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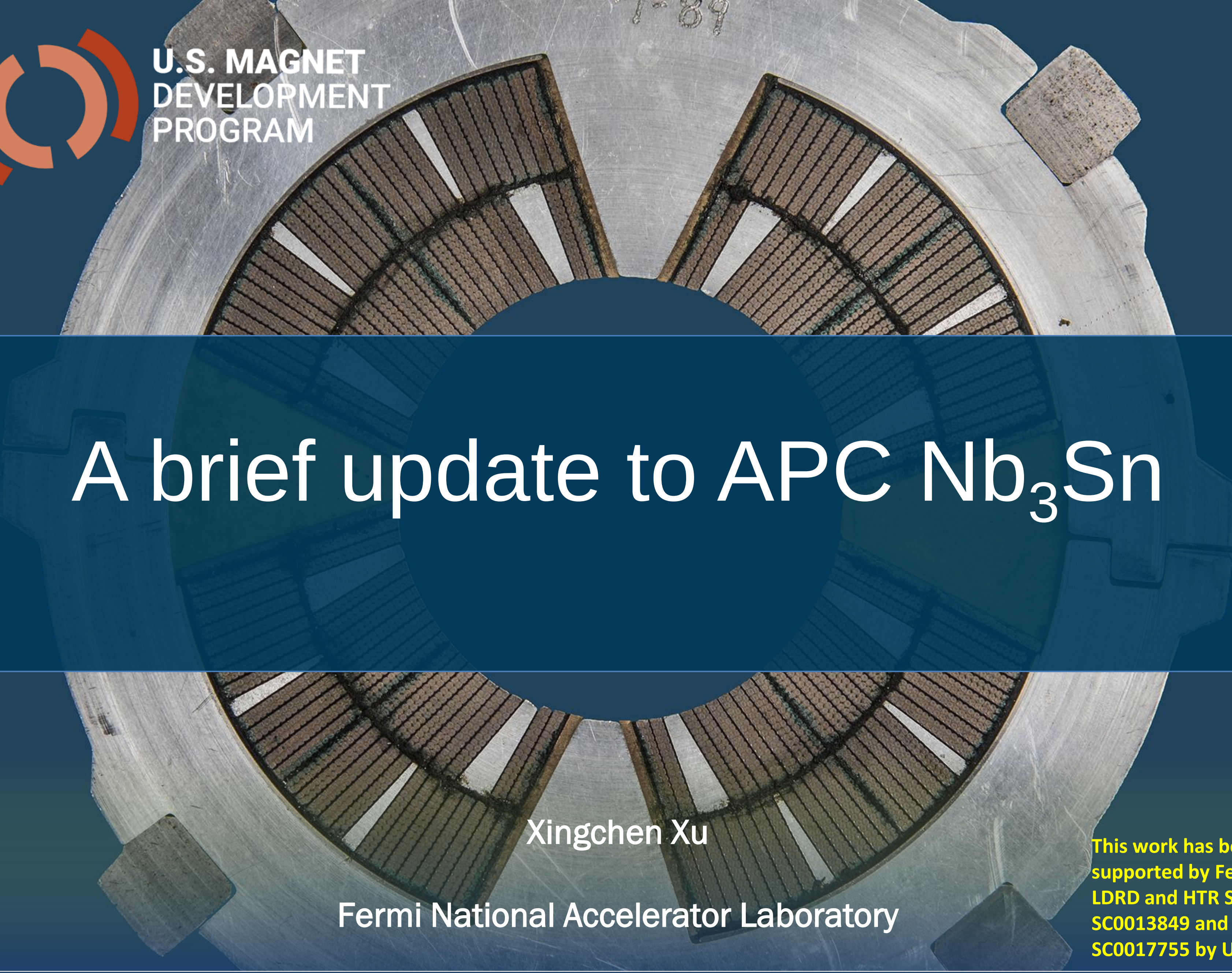

A brief update to APC Nb_3Sn

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This work has been supported by Fermilab LDRD and HTR SBIR DE-SC0013849 and DE-SC0017755 by US DOE.

