ShapeMetal Innovation B.V.

The producer of Nb_3Sn PIT conductors

SMI
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SMI activities

and

plans on PIT Nb_3Sn

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WAMS, Archamps, 23.03.04

Outline

- 1974 - 1990 ECN (history)
- 1992 - 2004 SMI (activities)
- 2004 - SMI - EAS (plans)

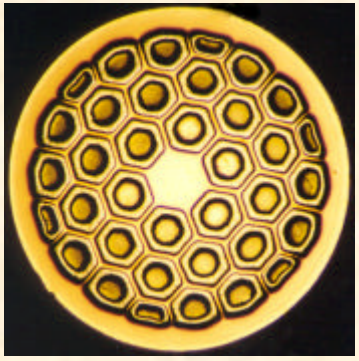
1974 – 1990

Development at Energy Research Foundation

ECN in Petten (NL)

- With pilot productions for Fusion and Accelerators

European Fusion Program



Cables for 12T coils of SULTAN-2 facility

(Coils are now part of ENEA test facility)

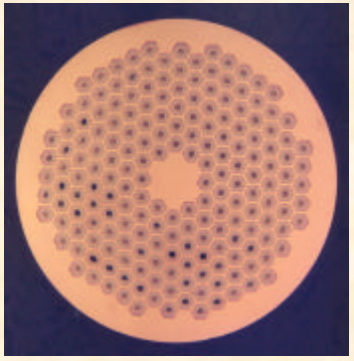
‘85 –‘86

PIT strand with 36 filaments

(12,2T; 4.2K)

Dia (mm)	Cu (%)	OD Nb (µm)	Ic (A)	N-value	Jc non-Cu (A/mm^2)	Weight (kg)
1.0	58	108	350		1060	167

Magnet development program of CERN



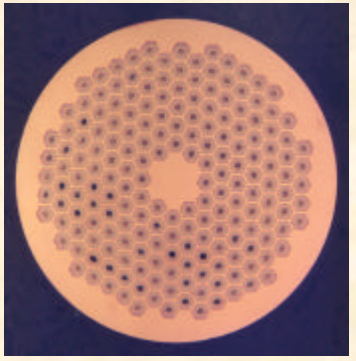
1 m Nb_3Sn model magnet ('87)

(ELIN made single pole)

'87 **PIT strand with 192 filaments for B-cable** (12T; 4.2K)						
Dia (mm)	Cu (%)	OD Nb (µm)	Ic (A)	N-value	Jc non-Cu (A/mm^2)	Weight (kg)
0.9	55	44	544	55	1898	47

'87 **B-cable (Keystoned Rutherford)** (12T; 4.2K)				
Dimensions (mm)	# strands	Ic (kA)	Jc non-Cu (A/mm^2)	Length (m)
1.45/1.77 x 16.4	36	18,8	1520	240

Magnet development program of CERN in co-operation with UT



11,5T Nb_3Sn 1 m model magnet ('90)

(Keystoned Rutherford Cables made by LBL Berkeley)

'90 **PIT strand with 192 filaments for A-cable** (12T; 4.2K)						
Dia (mm)	Cu (%)	OD Nb (µm)	Ic (A)	N-value	Jc non-Cu (A/mm^2)	Weight (kg)
1,25	53	62	657	40	1139	53

'88-'89 **PIT strand with 192 filaments for B-cable** (12T; 4.2K)						
Dia (mm)	Cu (%)	OD Nb (um)	Ic (A)	N-value	Jc non-Cu (A/mm^2)	Weight (kg)
1.0	53	49	541	40	1465	57

1992 – 2004

Activities of ShapeMetal Innovation
SMI in Enschede (NL)

- 1992 – 1995

  Main activity:

  Development and Production
  of SMA applications

- 1995 – 2004

  Development of PIT conductors

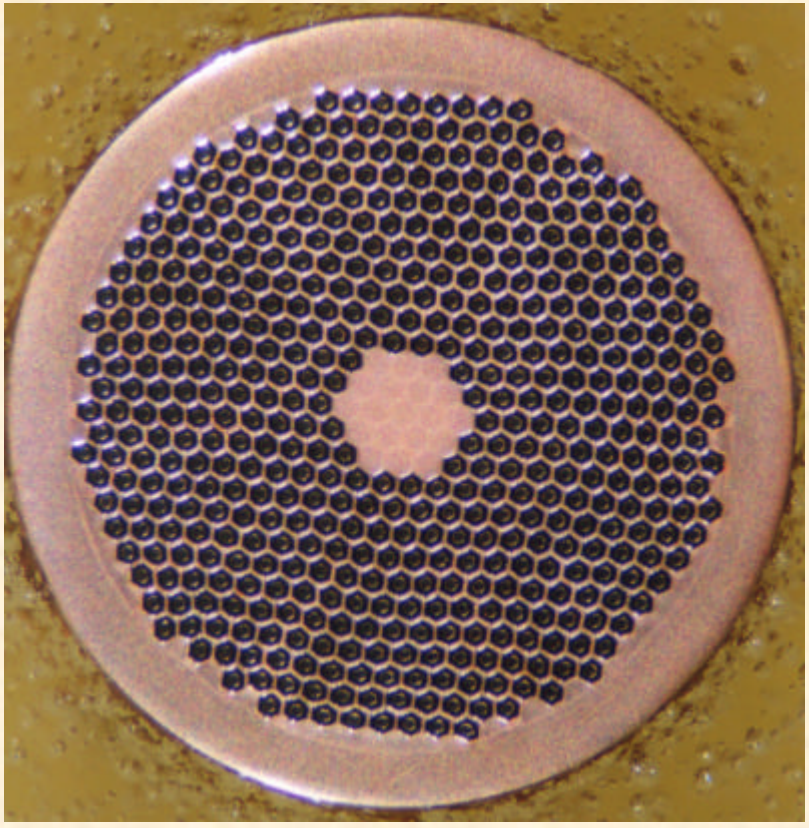
  With small production for
  Fusion, Accelerators and
  Laboratory Magnets

Development projects on PIT

(1995 – 2004)

- Fine filament conductor
- High field conductor
- Stress – strain behaviour
- Cabling
- Extrusion

Fine filament conductor



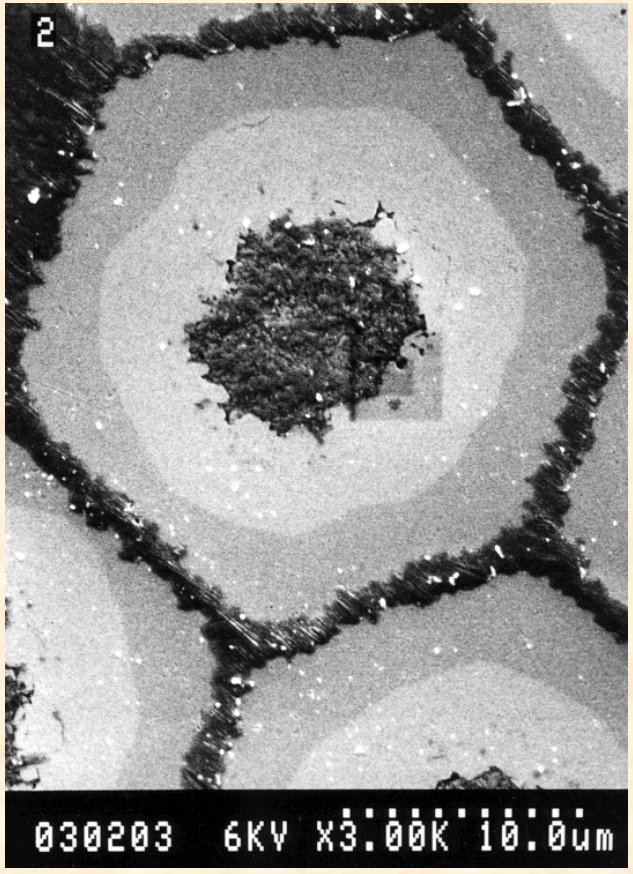
Binary conductor

- 504 filaments
- Matrix OFHC copper ca. 52%
- Diameter 0.9 mm; OD Nb 27,5 µm
- RRR value > 100
- Jc non-Cu: 1350 A/mm² at 12T
- N-value ca. 40 at 12T

In production for UT dipole magnet

Advanced Iter conductor ???

