eff} ~80-100 µm
- D_{eff} approximates diameter of filament bundle

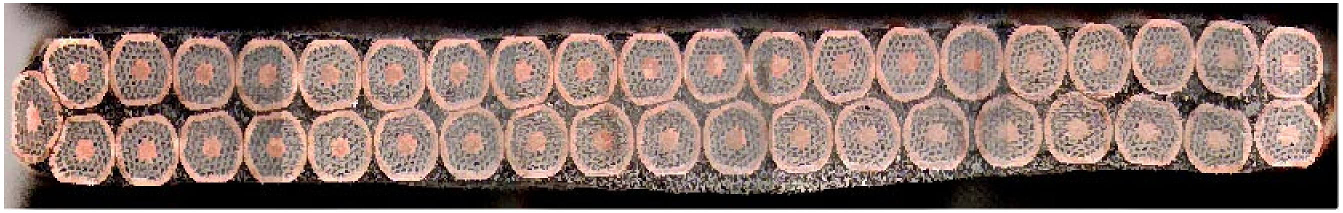
Data from NIST

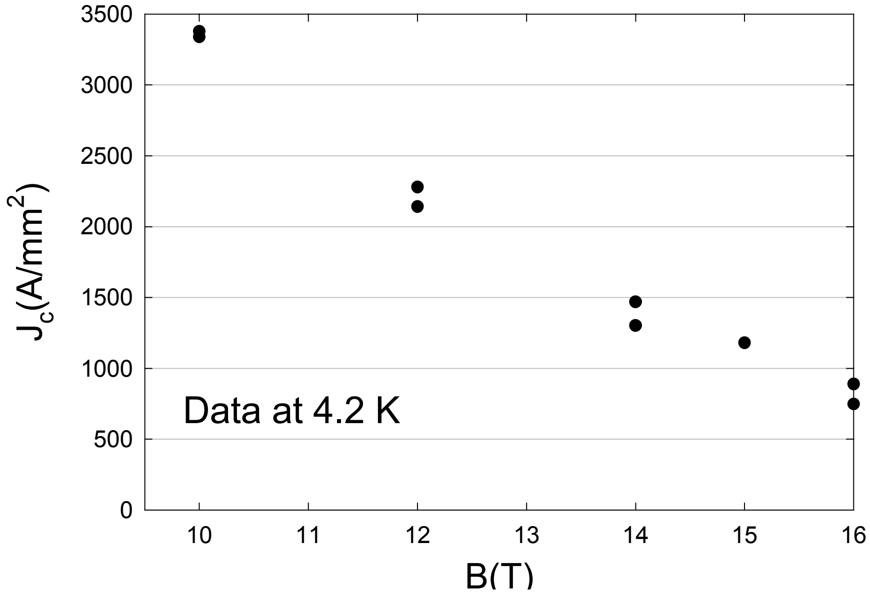


OXFORD

Hentges et al. (OI-ST), ASC 2000

LBNL MJR Cable Results





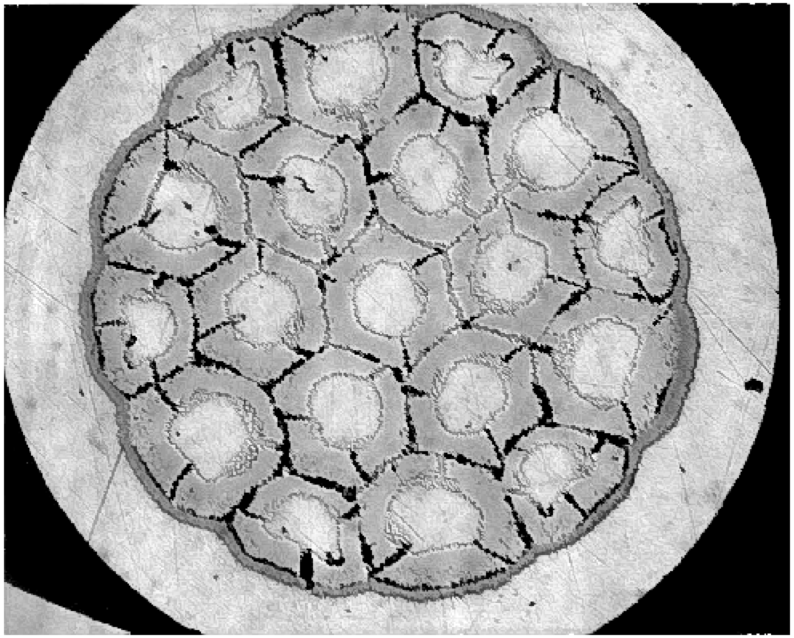
- 10 T J_c ~3200 A/mm^2
- 12 T J_c ~2100 A/mm^2
- 14 T J_c ~1300 A/mm^2
- 16 T J_c ~750 A/mm^2

OXFORD

Hentges et al. (OI-ST), ASC 2000

IGC-AS Program Goals

- Optimize composition to maximize J_c in internal tin conductor
- Determine optimum split configuration to optimize J_c/filament size
- Optimize billet design to maximize wire lengths



3-split sub-elements in 19-stack after reaction (splits are now void regions)

IGC ADVANCED SUPERCONDUCTORS
A DIVISION OF INTERMAGNETICS GENERAL CORPORATION

Ron Scanlan ASC2000

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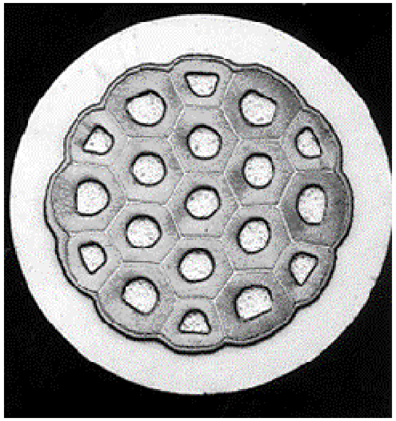
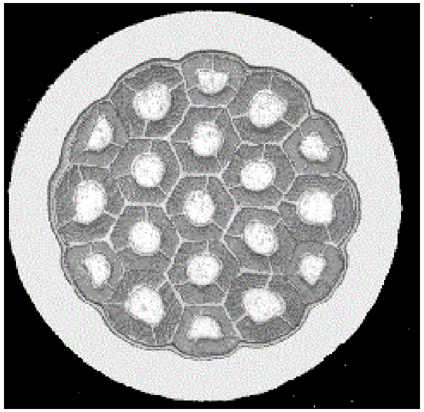
Summary of IGC-AS Conductor Parameters And Properties

Sample Name	Wire Ø. (mm)	LAR Cu/Nb	# ofSub	J_c (A/mm^2) at 10^{-14} Ω-m &12T		Q_h(mJ/cm^3)	D_{eff} (µm	Design Composition At. %			Measured Composition			Ø Fil. (µm)
				Non-	Fil.		@5T	Cu	Nb	Sn	Cu	Nb	Sn	
LDX	0.6	52/48	19	1140	2917	792	28	62.2	25.9	11.9	--	--	--	5.2
Large Fil. Un-Split	0.6	35/65	37	2200	4622	4860		51.0	33.5	15.5	38.1	39.0	22.0	3.8
Large Fil. 3-Split	0.6	35/65	37	1850	4189	3554	127	54.8	30.7	14.5	47.5	32.1	20.4	3.8
Early Fine Fil	0.6	47/53	19	1950	3924	5621	168	53.4	34.2	12.4	45.7	35.4	16.9	1.4
HD FF 3W-Split	0.8	20/80	19	1768	2993	6544	206	43.5	42.3	14.2	32.0	47.5	20.5	2.3
HD FF 3W-Split	0.7	20/80	19	1910	3233	6547	195	43.5	42.3	14.2	32.0	47.5	20.5	2.0
HD FF 3W-Split	0.6	20/80	19	1906	3231	6142	188	43.5	42.3	14.2	32.0	47.5	20.5	1.7



19-sub-element cross-section of fine filament material 0.6mm Ø strand



19-sub-element cross-section high density 3 split material 0.6mm in diameter

From Taeyoung Pyon and Eric Gregory, ASC 2000

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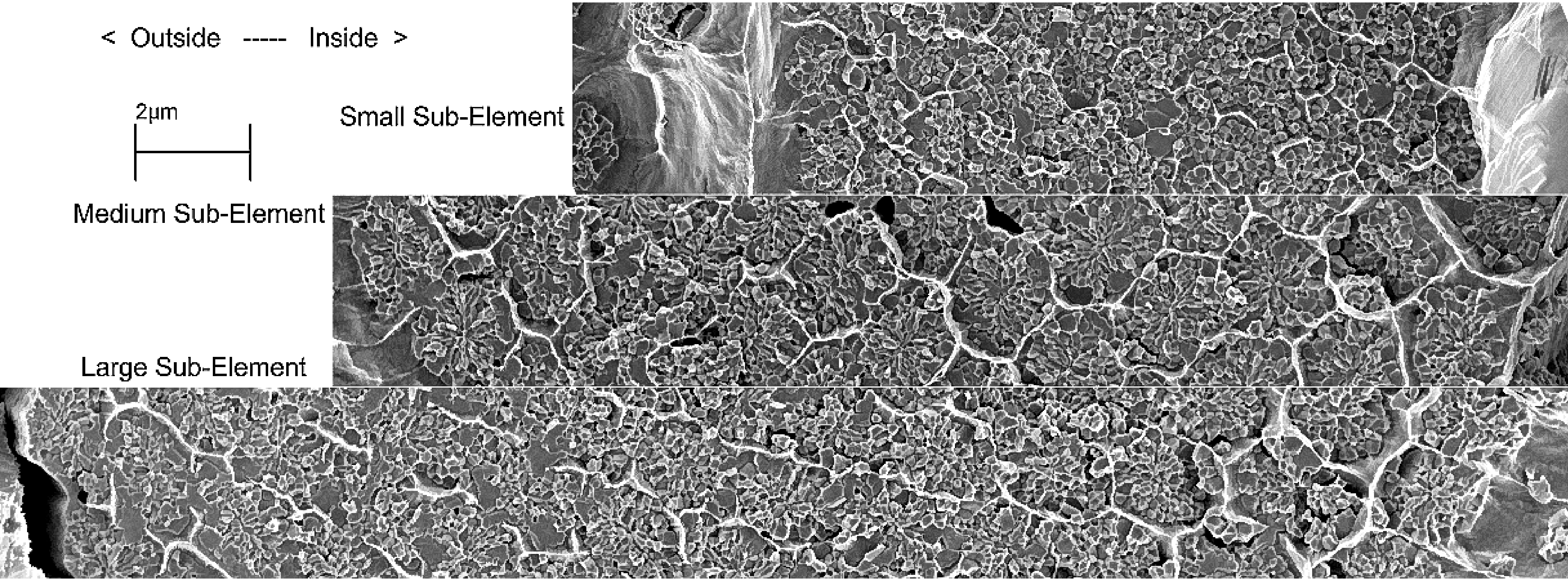
Effect of IGC-AS sub-element size on μ-structure being measured at the UW



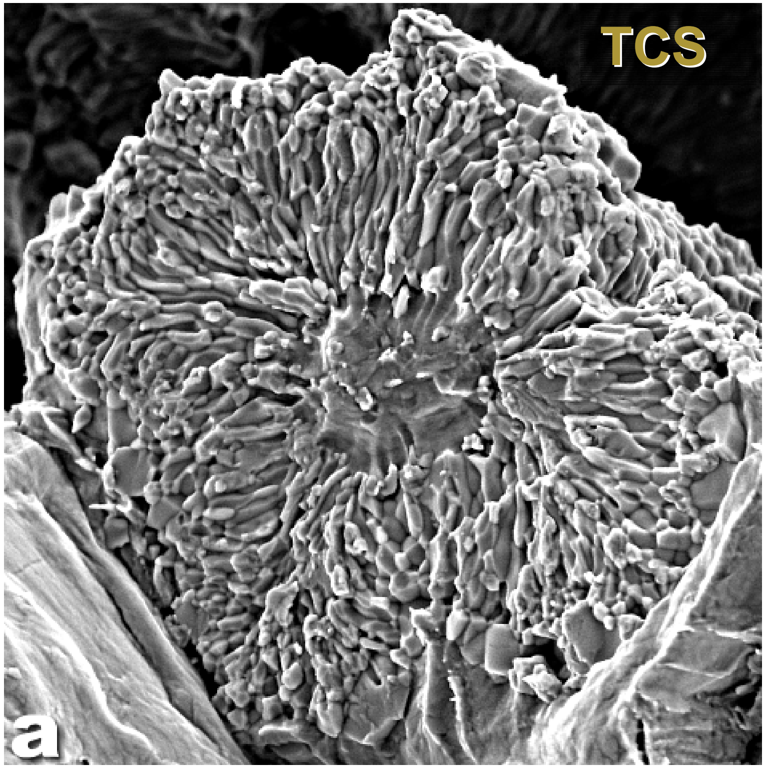
See μ-structure/diffusion effect in layer vs. filament in MJR slide . .