Confirmation of high B_{c2} (B_{irr}) in ternary APC conductors

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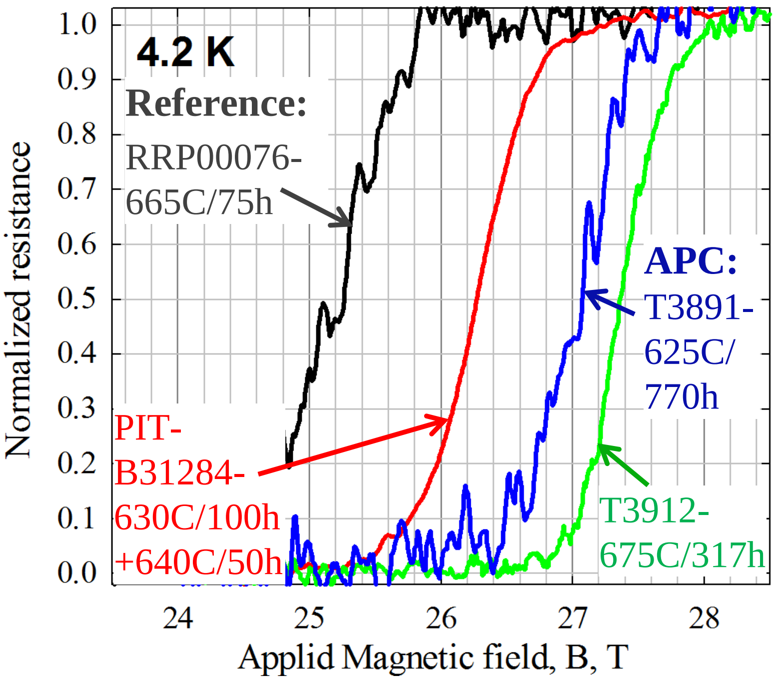
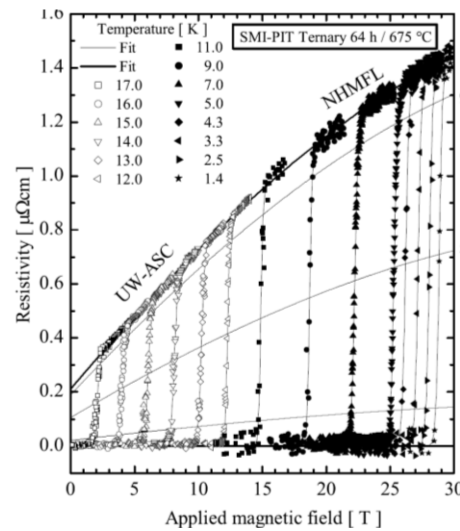
New wires been made since last NHMFL test in Sept. 2018. New tests in late Jan. 2019. Reported here.

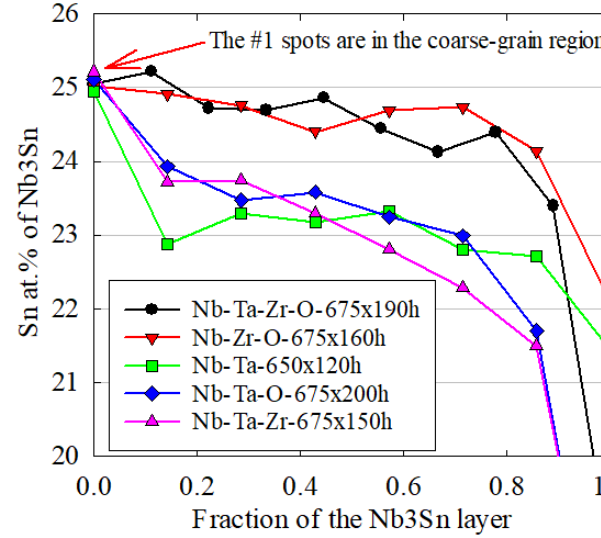
Tests in 09/2018 showed B_{irr} (B_{c2}) of ternary APC are higher than best RRP. The results are confirmed by the new tests.