High field conductor

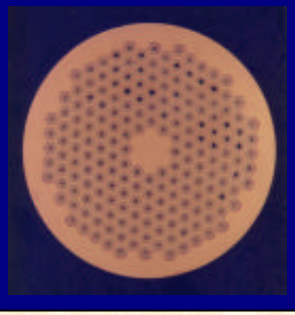


Tertiary conductor

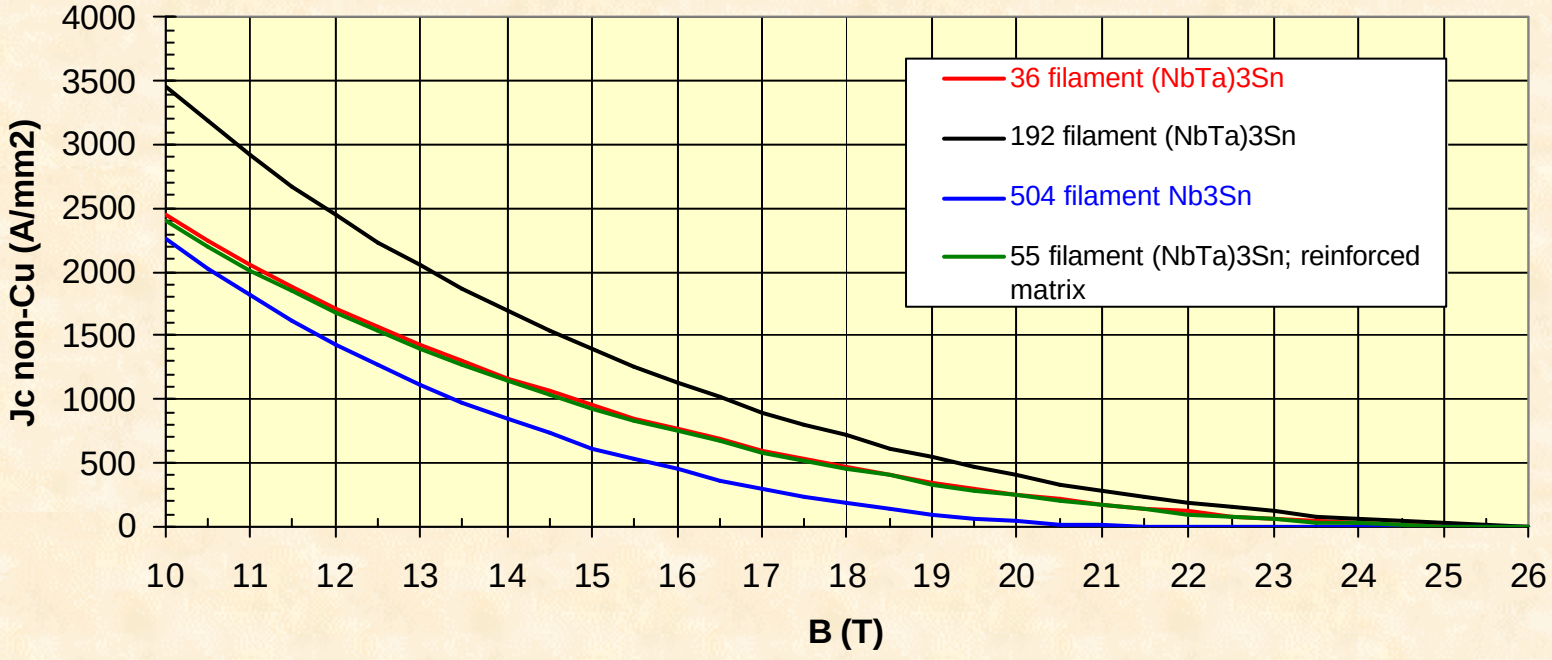
- 192 filaments
- Matrix OFHC copper 45 - 53%
- Diameter 1.0 mm; OD Nb 50 µm
- RRR value : >100
- Jc non-Cu : max. 2450 at 12T
  max. 700 at 18T
- N-values : > 40 at 12 Tesla