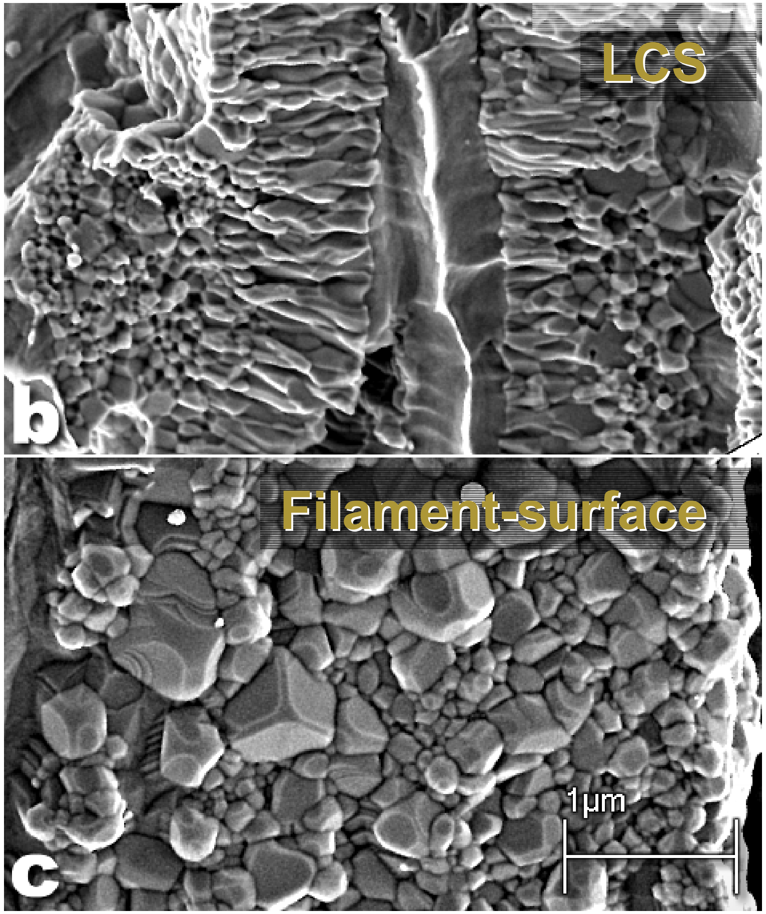
Lee, VLHC Annual Meeting 2000

VAC ITER Standard HT FESEM fractographs

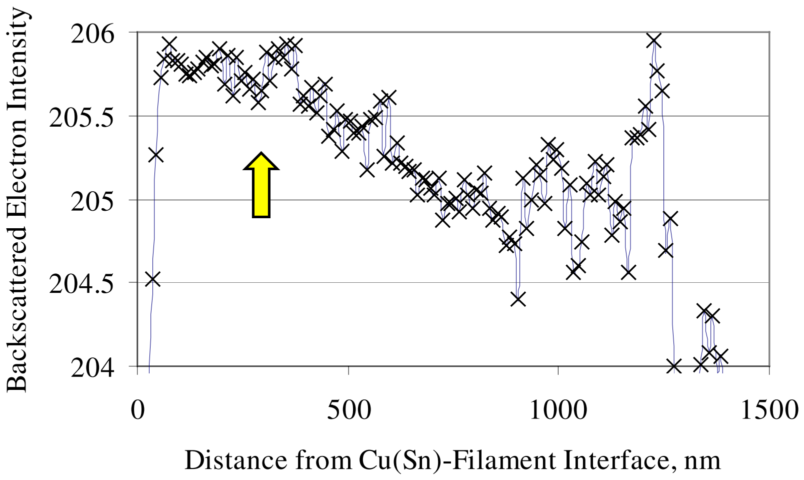
Microstructure not exactly homogeneous

Lee et al ASC 2000

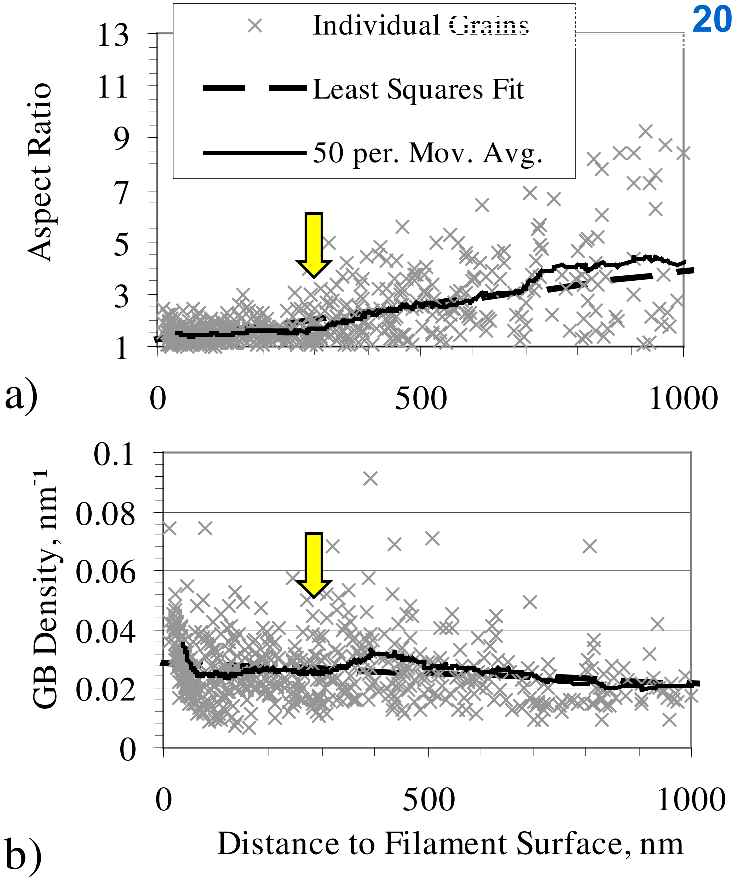




Chemical and Microstructural Changes At the Same Scale



Lee et al ASC 2000



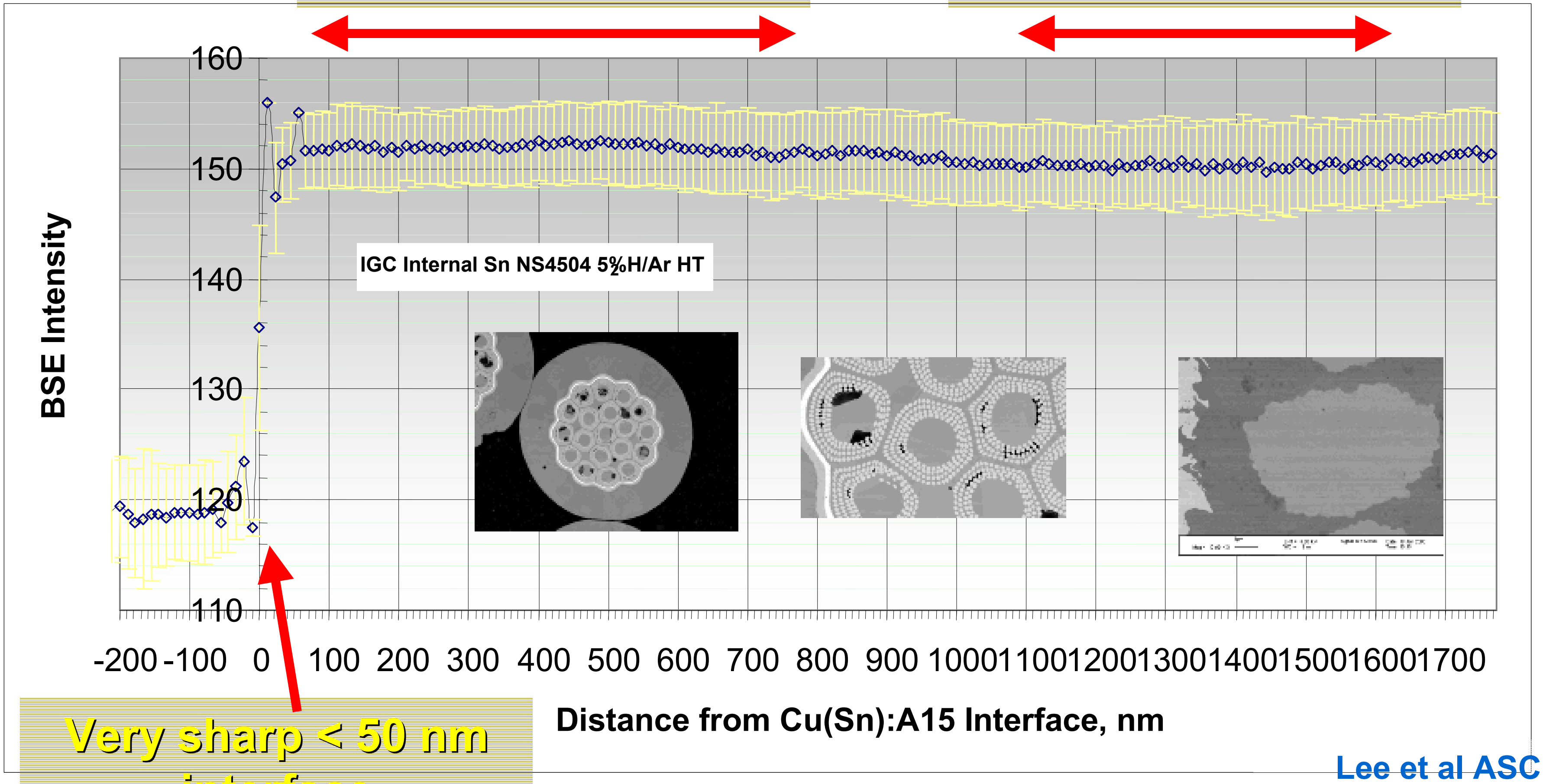
Detail from the traverse in showing a level backscatter intensity up to 300 nm followed by a continuous drop until approximately 900 nm.

Aspect ratio and GB density also show change in behavior at 300 nm

Example II. IGC ITER Internal Sn Filament (low Sn, low hysteresis loss design)

Plateau 1

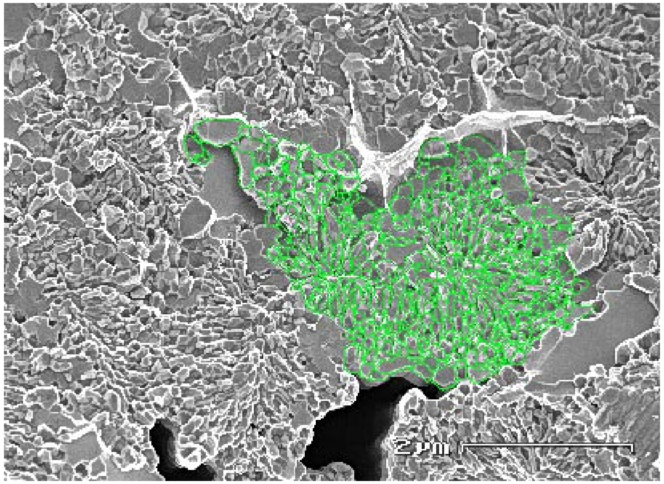
Plateau 2

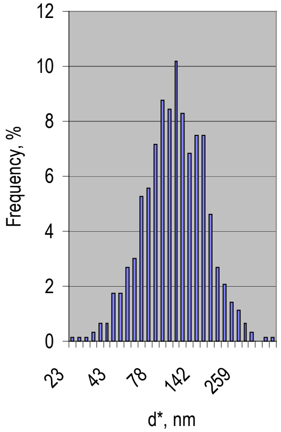


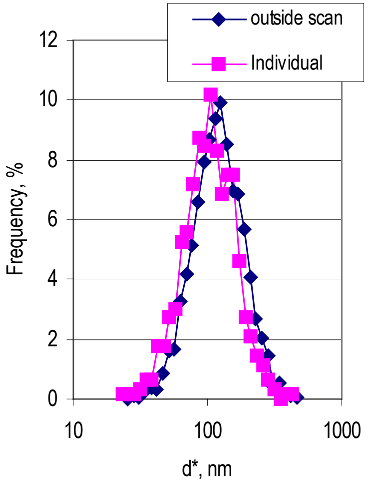
Very sharp < 50 nm interface

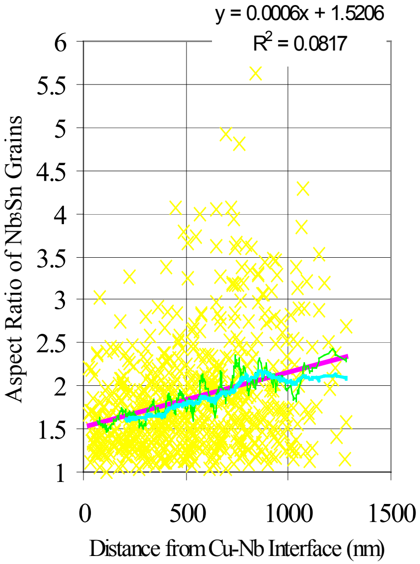
Lee et al ASC 2000

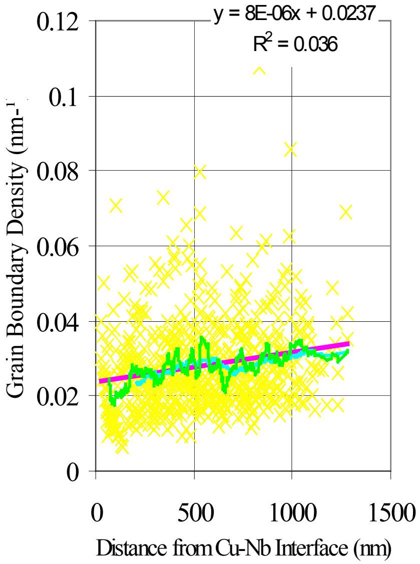
TWC 1912 Single filament

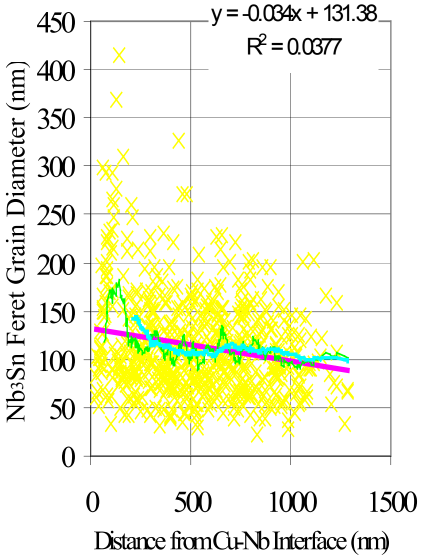










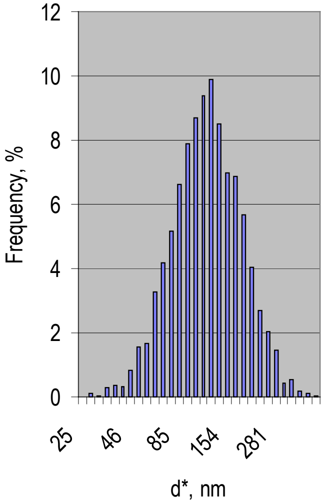


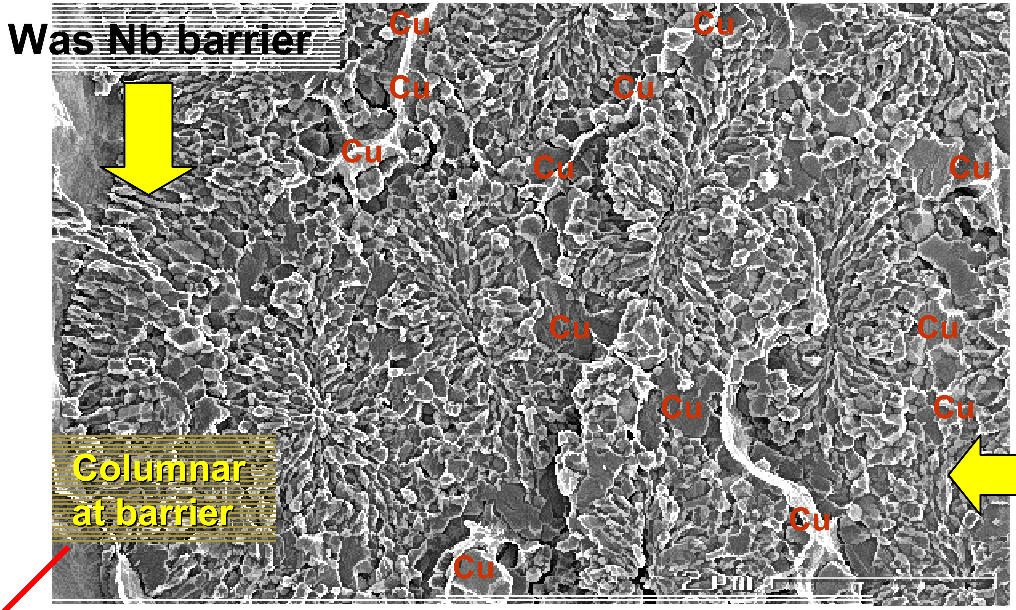
Even with densely packed filaments morphology variations occur across individual filaments.