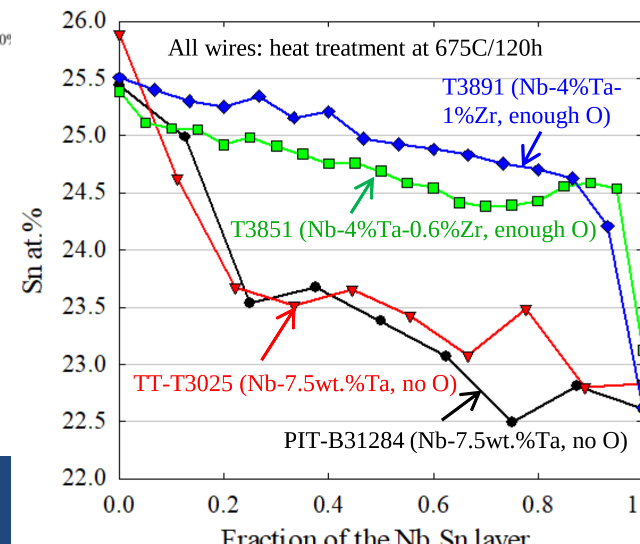


PIT results similar to Godeke's.



Godeke dissertation, 2005.





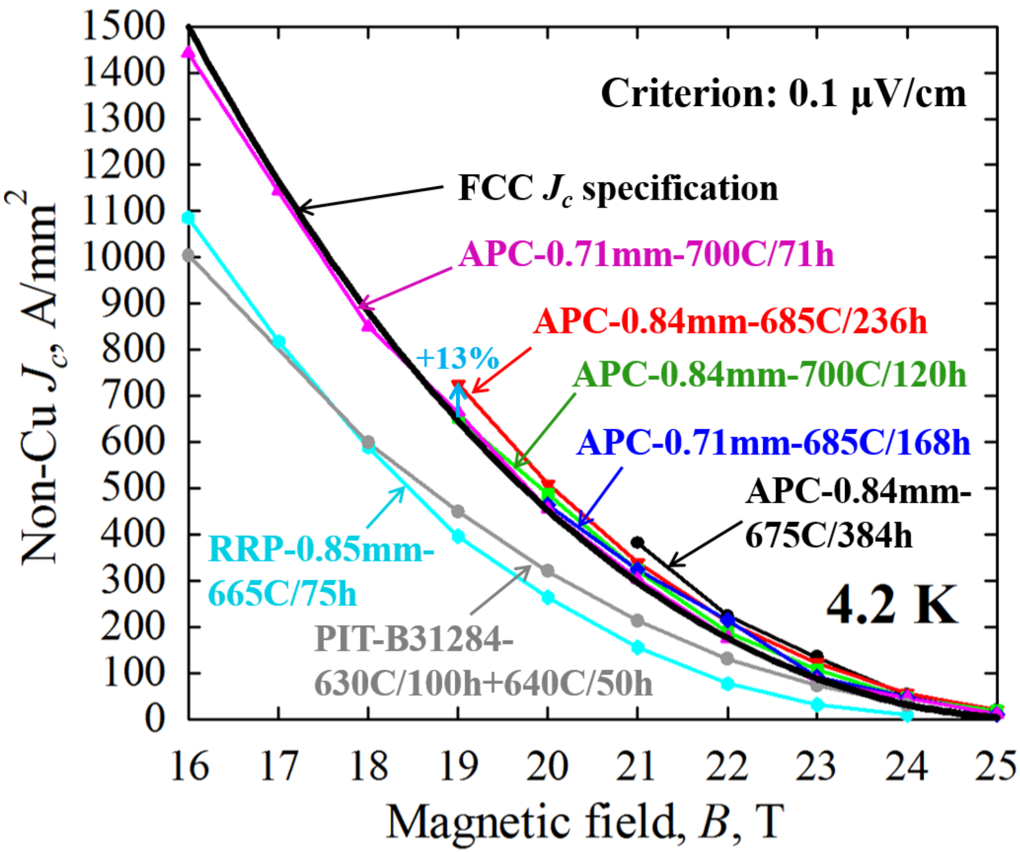
What accounts for the high Birr (Bc2) in the APC wires?
Answer: better stoichiometry.

A theory for Nb3Sn stoichiometry (backup slide).

