Microchemical Redistribution in Internal Sn Composites for High Field Application

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Outline

1. Distributed Nb-47Ti source Ti in Nb(Ta)

2. Ti Strips incorporated in barriers as test bed for shims of different materials.
Recap: Distributed 47Ti Ti sources in Nb

- OI-ST 7069 – Distributed Nb-47Ti
- Convoluted diffusion path
- No Cu-Ti particulates observed
- Intercurling of Nb-Ti, Cu and Nb

Nb-47Ti etched faster than other components
Ti distributes uniformly

Cu K 162 — 5450
Sn L 157 — 1693

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Sn L 157 — 1693

5 µm

Nb L 179 — 11022

Ti K 86 — 470 net counts
Ti and Cu Hot Spots (Red)

Ti Hot Spots: Red 5 µm

Cu Hot Spots: Red 5 µm

Ti hot spot offset for Cu hot spot

50 hrs@665°C
High Ti Region After SI: BEI Image

- **Contamination Spot from 150 minute Spectral Image**
- **Darkest Phase:** Low Atomic Number.
- **Medium Dark Spots:** Similar Contrast to Nb barrier (bottom right). Larger than Low-Z phase.
- **Most Dark and Medium particles occur on side of Cu-rich island away from Sn source but some on isthmus between.**
- **High Cu Island Etch Differently than 2nd Phases in A15.**
- **Dark lines pass through holes so not indicative of two-phase.**
Summary

Within the resolution of SEM-EDS the Ti distribution appears to be uniform at ~1.5 Atomic %.

Ti-rich region on outer side and between Cu-rich islands. Although the local (1 µm SEM-EDS resolution) Ti content increases to up to ~10 At.% the concentration is presumably more localized to low-Z 2nd phase particles that are closer to 50 nm in diameter.

The Ti rich region has both low and medium atomic number particles. The sub-micron composition variation is beyond the resolution of the SEM – but is a good application of FIB

The Ti-rich particles form on the “outer” side of the 47-Ti sources – away from the Sn source.
Distributed Nb-47Ti in Nb(Ta)_3Sn

OI-ST High $J_c$ type (Nb-7.5Ta)RRP ORe8056

50hrs@665°C
Reducing the low field $J_c$ in RRP for HEP

- First attempt to make high $J_c$ Nb-Ta-Ti likely over-doped (uncertain how much Ti would leave the Nb-47Ti rods)
- Heat treatment likely not optimized- Ti changes kinetics
- Suggests potential for maintaining 15 T $J_c$, reducing low field $J_c$
Overview EDS-Spectral Image FESEM

20 kV

Ti-K Net Counts
Analysis Area
Spectral Imaging

Lower (lighter) Ti towards filament centers?
Microstructural Note . . . .

Some columnar
-suggests insufficient Sn for best reaction
2. Barrier Strips

Strips in barrier of MJR sub-elements used as test bed for potential divider material

Example: 1-Ti alloy

Left: Example of true sub-divided sub-elements using Ta.

Sub-division of sub-elements is a technique for reducing $D_{\text{eff}}$. 
OST Ti Strips in Barrier as testbed for divider technology

ORE244 0.025” Ti Strips ORE245 0.05” Ti Strips

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MO: Effect of 0.025” strips strong enough to allow penetration to core in some cases

ORE 244 T=5.5 K ZFC

#76 H=100 mT

T=10K

#77 H=0 mT

1\textsuperscript{st} penetration where strips coincides with thin-side of layer

Polyanskii
ORE 245 with thicker 0.05” Ti-shims

$H=120 \text{ mT}$  $ZFC \ T=10K$  $H=0 \text{ mT}$

Thicker Shims clearly changing penetration

Polyanskii
0.025” Ti Strip After HT: Overview BSE

Barrier fully or mostly reacted

FESEM
Spectral Imaging 0.025” shims: Ti stays mostly at shim location

Spectral imaging indicates Ti distributes from shim – higher Ti outside

High peak levels
0.025” Ti Spectral Image: Sn

Lower Sn outside shim
Outer Nb₃Sn layer broken – coincidence?

Cu Stabilizer

Ti leakage?

High Ti/Cu/Sn phases

Nb₃Sn fracture

Nb₃Sn fracture

Cu Stabilizer

Ti leakage?

High Ti/Cu/Sn phases

Nb₃Sn
0.05” shim: Cu and Sn rich regions in Ti shim region

- Sn lost to Ti shim region
- Measurement of Sn content of outer Nb₃Sn compromised by resolution of EDS (1-2 µm)
Mike Naus: Universal Plot of Goodness for both Internal Sn and PIT

Low $T_c$'s from low-Sn A15 of MJR base. More Ti makes it worse.
Summary

- Distributed 47-Ti Ti sources produce a more uniform Ti distribution in pure Nb material than for Ta alloyed rod.
- There is a radial component to the Ti distribution across the layer.
- Ti strips could act as
  - a source for Ti
  - as well as divider by the production of non-superconducting high Cu and Sn Ti phases
  - but also reduces Sn availability and can locally over-dope in Ti.