Lee et al ASC 2000

CRe1912 overall μ-structure

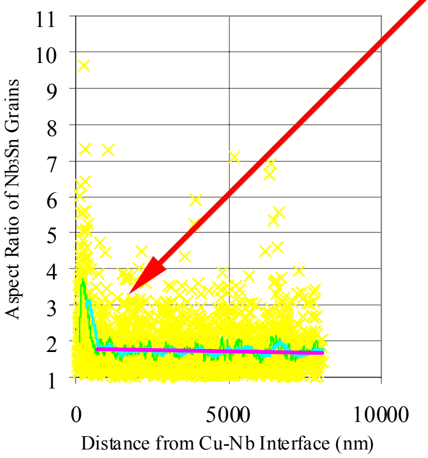
Lee et al ASC 2000

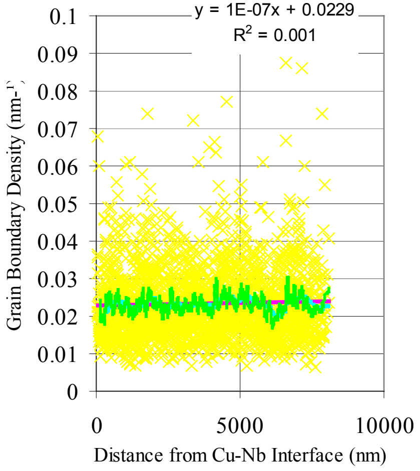


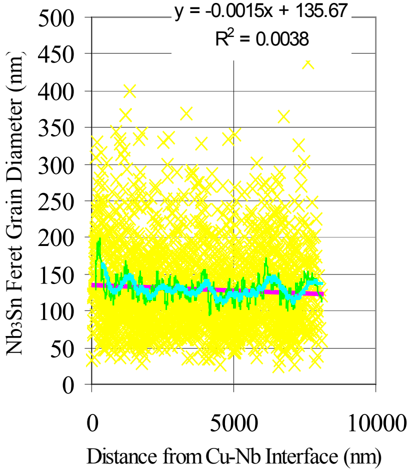


Was Sn core

Was Nb-1%Ti





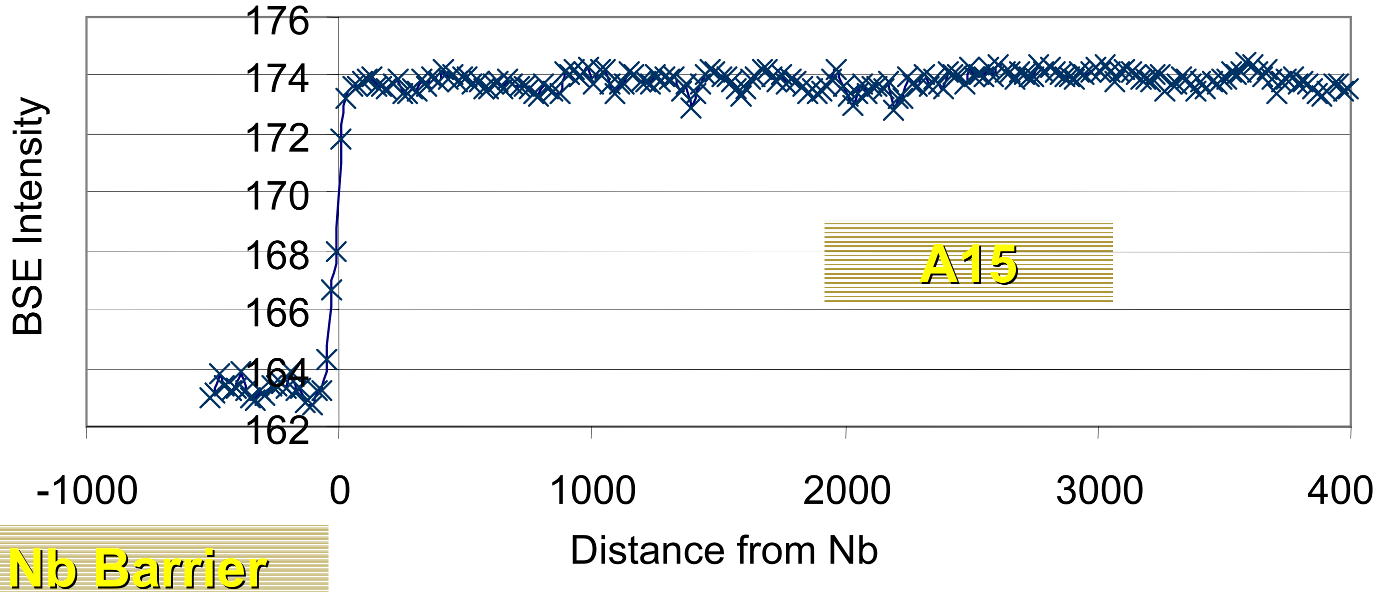


Apart from the columnar grains at the barrier there is a continuous but small morphological variation across the layer in grain boundary density.

Overall BSE-Composition Across Outer Layer

Lee et al ASC 2000

Overall Flat



A15

With Local Variations

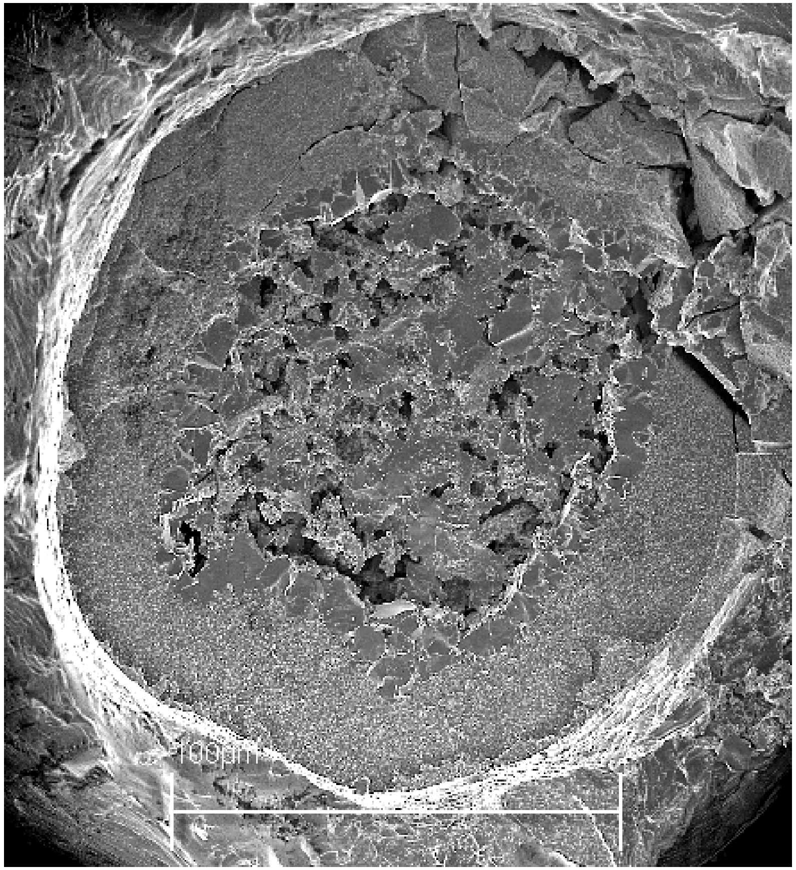
Nb Barrier

Columnar Region Barrier reaction

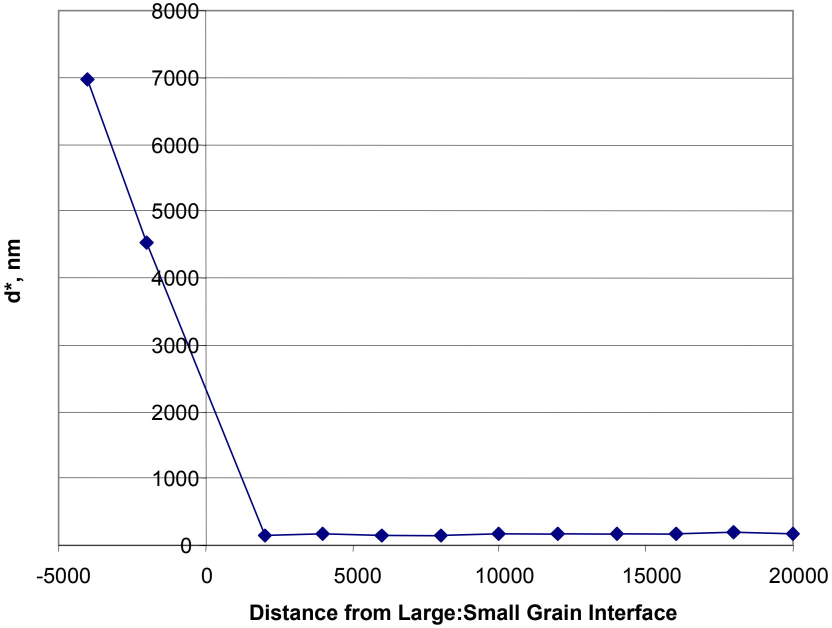
A15 from Nb-1%Ti Filament Reaction

ECN-Type PIT Example of Very High Sn source

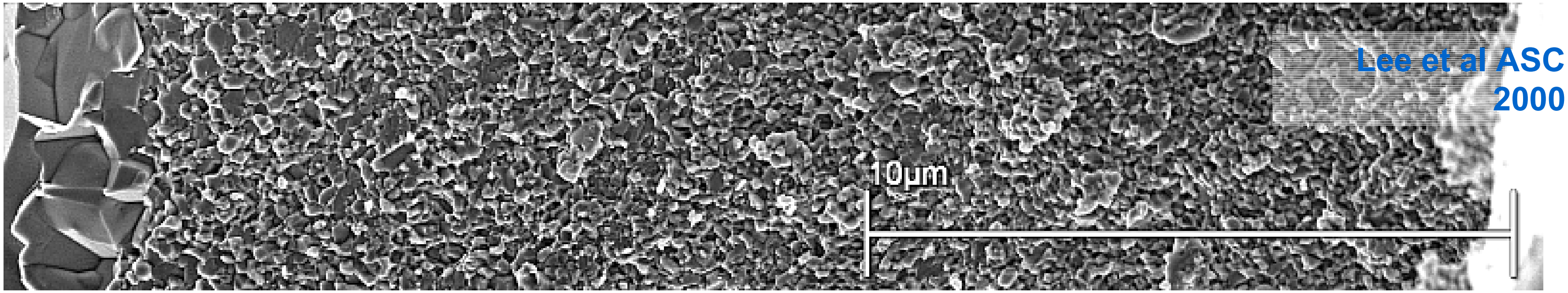
Lee et al ASC 2000

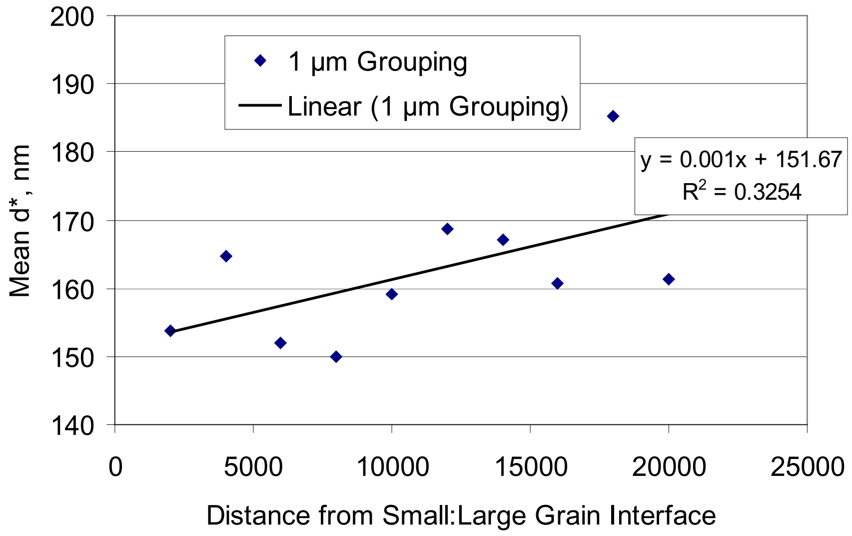


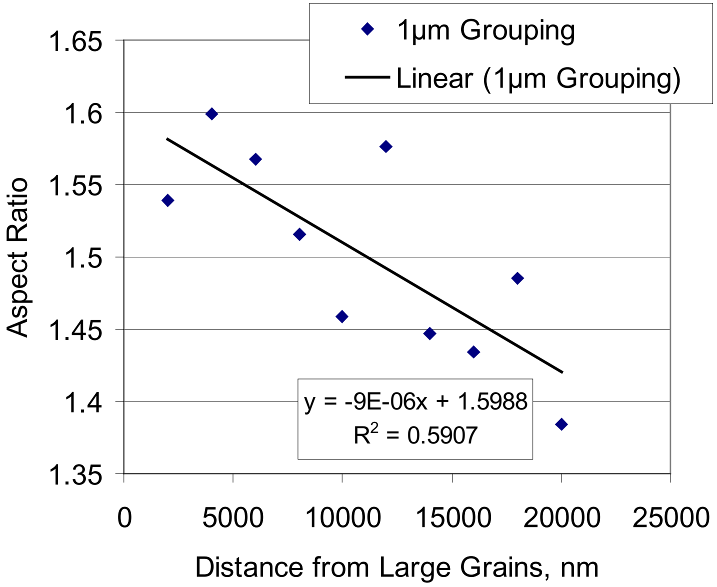
Fracture of Supercon PIT Monofilament Reveals inner large grain region and outer fine grain region around residual powder core



20 µm Wide Fine Grain Region

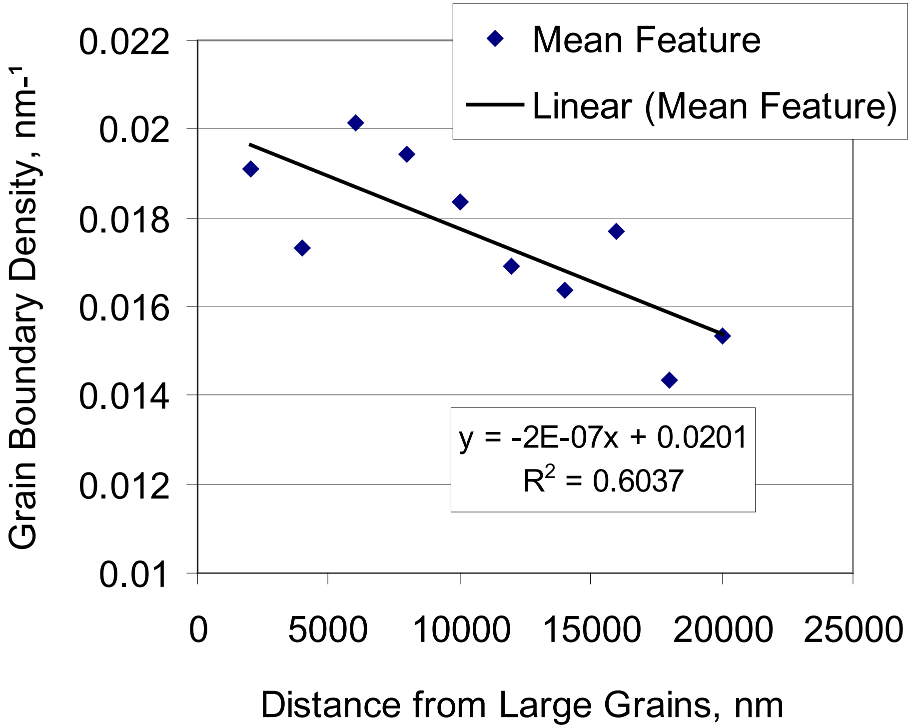






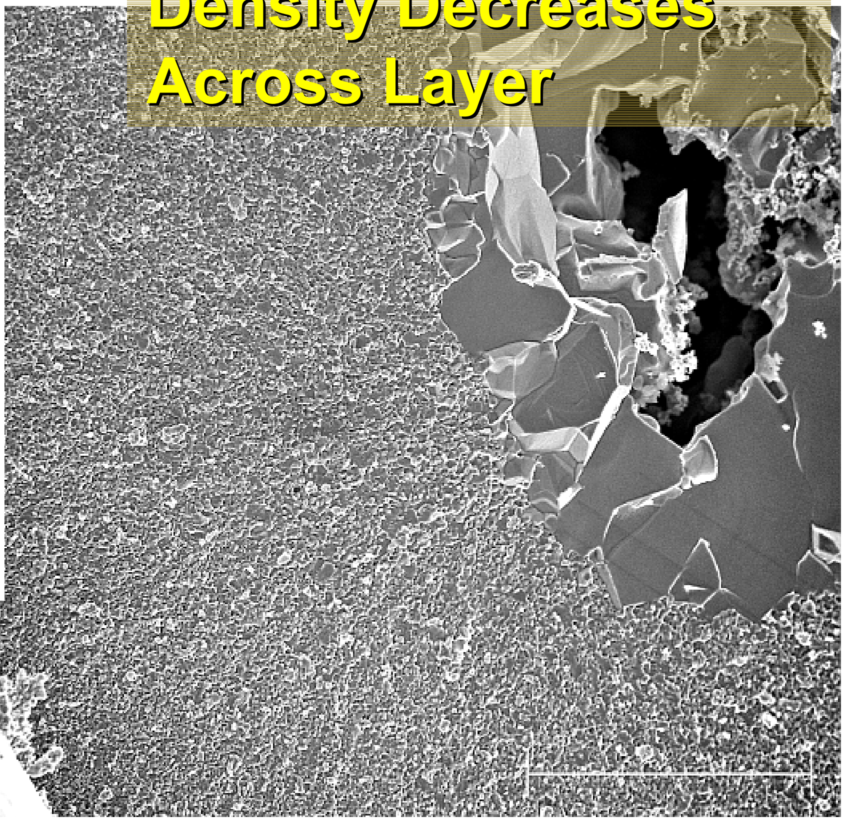
- Shallow gradient in d* across layer, surprising aspect ratio gradient