In regular production for accelerators

SMI
SHAPEMETAL INNOVATION B.V

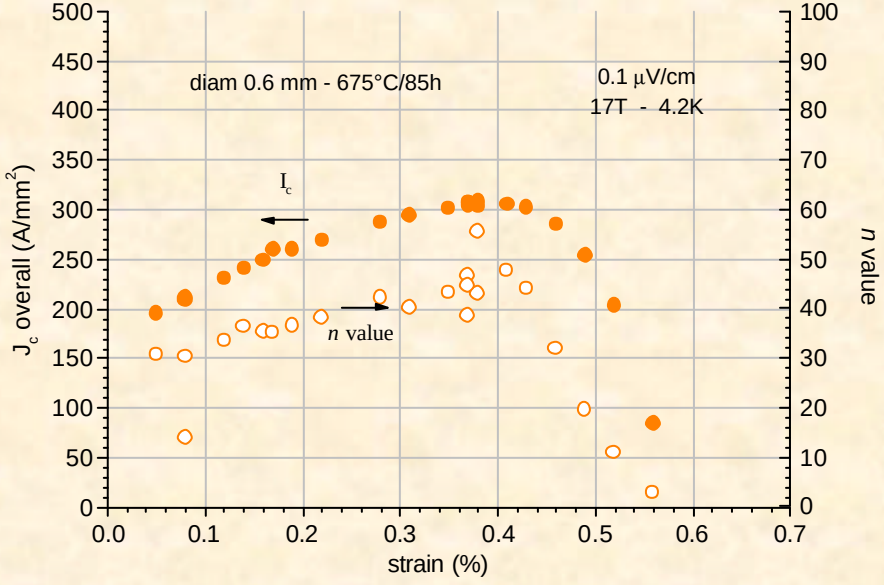


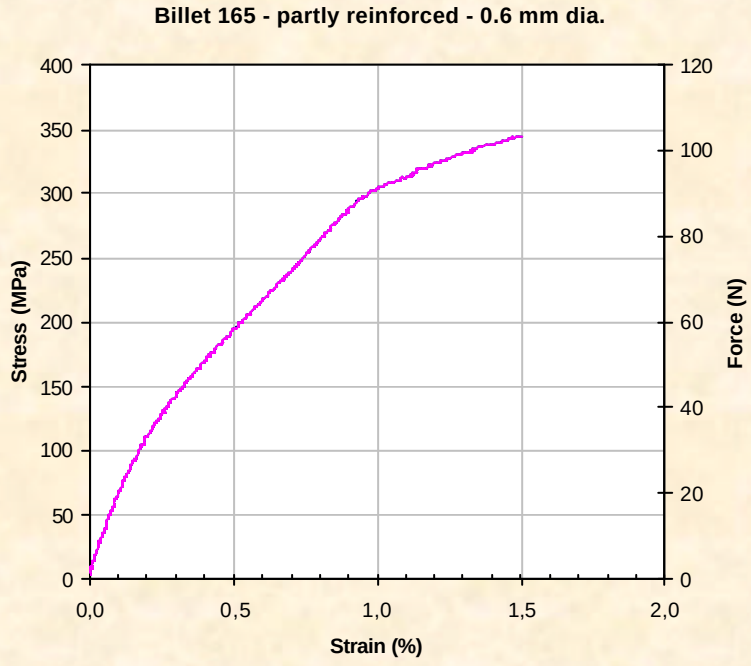
Powder in Tube conductors



Stress – strain behaviour

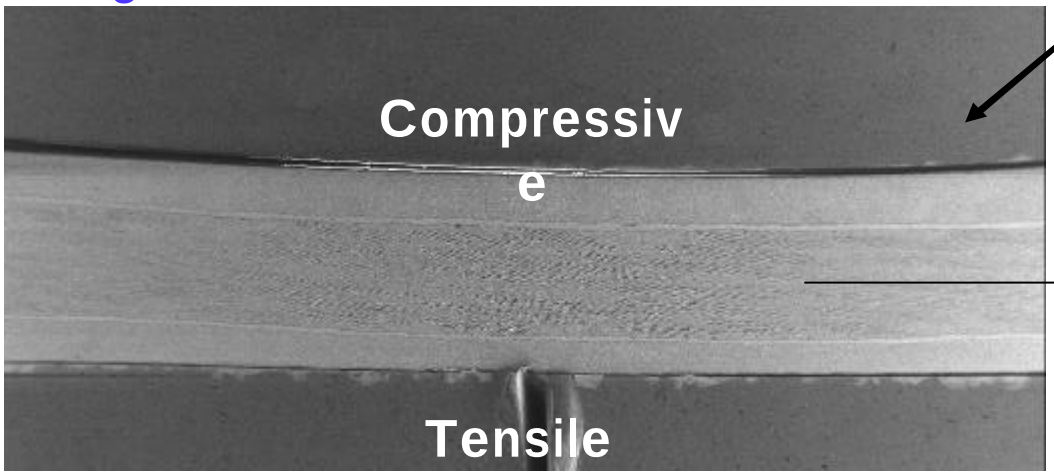
UNIVERSITÉ DE GENÈVE





Experimental Procedure

Longitudinal Cross-Section

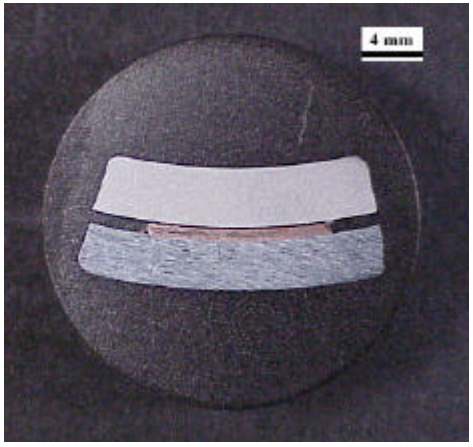


Stainless steel clamp, bent to 0.5% of wire radius

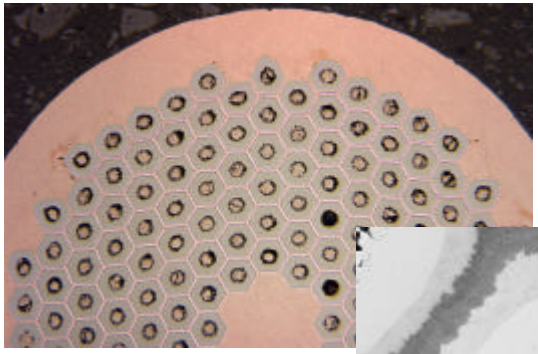
Neutral Axis