Grain Boundary Density



Lee et al ASC 2000

Grain Boundary Density Decreases Across Layer



Recent Microstructure Results

- In low-Sn internal Sn and bronze-process strand we observe the onset of columnar growth simultaneously with a downturn in %Sn at 300-600 nm into filament.
- In the high-Sn strand we observe that the principal variations are across the original filaments and not across the coalesced filament pack.
- This should impact filament size choice for rod based internal Sn.
- In the ECN style PIT monofilament, with a very high Sn content powder core, a uniform, and fine grain size can be achieved over a very long distance.
- See following results on OI-ST powder route . . .

Cabling work in support of the conductor development program includes

- Reducing cable I_c degradation for high J_c Nb_3Sn strands
- Understanding the J_c vs strain behavior for Nb_3Sn strands made by different processes
- Fabricating new cables designed for react and wind coils
- Exploring cabling alternatives for a more cost-effective conductor

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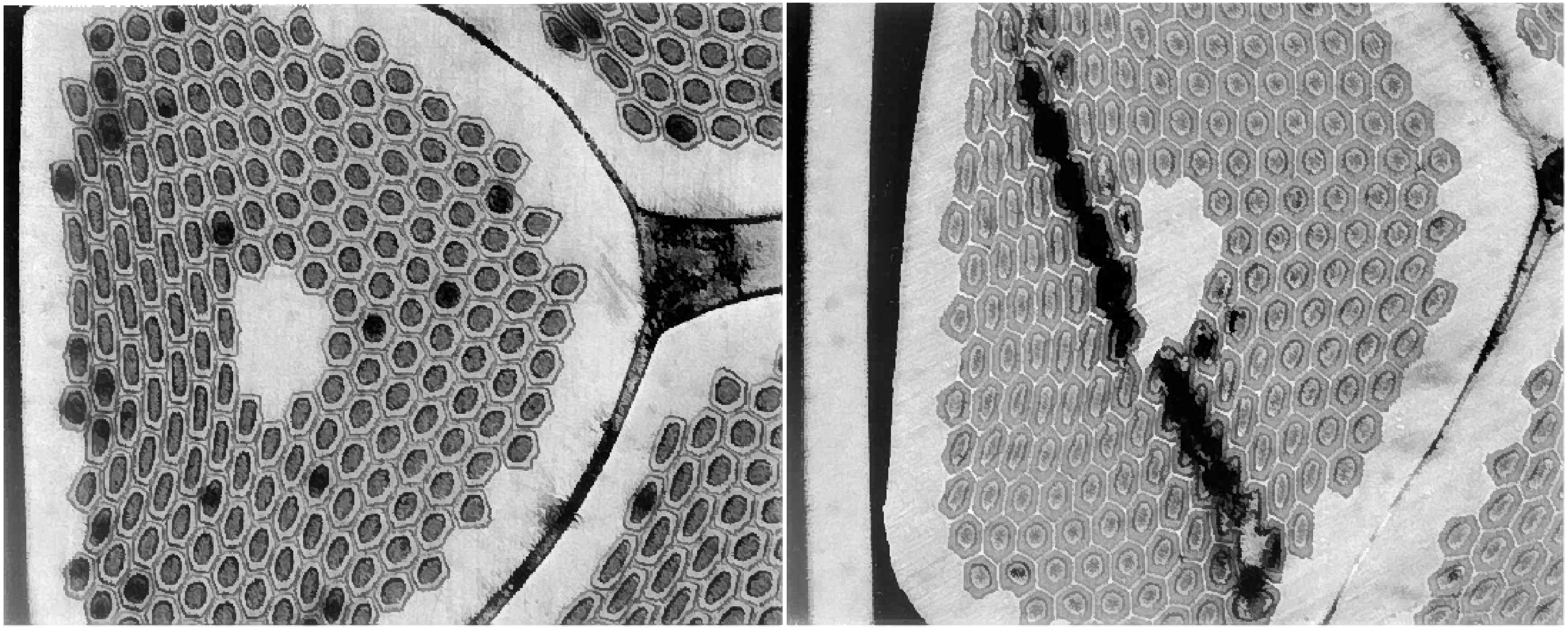
PIT Nb_3Sn strands at edge of Rutherford cable



Moderately compacted *Highly Compacted*

Ron Scanlan ASC2000

PIT strand Chronology from Twente

pre-print of paper 4LB-02, presented at the Applied Superconductivity Conference, Virginia Beach, September 2000

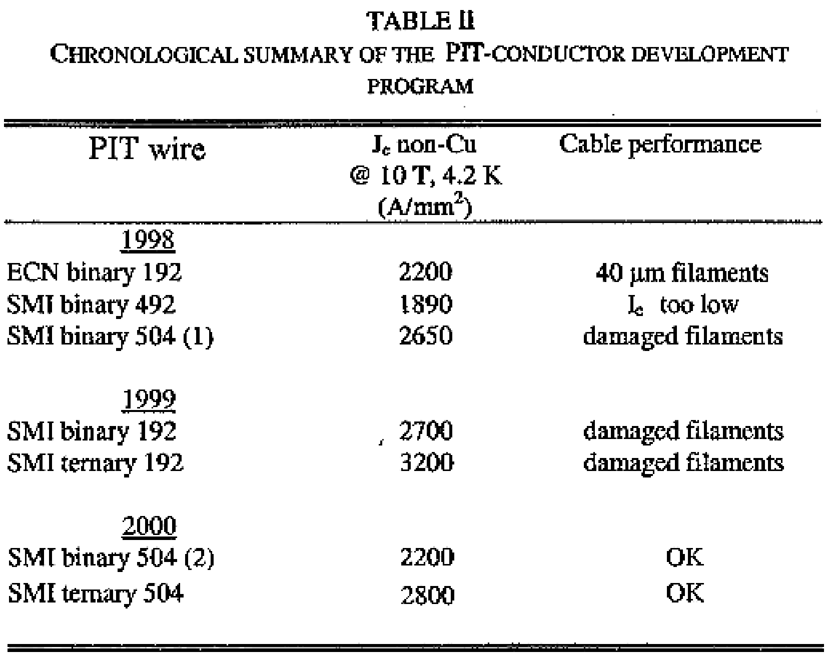


TABLE II

CHRONOLOGICAL SUMMARY OF THE PIT-CONDUCTOR DEVELOPMENT PROGRAM

PIT wire	J_c non-Cu @ 10 T, 4.2 K (A/mm^2)	Cable performance
1998		
ECN binary 192	2200	40 µm filaments
SMI binary 492	1890	I_c too low
SMI binary 504 (1)	2650	damaged filaments
1999		
SMI binary 192	2700	damaged filaments
SMI ternary 192	3200	damaged filaments
2000		
SMI binary 504 (2)	2200	OK
SMI ternary 504	2800	OK

Andries den Ouden et al. ASC2000

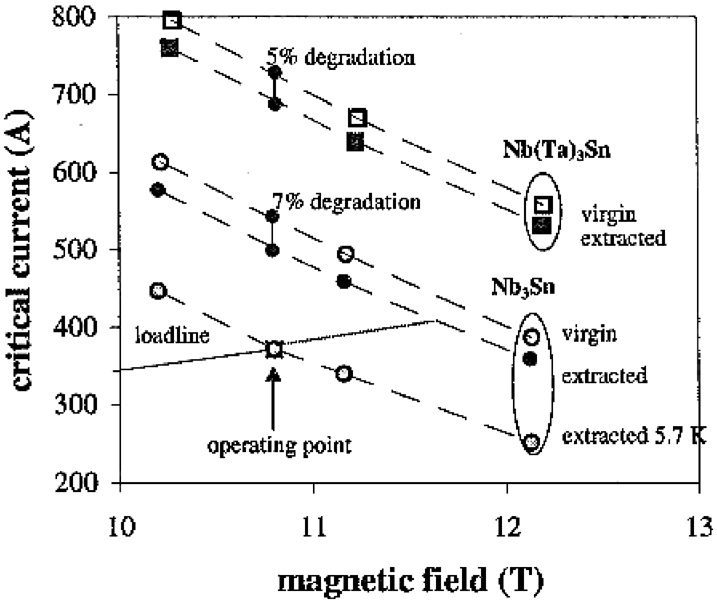
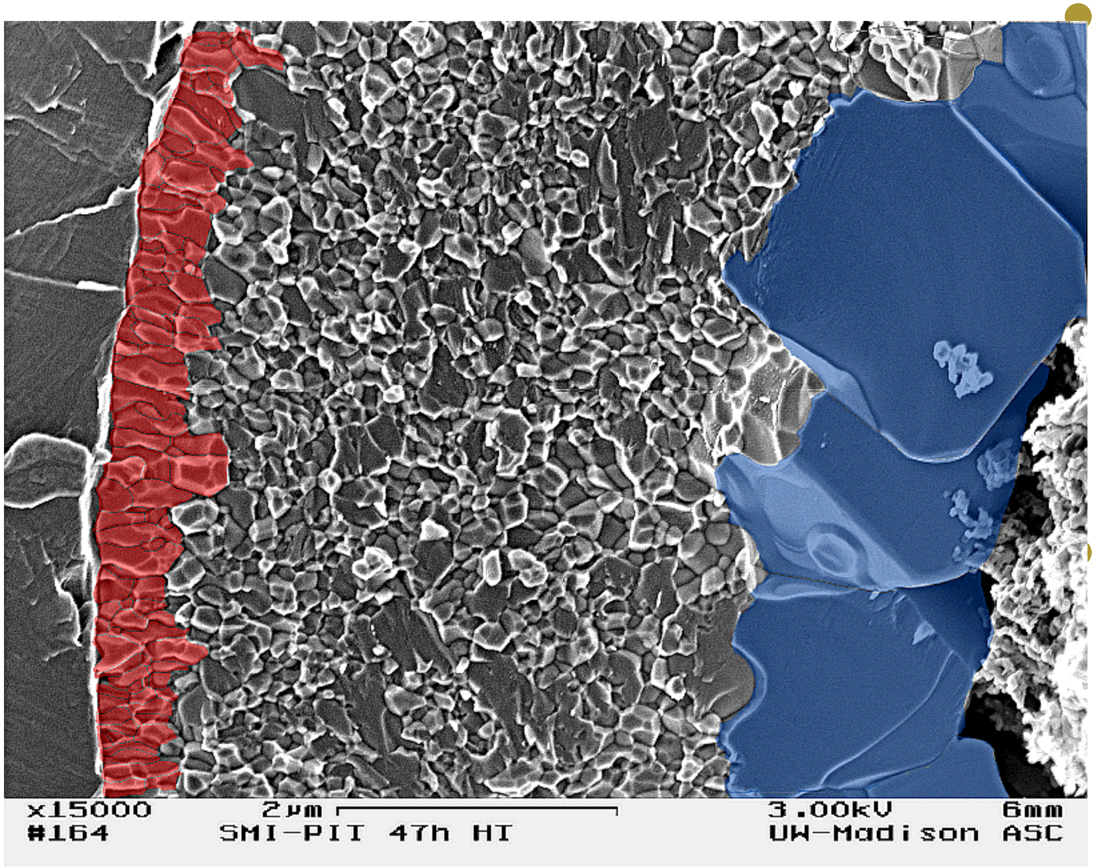


Fig. 1. Critical current at 4.2 K of binary and ternary PIT-Nb$_3$Sn conductors as a function of the self-field corrected applied magnetic field of both virgin wires and extracted strands. Also shown is the predicted critical current of the binary extracted strand at 5.7 K.

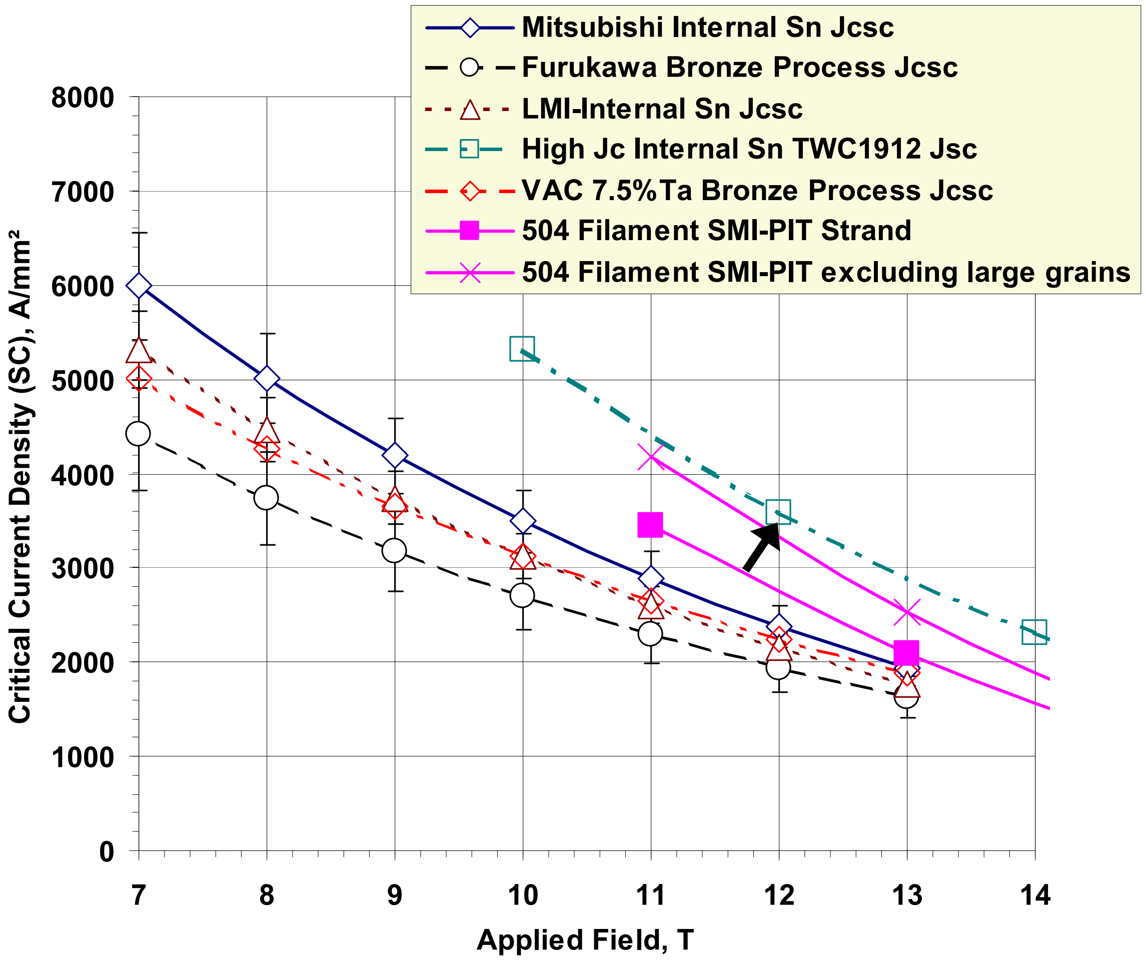
Analysis of Layer J_c and Q_{gb} in non-alloyed SMI-PIT strand



- In this partial fracture cross-section of a SMI-PIT strand, three distinct grain size/morphology regions are observed.
  - Columnar adjacent to the Nb
  - Fine equiaxed center
  - Very large grains adjacent to core.
- If the very low grain boundary density in the large-grain area means that this area does not contribute significantly to I_c then we can adjust the J_{csc} data to reflect the “good” area.