- 1 cm-long samples were mounted in stainless steel clamps with a radius of 200x the radius of the wire.
- Longitudinal face hot-mounted, ground, and polished to 0.05 μm
- Samples etched in 37% HNO_3, 13% HF for ~10 sec. to reveal crack location
- Images acquired on field-emission scanning electron microscope and optical microscope
- All wires received manufacturer recommended heat treatment

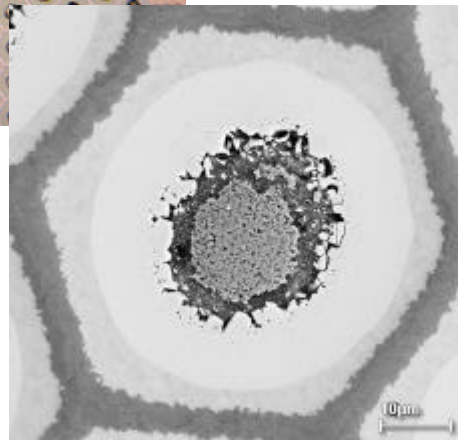
Mitsubishi wire in clamp



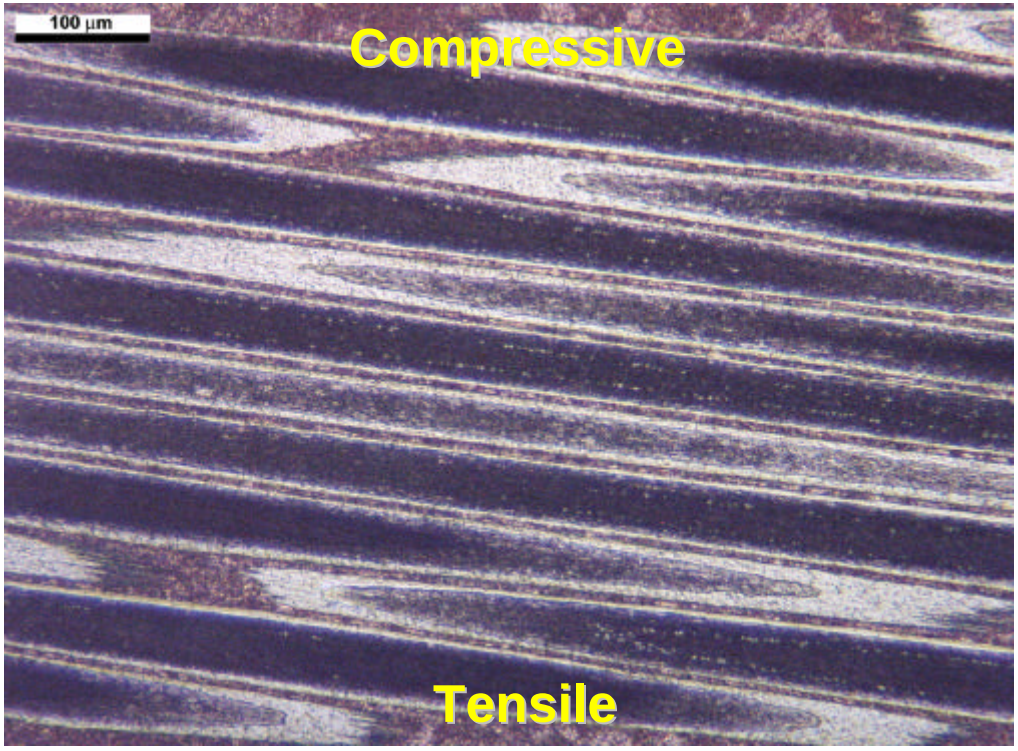
SMI Powder-in-tube Billet 34(Ta)



Transverse Cross-section

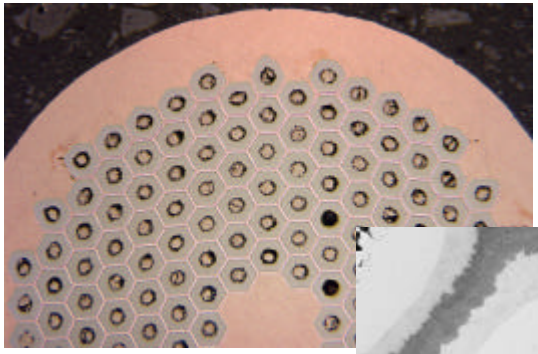


0.5% strain

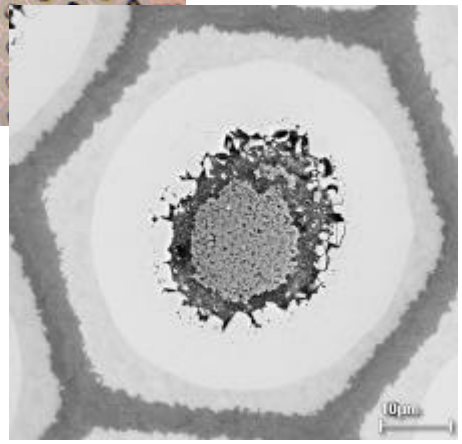


- No cracking seen at 0.5% strain

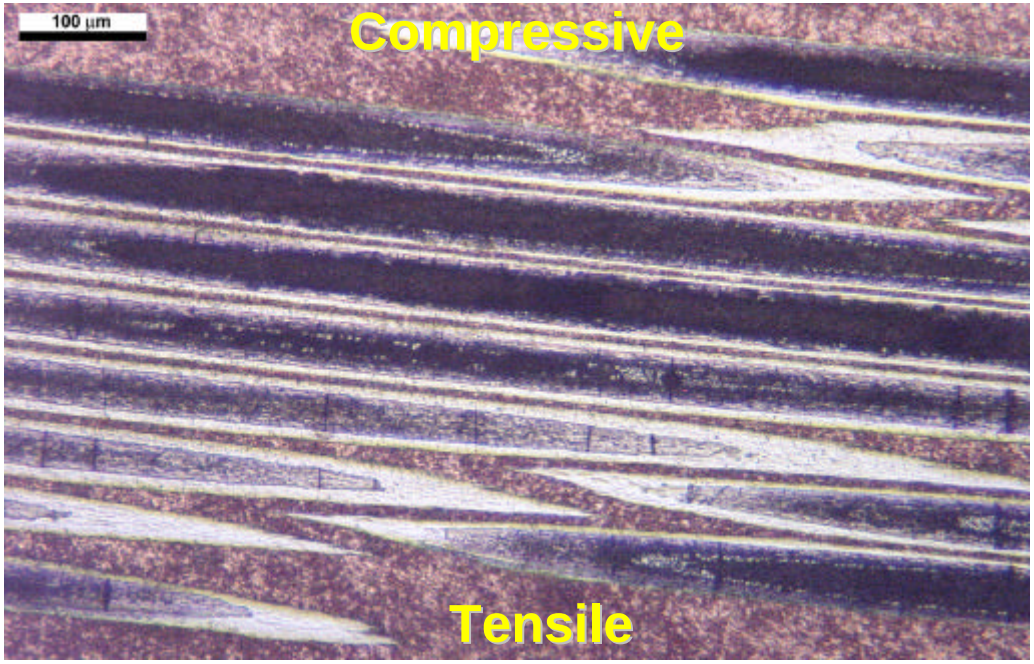
SMI Powder-in-tube Billet 34(Ta)