Lee et al. (UW)

Non-Alloyed SMI PIT J_{csc}

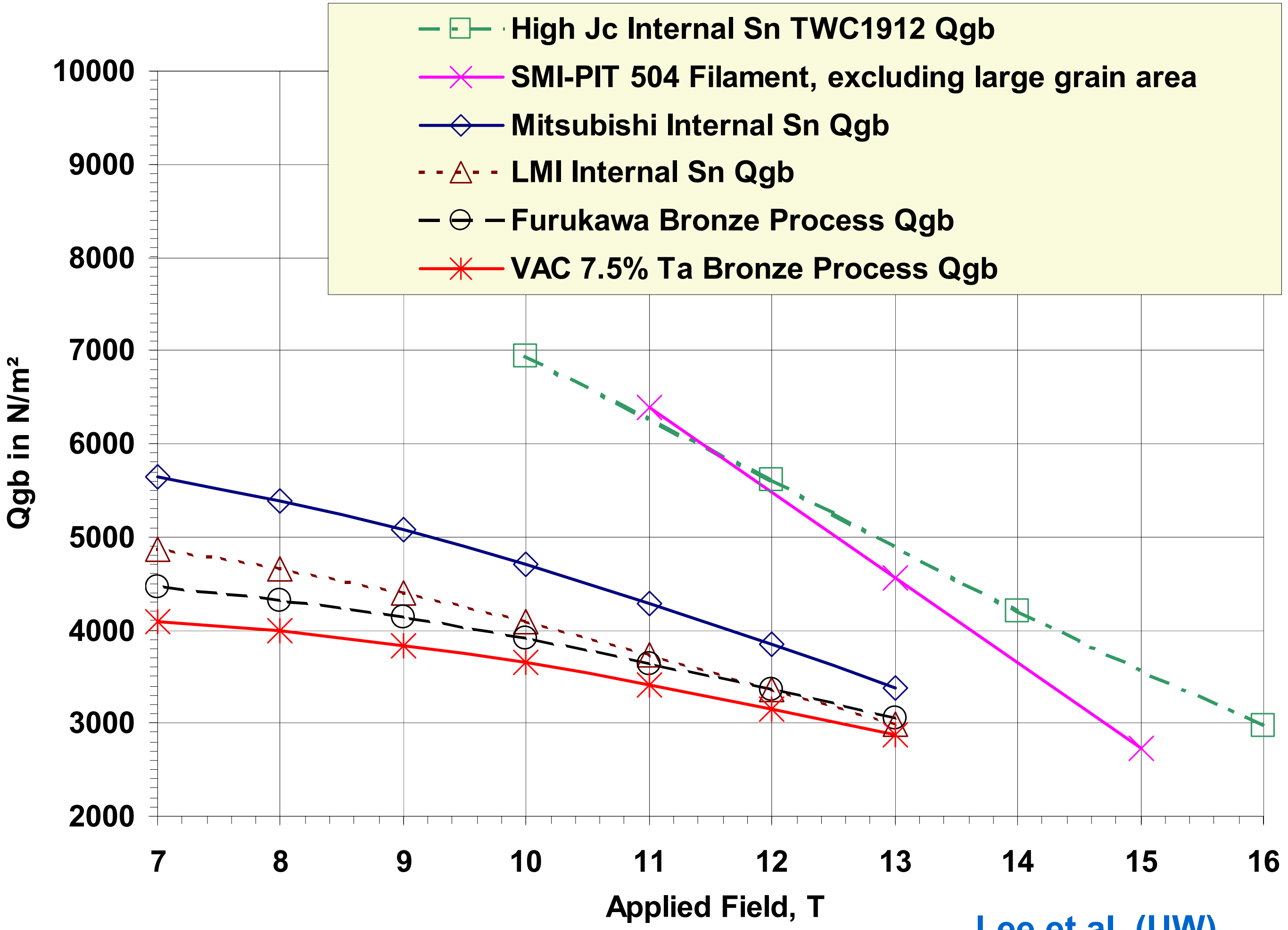


Lee et al. (UW)

When the J_{csc} data is calculated excluding the non-contributing large grain area the performance of the PIT A15 more closely matches the high J_{csc} internal Sn strand.

The higher J_c of the new $Nb(Ta)_3Sn$ can be expected to increase the J_{csc} further

Specific Grain Boundary Pinning Comparison



Lee et al. (UW)

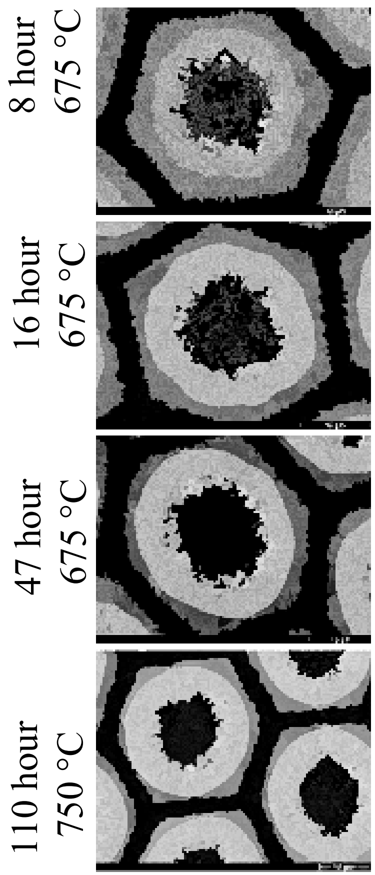
High Sn and PIT strands have 50% higher Q_{gb} (and J_{csc}) than ITER style strands

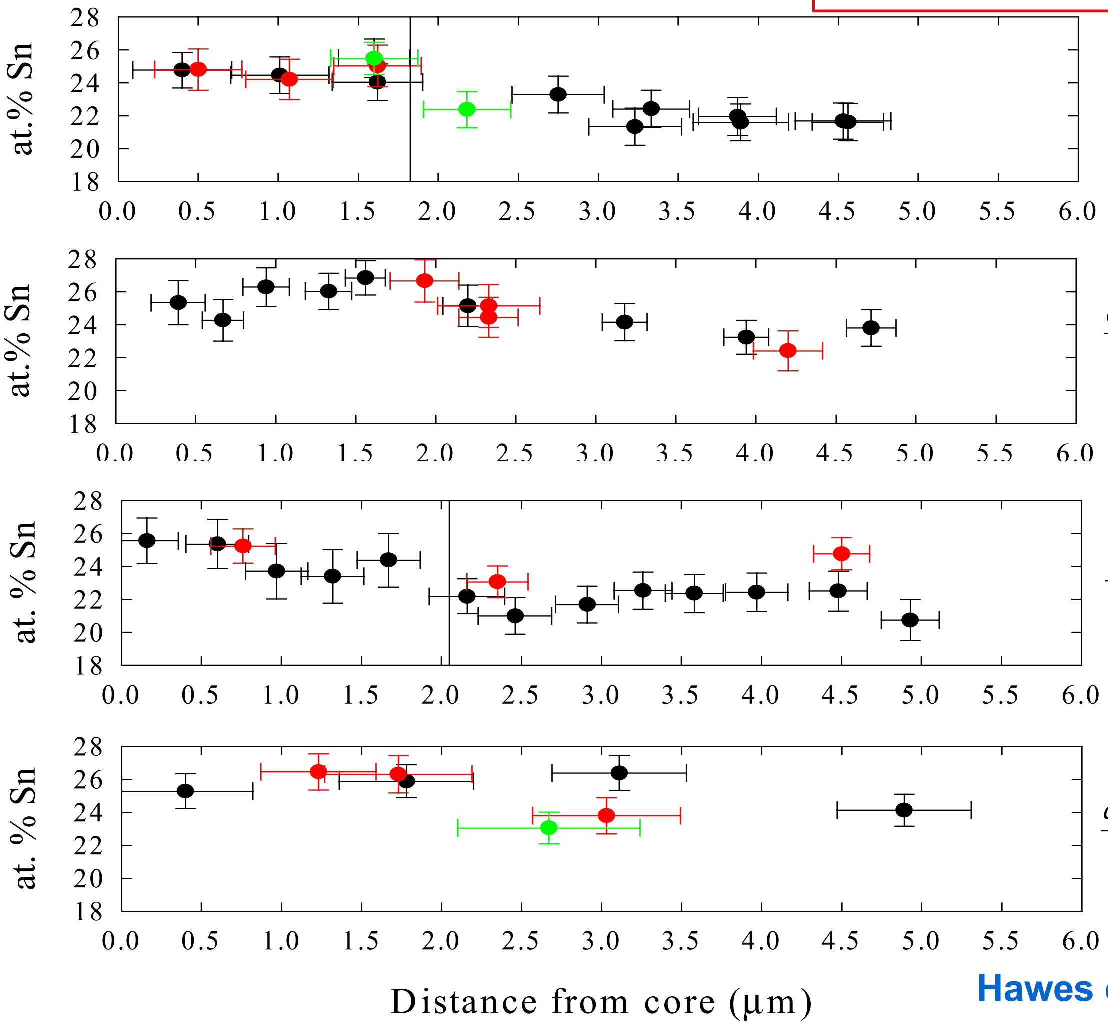
The new $Nb(Ta)_3Sn$ PIT should not have the high field tail off observed here.

EDX Measurements

Note: again we have highest Sn in low grain boundary density area!

Large grains Small grains





$$\frac{at.\%Sn}{\mu m} = -0.92$$

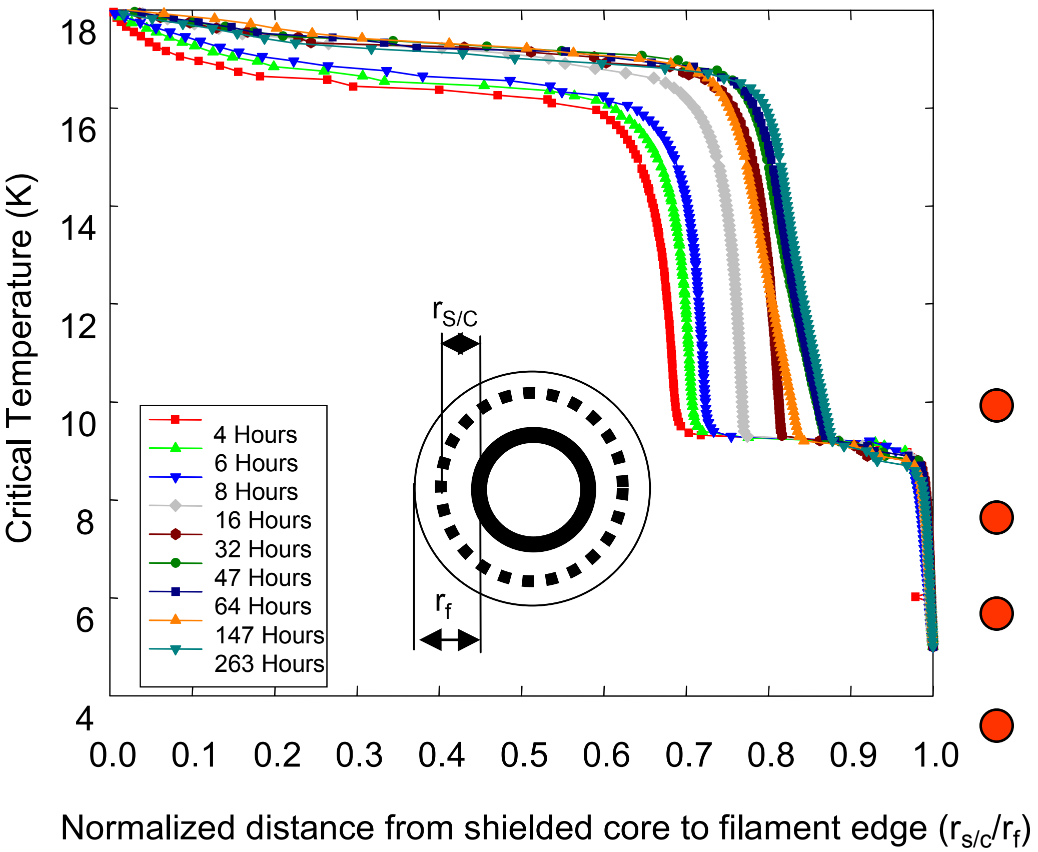
$$\frac{at.\%Sn}{\mu m} = -0.69$$

$$\frac{at.\%Sn}{\mu m} = -0.64$$

$$\frac{at.\%Sn}{\mu m} = -0.37$$

Hawes et al. (UW) ASC2000

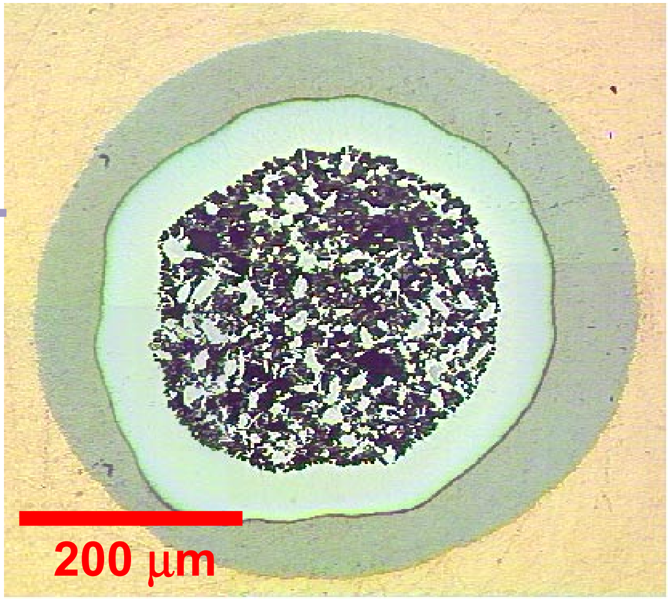
675 °C T_c Profiles in SMI PIT



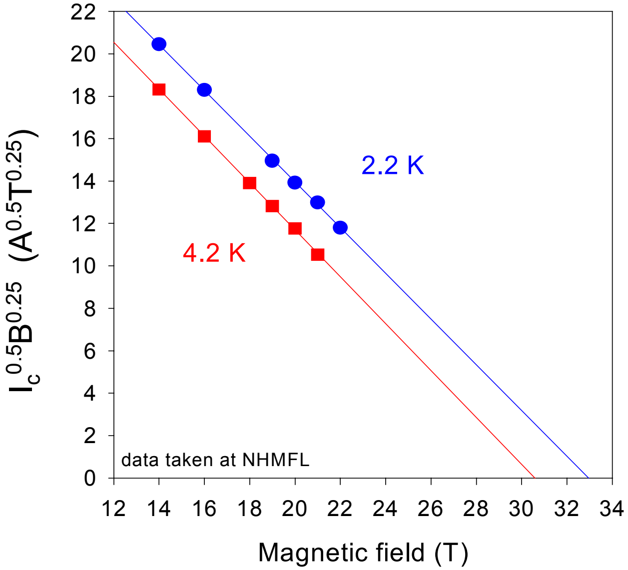
- *The Nb_3Sn in PIT filaments has progressively higher Sn into the filament from the barrier, thus the change in properties through the layer can be analyzed without the shielding that occurs in bronze and internal Sn filaments.*
- 4-8 hr plots have a steeper slope.
- Layer growth visible.
- After 32 hrs growth rate slows.
- Tail appears at ~ 14 K after 47 hour HT.