Transverse Cross-section



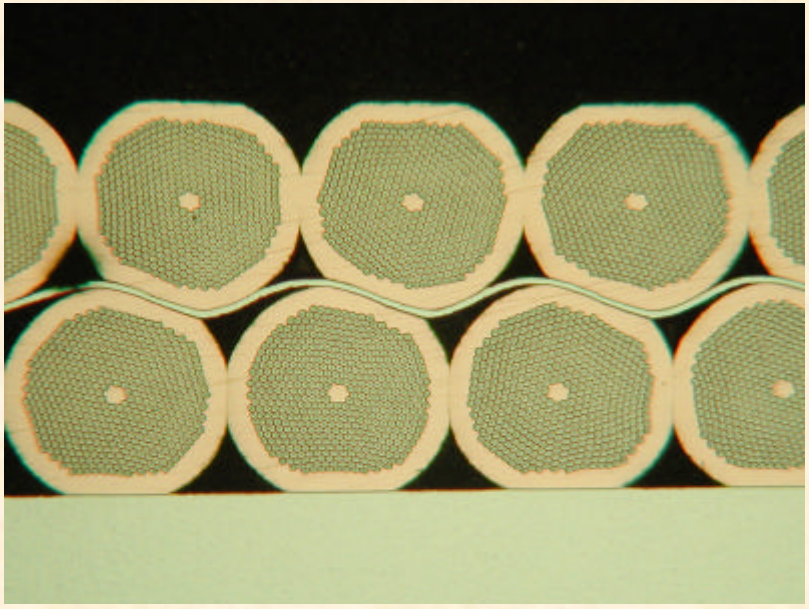
0.625% strain

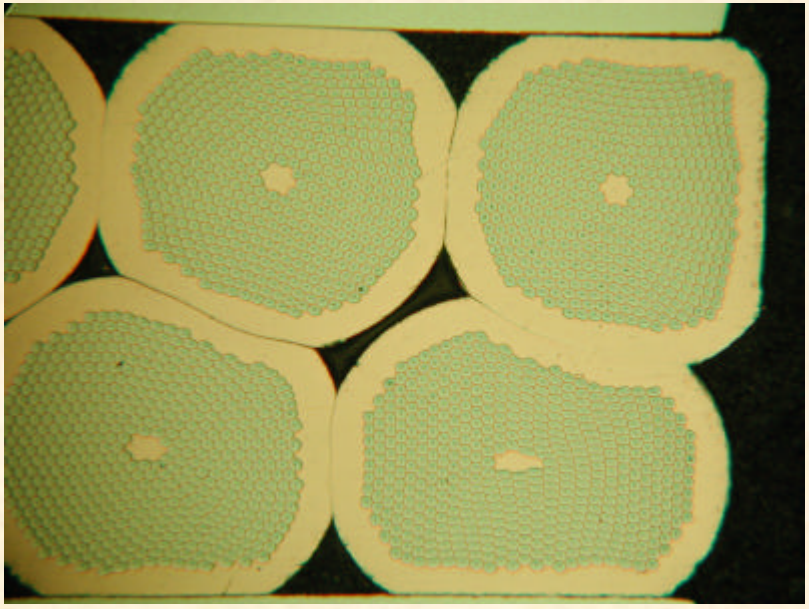


- Trans-filamentary cracking present at 0.625%
- Ductile Nb arrests crack propagation

Cabling

Keystoned Rutherford cable (LBL Berkeley)





Extrusion

- Extrusion succesful of
  - Small billets (since longer times)
  - Middle sized billets (recently)
- Extrusion of large billets expected soon

SMI's activities

today

- Fermilab

  small quantities; 1.0 mm dia
  tertiary conductor (192 fil)
  Ic > 700A @ 12T; 4.2K
  filament dia < 50 µm

- CERN – UT (Nb_3Sn dipool)

  last small part (< ¼); 0.9 mm dia
  binary conductor (504 fil)
  Cu 45 - 60%
  Ic ≥ 460 A @ 10,8T; 4.2K
  N-value ≥ 40 at 10,8T; 4.2K

- Iter qualification

  100 kg; 0.81 mm dia.
  binary conductor (1st test billet)
  Ic < 280A @ 12T;4.2K
  hysterese loss ≤ 500 kJm^3 (± 3T)

- Laboratory and other magnets

  small quantities; 0.5 – 1.2 mm dia
  binary/tertiary conductors (36–192 fil)
  reinforced matrix on request
  with high Ic values

SMI's plans on PIT Nb_3Sn

- Make co-operation with EAS succesful
- Qualify for:
  - Fusion (ITER)
  - Accelerator projects (e.g. CARE/NED)
  - NMR
- Start large scale production

Next European Dipole (NED)

Strand specification (Nb_3Sn)

– diameter	1,25 mm
– Cu	55 % (Cu : SC = 1,25 : 1)
– Jc non-Cu	1500 A/mm^2 @ 15T; 4.2K
– filament diameter	< 50 microns
– piece length min.	1 km (pref. 3 km)
– tot. length	16 km (1 + 5 + 10 km)