Hawes et al. (UW) ASC2000

Powder-in-tube Nb_3Sn development at OI-ST



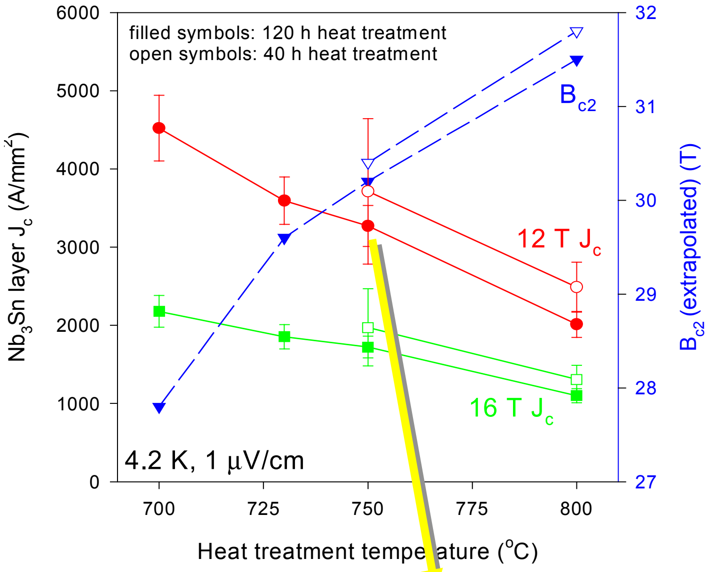
- Ta+Sn+Cu mixed together, similar to Tachikawa et al. process (ASC'98)
- thick $(Nb,Ta)_3Sn$ layers
- high Nb_3Sn layer J_c
- high B_{c2}



OXFORD

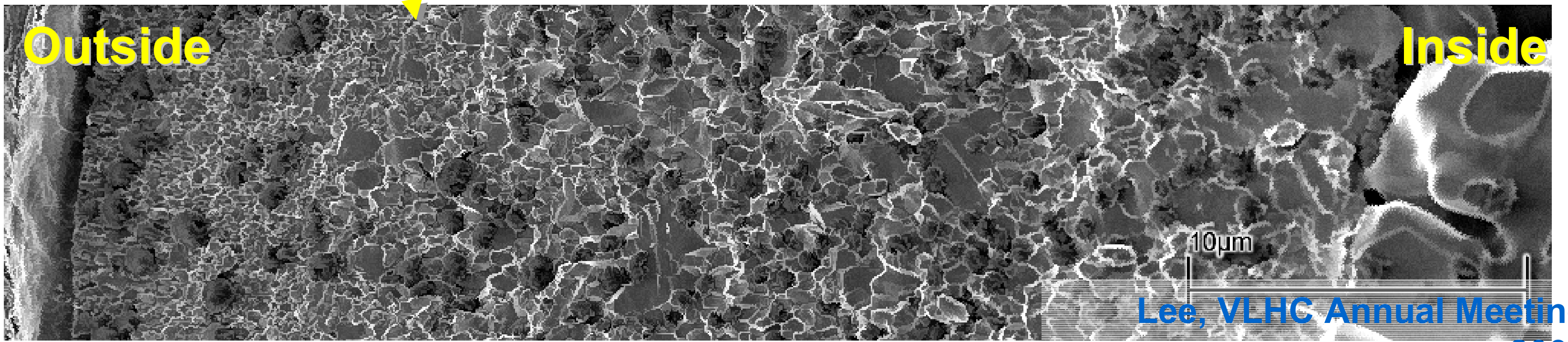
Hentges et al. (OI-ST), ASC 2000

μ-Structure from UW shows fine enough grain size for pinning and high Kramer extrapolation



The effect of heat treatment on J_c and B_{c2} for PIT wire. B_{c2} data is extrapolated from 16 T.

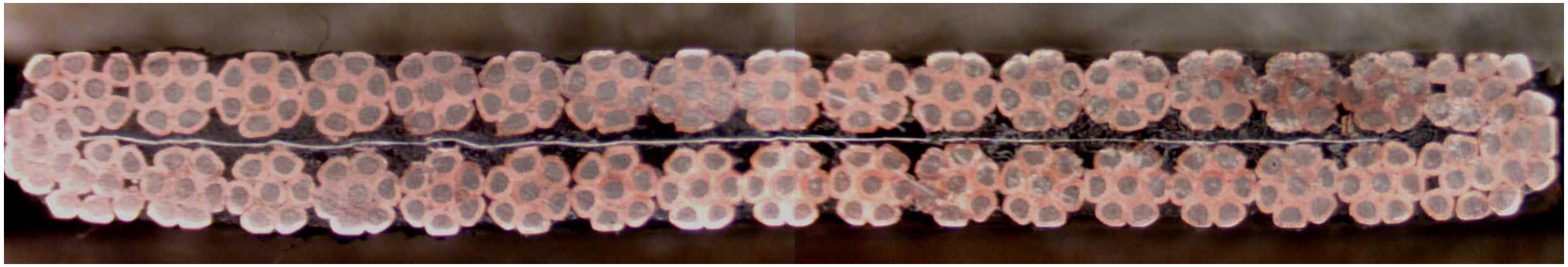
Note grain size gets smaller towards the outside.

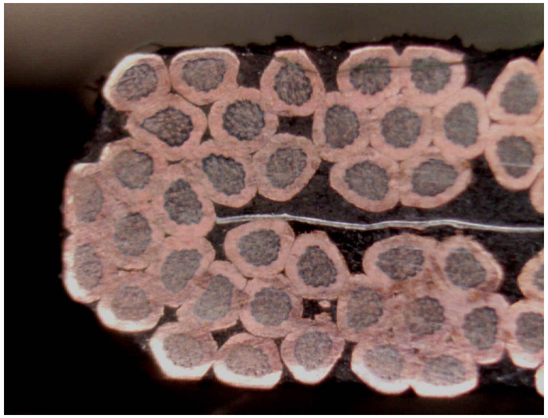


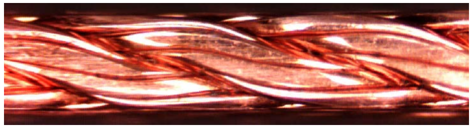
Lee, VLHC Annual Meeting 2000

FNAL R&W R3I-00741a Mfg. LBNL 2/17/00

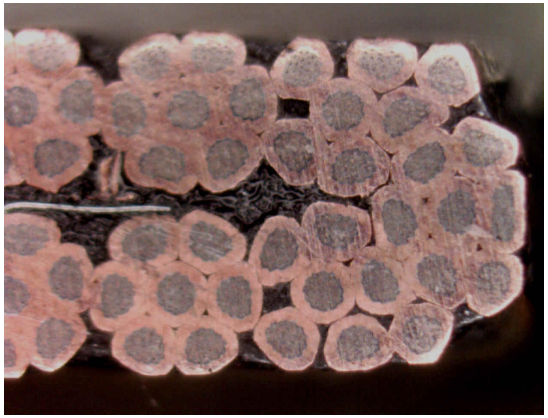
6-in-1 Cabling

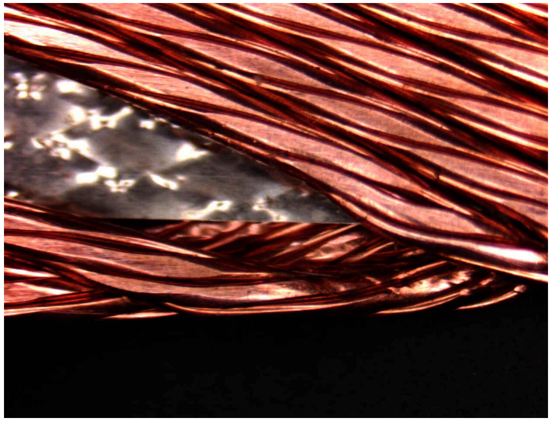


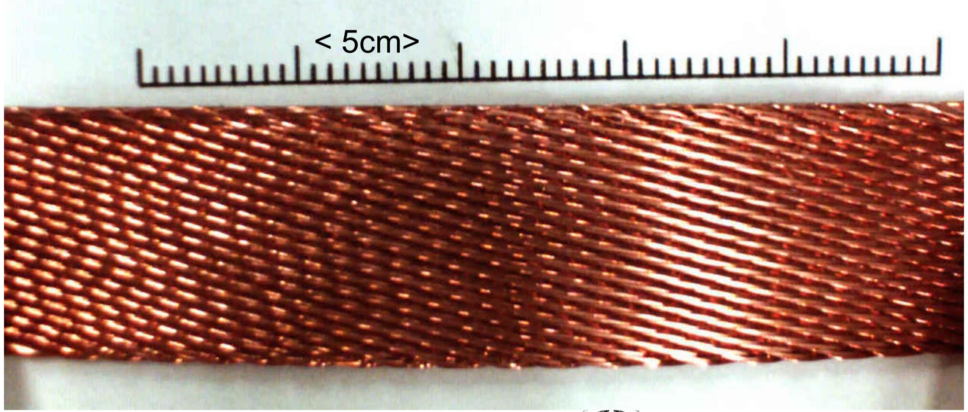




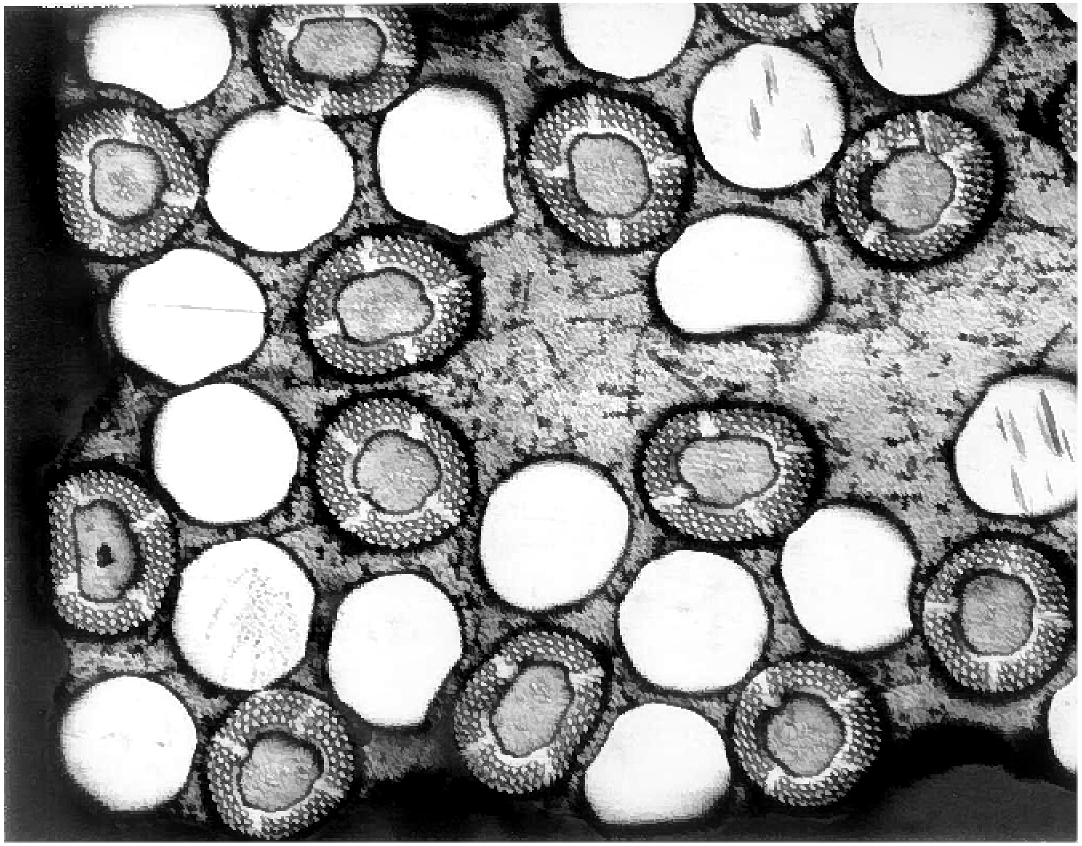
Ron Scanlan ASC2000







Rutherford cable made from sub-cables with 4 copper and three superconductor strands



Ron Scanlan ASC2000

A High Current Density Low Cost Niobium$_3$Tin Conductor Scaleable to Modern Niobium Titanium Production Economics MEIT Approach

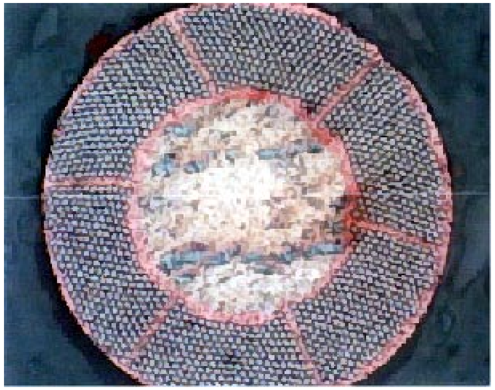
- To meet the VLHC target one has to
  - Increase current density by adding niobium and tin at the expense of copper
- Reduce cost by designing a process that can be manufactured in large scale 450kg billets
  - eliminate barrier?, lower cost barrier,

Zeitlin (Supergenics), Gregory and Pyon (IGC-AS), ASC 2000

Design Approach

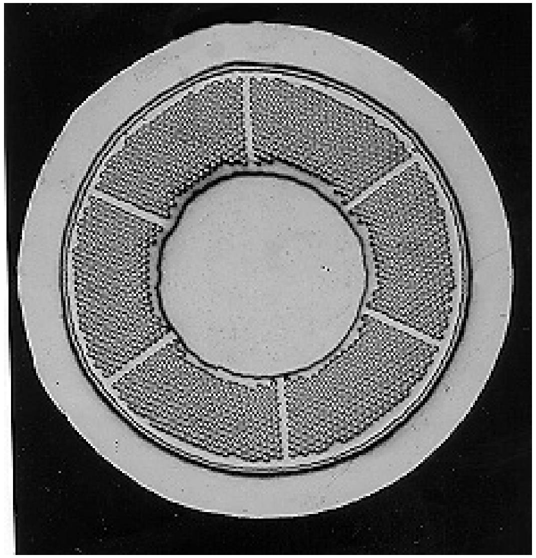
- Single element composite for fabricability
- Fine filaments to speed reaction and decrease grain size
- Segmented to reduce loss
- Minimize composite copper thus boosting tin and niobium
- Evaluate need for barrier

Zeitlin (Supergenics)
Gregory and Pyon (IGC-AS)
ASC 2000



BAZ1 six segment wire 0.142mm

Conductor Configurations



Cross Section Before Reaction

Zeitlin (Supergenics)
Gregory and Pyon (IGC-AS)
ASC 2000

Billet,178mm	BAZ1 6 seg.	BAZ2 3 seg.
Filament #	1434	1475
Nb: area%/At%	31.7/28.0	32.7/29.1
Sn: area%/At%	27.1/16.1	27.1/16.2
Cu: area%/At%	41.2/55.9	40.1/54.7
Bronze At%	22.4	22.8

Reduced Sn	BAZ1 6 Seg.	BAZ2 3Seg.
Nb: area%/At%		29.5/24.9
Sn: area%/At%		22.2/12.6
Cu: area%/At%		48.3/62.5
Filament Size at 0.14 mm	1.9 μm	1.9 μm
Segment Size at 0.14 mm	22x55 μm	22x110 μm

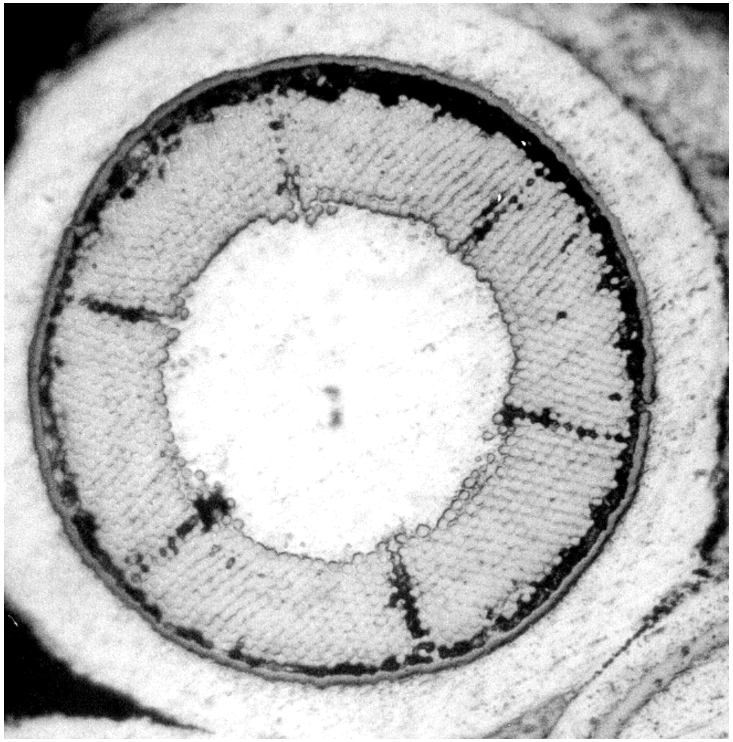
MEIT Fabrication Results

179 mm 1434 filament Billet

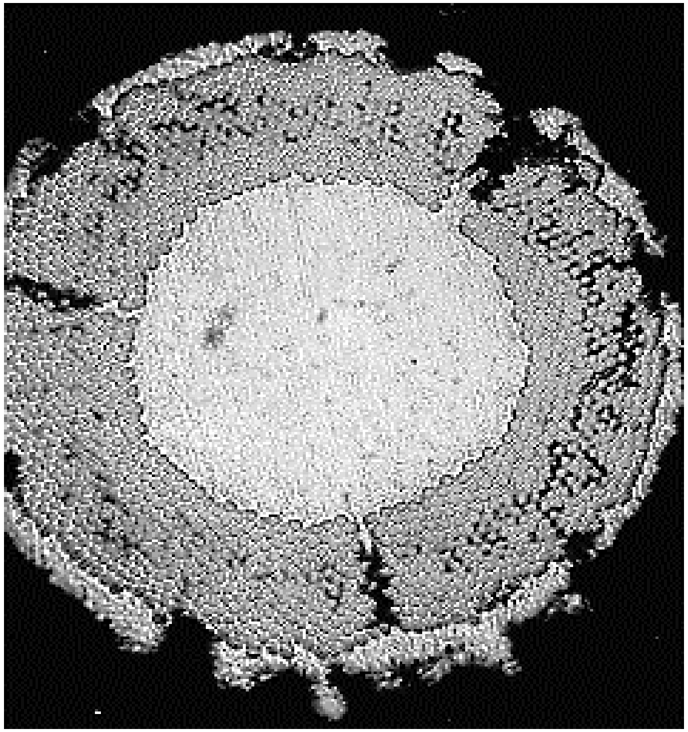
- Fabrication and wire drawing
  - Processing was smooth,
    - one break at 1.5 mm , mechanical
  - 10000 and 30000 meter lengths at 0.14 mm
    - Break was mechanical, commercial wire draw
- Barrier required at high tin
  - could engineer barrier free but J_c would suffer

Zeitlin (Supergenics), Gregory and Pyon (IGC-AS), ASC 2000

Reacted Cross Sections



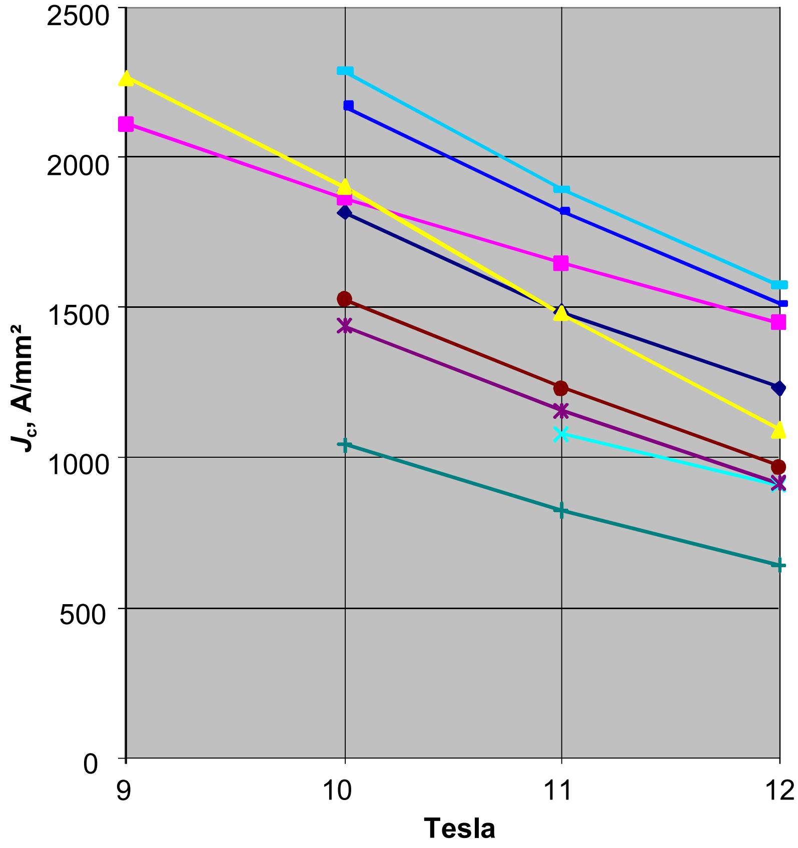
TaBrBaz1 Tantalum Barrier 0.2mm



BAZ2A lower tin 0.20 mm

Zeitlin (Supergenics), Gregory and Pyon (IGC-AS), ASC 2000

Test Results



	Cable ID	Barrel# Heat Treat	Wire Size mm	Filament µm	Comment
■	BAZc101	688 - C	0.60	0.9	19 TIB
■	BAZb1O1	682 - B	0.60	0.9	19 TIB
■	TaBBAZ1	220 - A	0.20	1.9	TIB
◆	TaBBAZ1	216 - A	0.30	2.8	Ta Integ Barrier (TIB)
▲	TaBBAZ1	224 - A	0.14	1.4	TIB
●	BAZ2A	227 – A	0.20	2.8	SB
✳	BAZ2A	206 - A	0.29	4.0	SB
✕	TaBarAll	229 - A	0.29	2.8	TIB
+	BAZ1-2-1	201 - A	0.29	4	Separated Barrier (SB)

Data from Zeitlin (Supergenics), Gregory and Pyon (IGC-AS), ASC 2000

Test Results

- 19 element 0.9 μm J_c normalized to Nb 5400-5500 A/mm^2 at 12 T
  - 650 °C 240 hrs
- Mono element with barrier (MEIT), 2 μm filament 4800 A/mm^2
- MEIT at 1.4 μm less 3600- over-aged?
  - 700 °C 24 hrs.

Zeitlin (Supergenics)
Gregory and Pyon (IGC-AS)
ASC 2000

Cost Model Assumptions by Supergenics

- Full scale 300 mm dia. billet as per table
- Two production volumes, 300 and 12000 tonnes
- 400 % and 300% overhead rate with 40% GM
- Material prices as quoted from suppliers
- Barrier introduced at later stage of processing - semi to continuos clad

Zeitlin (Supergenics)
Gregory and Pyon (IGC-AS)
ASC 2000

Design Elements of Full Scale Billet

	Full Scale Billet	*Clad Niobium*
Extrusion Billet	300 mm dia. x 810 mm length	250 mm dia. x 610 mm length
Copper Clad Nb Hex Rod	3.2 mm	200 mm
Tin Alloy Core	2.6 mm	
Filament #	4614	1
Nb/Sn/Cu %	36/24/49	66.4
Yield	85% - 429 kg	94% - 239 kg

Zeitlin (Supergenics), Gregory and Pyon (IGC-AS), ASC 2000

MEIT Cost Model Results

0.25mm core@300 %OH	J_c A/mm² 12 T	Price \$/m Nb_3Sn	Price \$/m cable	Price \$/kAm
5%Ta Bar	2000/3000	0.12	0.50	1.23/0.82
2.5%TaB	2000/3000	0.10	0.42	1.06/0.71
5% Ta40Nb	2000/3000	0.11	0.46	1.12/0.75
2.5% Ta40Nb	2000/3000	0.10	0.40	1.00/0.67

Zeitlin (Supergenics), Gregory and Pyon (IGC-AS), ASC 2000

MEIT Conclusion

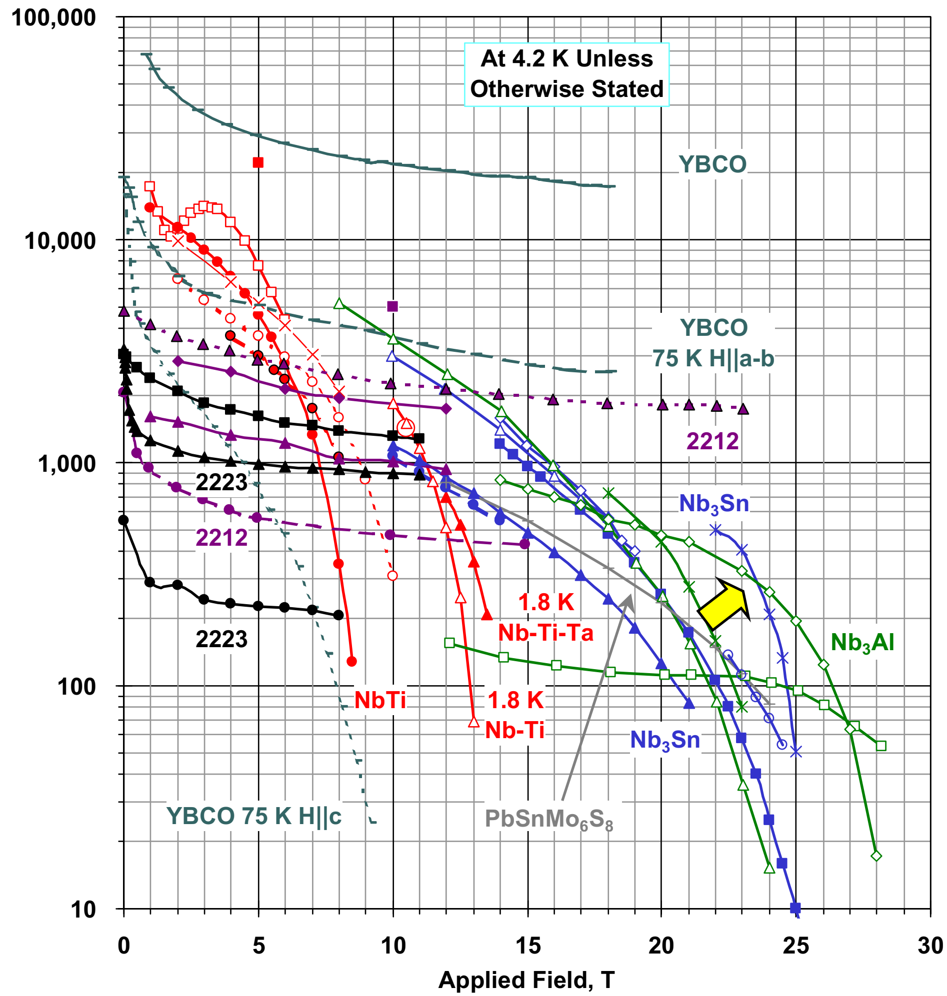
- Target costs and performance for VLHC appear feasible
  - MEIT conductor promises to be easy to fabricate
    - Low cost cladding technique still to be developed
    - SnTi alloy has to be commercialized to lower cost
  - Layer J_c of 5500 A/mm^2 with 50% Nb could yield 2750 A/mm^2 at 12 T
    - Need to improve understanding of layer current density and additives - build margin

Zeitlin (Supergenics)
Gregory and Pyon (IGC-AS)
ASC 2000

Rapid quench process Nb_3Al has advanced significantly this year.

- Best material has similar J_c at 12 T, 4.2 K, A-15 area to MJR Nb_3Sn
- Major advances this year relate to the super high field needs of 1 GHz NMR (23.5 T @ 1.8 K)
  - DRHQ shows dramatic J_c improvement at > 20 T
    - D = 2nd RHQ treatment added
    - 1st RHQ - Synthesis of Nb-Al Supersaturated solution
    - 2nd RHQ - phase transformation to A15 Nb_3Al
- New TRUQ process has greater potential for cladding and cabling than older RHQ processes. After quenching it has a ductile bcc supersaturated solid solution. “Transformation-heat-based up-quenching.”