Cable specification

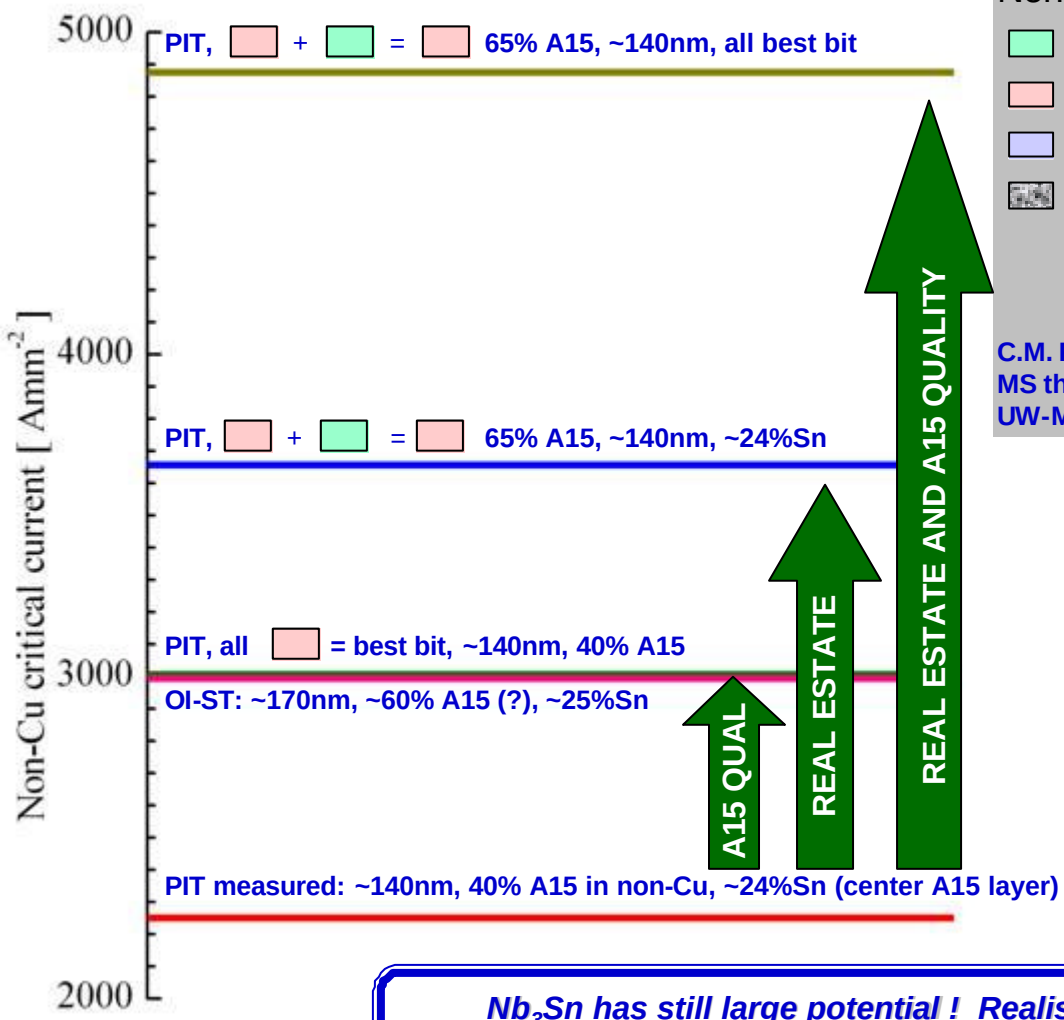
– type	Keystoned Rutherford
– number of strands	40 (max.)

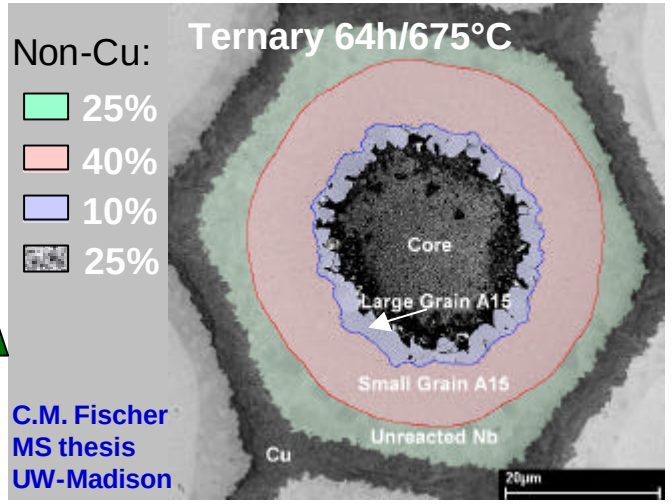
Development for NED

With regard to following topics

- Powder composition
- Cross section
  (in relation with cabling properties)
- Heat treatment
- Barrier
- Extrusion

What are the Limits in Present High J_c Nb_3Sn Wire Designs?





Pinning wise:

- SMI-PIT $Nb(Ta)_3Sn$
  - Grains ~140nm
- OI-ST $Nb(Ta)_3Sn$ 2900 A
  - Grains ~170nm
- At 12T => vortices
  - Spacing ~14nm
- More possible?

Nb_3Sn has still large potential ! Realistic ?
~5000 Amm^{-2} physical limit with present wire designs?
Getting the Sn up and homogeneous is important!

Complete HEP program includes complementary SBIR/STTR work

- FY 2001
  - *Nb_3Al--$1,200K
  - *PIT Nb_3Sn--$1,100K
  - *MJR/Int. Sn Nb_3Sn--$400K (+$500K direct HEP)
- FY2002
  - *PIT Nb_3Sn--$1,500K
  - *MJR/Int. Sn Nb_3Sn--$700K(+$440K direct HEP)
    MJR Nb_3Al--$60K direct HEP
  - *SC Processing--$1,000K