DRHQ process from NRIM shows further potential of Nb_3Al



TRUQ

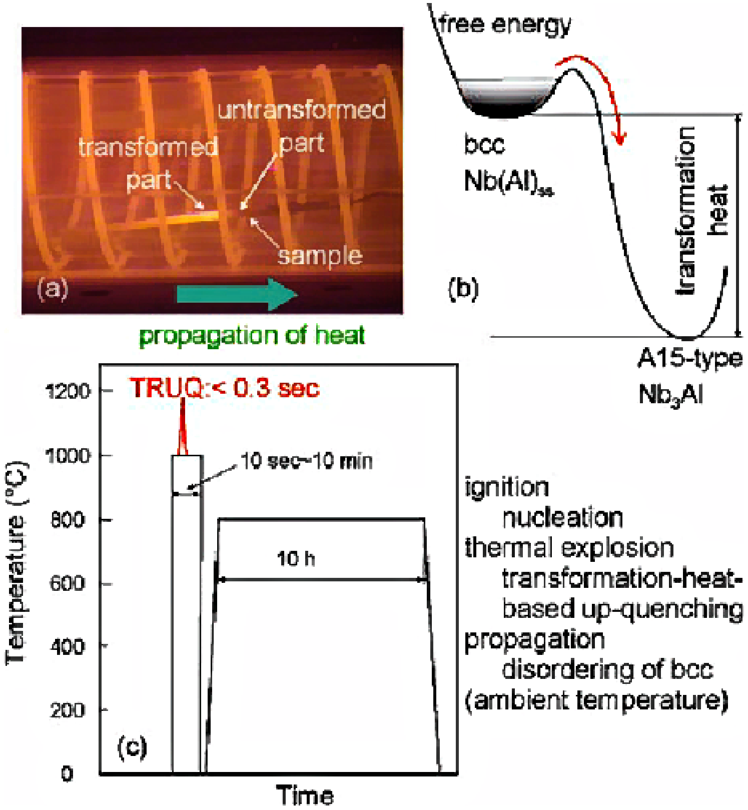


Figure 2. Illustration of TRUQ: (a) the propagation of the transformation interface from the left to the right in a Nb/Nb(Al) composite quickly pushed into 1000 C region in a gold-mirror furnace, (b) the enthalpy release during the transformation from bcc to A15 and (c) the temperature profile for the whole heat treatment process.

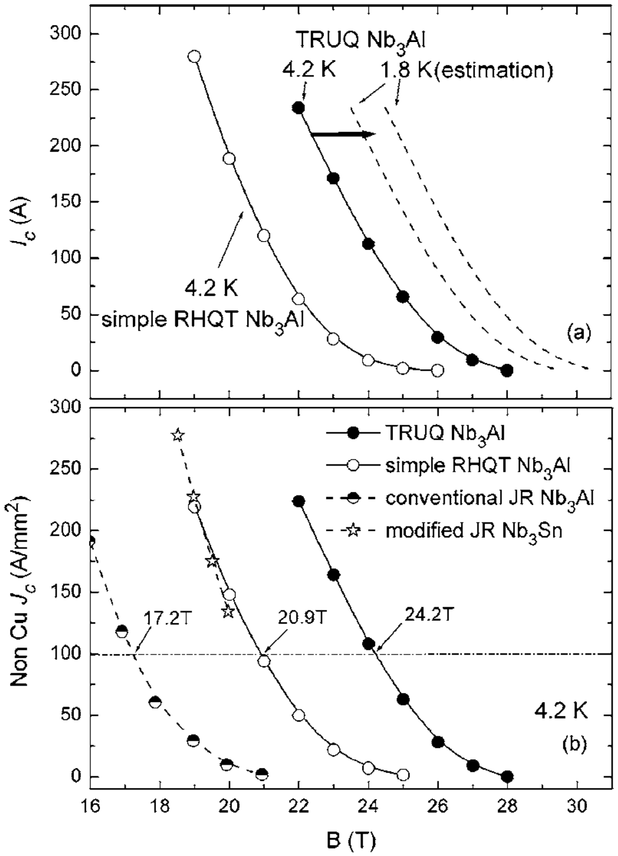
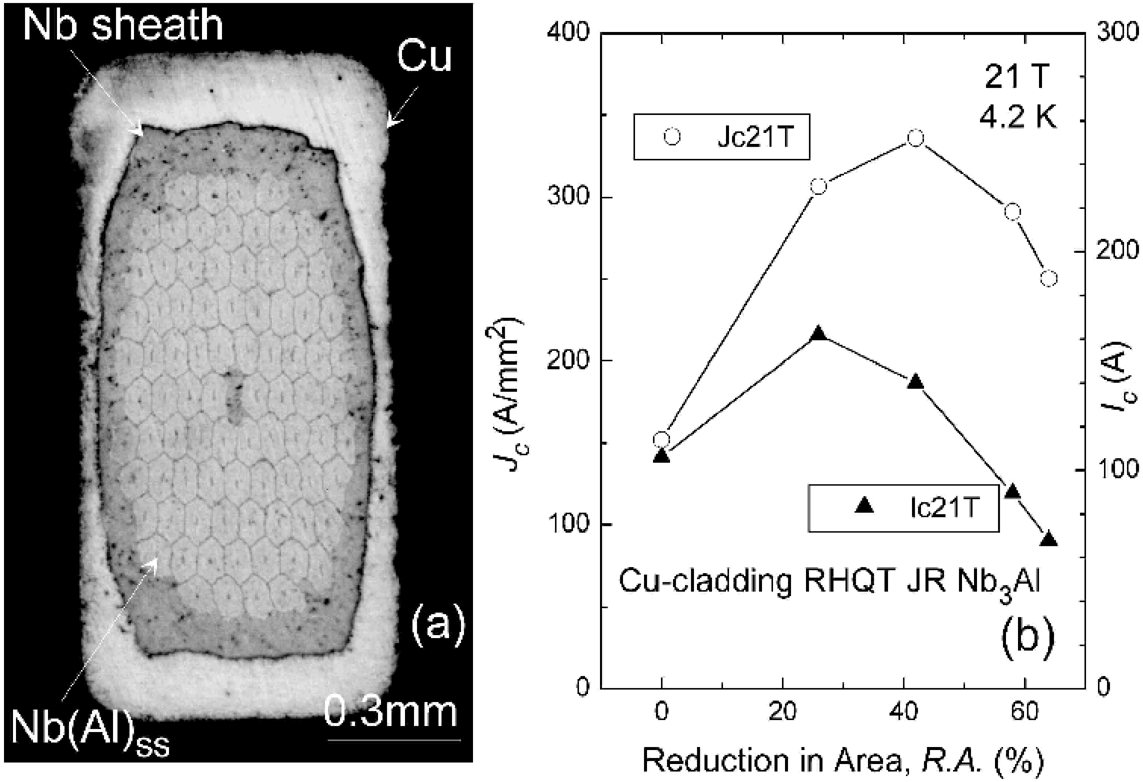


Figure 3. (a) and (b) non-Cu versus curves of TRUQ-processed Nb_3Al tape conductor (3.5 mm in width and 0.3 mm in thickness), in comparison with those of conventional, low-temperature-processed, JR Nb_3Al [17] and simple RHQT, JR Nb_3Al (1.25 mm in diameter) [4] conductors, and a modified JR Nb_3Sn conductor [18]. An estimation of (1.8 K) of TRUQ Nb_3Al is made by shifting the (4.2 K) data toward the higher field by 1.5–2.5 T.

From Takeuchi et al. Sc. Sci. Tech. Vol.13, 2000

Cladding of RHQT - NRIM

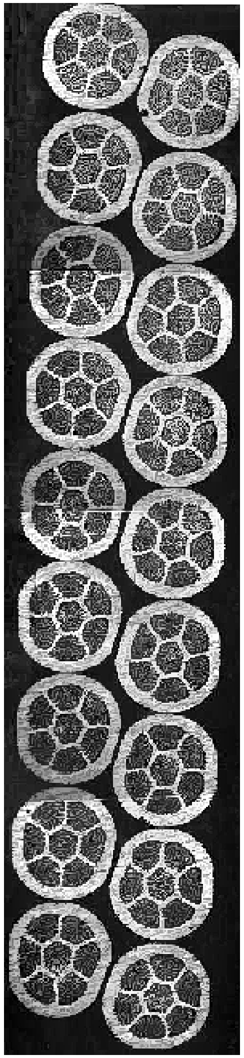


External stabilization for RHQT JR Nb$_3$Al by mechanical cladding method: (a) transversely overall cross-sectional image, (b) J_c and I_c against R.A. at Cu-cladding.

From: Takeuchi et al. ASC 2000 paper 5ML02

Bi-2212 round wire continues to show promise for accelerator magnets

- J_c(12 T, 4.2 K, non-Ag) > 1500 A/mm² in new material (ASC2000 paper 2MC03)
- Long lengths(> 250 m) are being produced; scale-up to >1000 m unit lengths is in progress.
- J_c vs strain for Rutherford cables looks promising(ASC 2000 paper 4MG06)
- React and wind coils are being made (ASC 2000 paper 3LE06)
- cost is still a major issue



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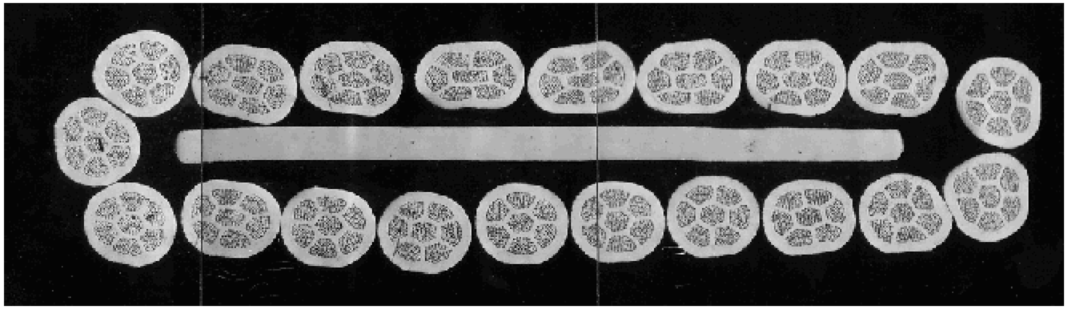
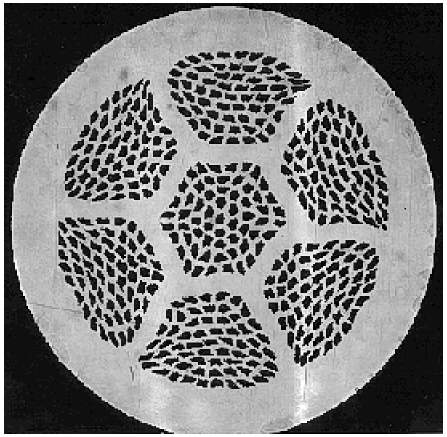
ASC2000

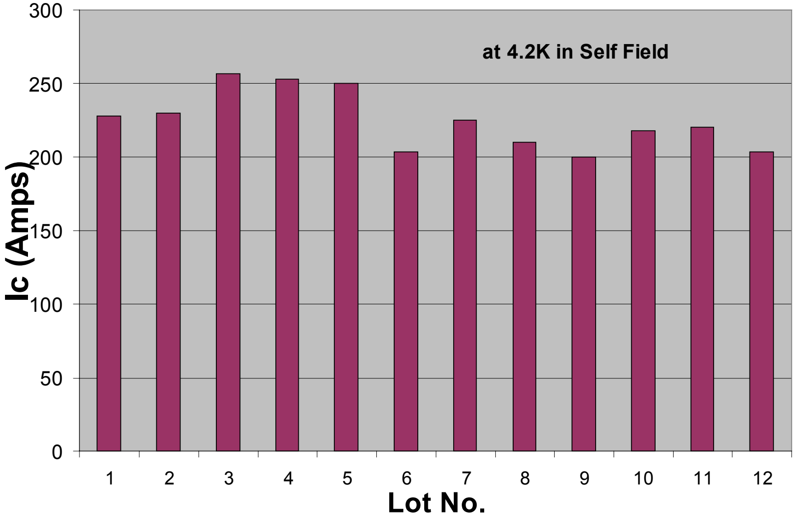
Bi-2212 IGC-AS

BSCCO-2212 0.81mm wire

427 filaments, 15μm filament diameter







L. Motowidlo, R. Sokolowski IGC-AS

T. Hasegawa, Showa Electric

R. Scanlan, LBNL

80 m of cable fabricated

I_c in self-field 3000 A

From Arup K. Ghosh, BNL Accelerator Magnet Divn: VLHC-FNAL Magnet Technologies Workshop

BROOKHAVEN NATIONAL LABORATORY

BSSCO-2223 Multifilament Tape

Conductors for BNL HTS coils

	Vendor	Length [m]	Width [mm]	Thickness [mm]	I_c (77K,SF) [A]	J_e [A/mm^2]	Axial stress [Mpa]	Matrix
1998	IGC	6x100	3.55	0.22	25	32		Ag
1999	NST	210	3.02	0.238	27	38	150	Ag-alloy
1999	NST	590	3.02	0.238	31	43	150	Ag-alloy
1999	VAC	155	3.78	0.22	53	64	>90	Ag-Mg
1999	VAC	155	3.82	0.23	58	66	>90	Ag-Mg
1999	VAC	155	3.86	0.23	58	65	>90	Ag-Mg
2000	ASC	210	3.04	0.171	68	131	75	Ag-alloy
2000	ASC	210	3.04	0.175	71	134	75	Ag-alloy
2000	ASC	210	3.13	0.175	81	148	75	Ag-alloy
2000	ASC	210	2.93	0.163	70	147	75	Ag-alloy

Cost $25/m

From Arup K. Ghosh, BNL Accelerator Magnet Divn:
VLHC-FNAL Magnet Technologies Workshop

BROOKHAVEN
NATIONAL LABORATORY

What does the future hold for HTS

- YBCO needs a lot of development before it can be a realistic conductor for magnets.
  - Conductor of choice for magnets operating at temperatures > 20 K
- BSCCO-2223 has slowly but steadily improved. Km lengths of reasonable J_c are feasible. More uniform conductor now available with improved manufacturing techniques
- BSCCO-2212 is potentially a better choice than 2223 at 4.2 K.
  - Probably will be less costly than 2223.
  - Can be fabricated as a tape or round wire suitable for Rutherford cables
  - Potential J_c at 12 T exceeding that of Nb_3Sn

From Arup K. Ghosh, BNL Accelerator Magnet Divn:
VLHC-FNAL Magnet Technologies Workshop

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FY 01 and beyond ….

- Continue programs at IGC and OST
- New Conductor Initiatives
  - --Powder in tube RFP (anticipate 3-4 responses)
  - --Nb_3Al Precursor Fabrication RFP (anticipate 3-4 responses)
  - --Special processing facilities
- Additional support for heat treatment, characterization, and I_c testing work
- Scale-up key manufacturing steps to establish large scale processing costs
- Develop realistic cost data to include in VLHC design studies

Ron Scanlan ASC2000

New Materials Program--Summary

- New Materials Program is underway, with broad community support and participation
- Two contracts are in place (IGC-AS and OI-ST)
- Nb_3Sn manufacturers are using this as an opportunity to rebuild their development teams
- I am optimistic that we can meet the performance and cost goals for Nb_3Sn
- Nb_3Al and Bi-2212 show promise as potential high field dipole conductors

Ron Scanlan ASC2000

VLHC Conductor 2000 Summary

- Conductor Development Program Started - *at last the major suppliers get direct HEP focused research money.*
- Internal Sn in transition to high J_c and lower cost. *What should our J_c vs $$$ balance be at this point?*
- Nb_3Al: the most progress in 2000 but still expensive and developments are for short lengths. *How important is strain intolerance - with magnet design advances?*
- HTS slow but steady progress. *How long would you like to wait?*