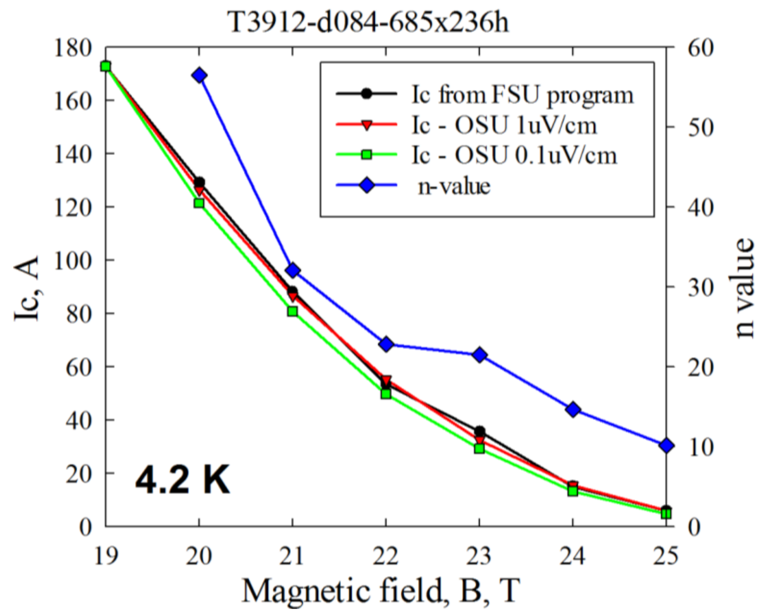
EDS Line scans measured by Ian Pong at LBNL ➔

J_c in most recent APC conductors

Many thanks to David and ASC for the J_c rig, PS, DAQ, etc., and to Griffin for the help in the J_c tests in NHMFL.



Comparison of those given by the testing program and our analysis:



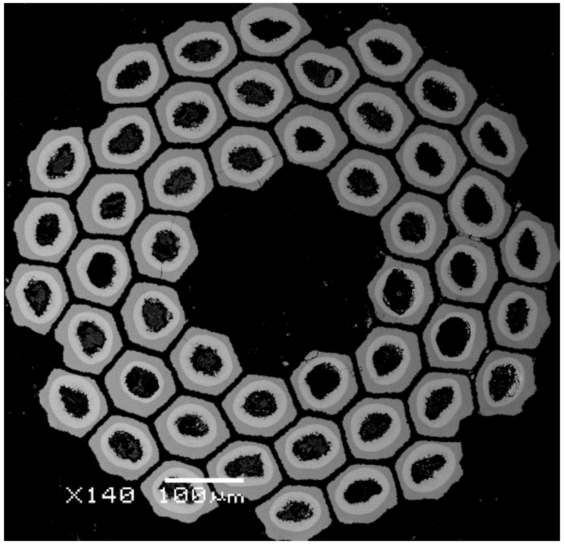
Observations:

1. Wires of 0.71mm (Ds ~ 70 µm) and 0.84mm (Ds ~83 µm) have similar J_cs.
2. Lower HT temperature (675 or 685 °C) leads to substantially higher Jc than 700°C.
3. Still need more heat treatment optimization.

Paths to further improvement

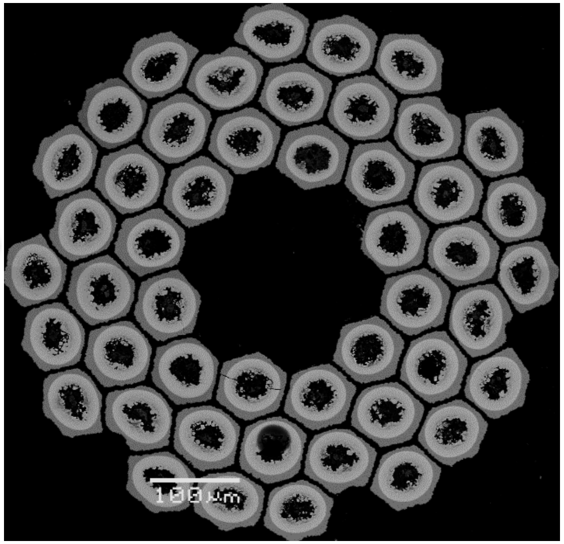
The progress in J_c was mainly driven by improvement of recipe, which allows formation of more A15.

09/2018: T3882-0.84-675C/330h



FG Nb_3Sn %	Residual Nb%
22%	45%

01/2019: T3912-0.71mm-700C/71h



FG Nb_3Sn %	Residual Nb%
32%	33%

Development is still ongoing.

Further optimization of recipe.

The goal: similar to standard PIT wires.

The goal:

FG Nb_3Sn %	Residual Nb%
40%	25%

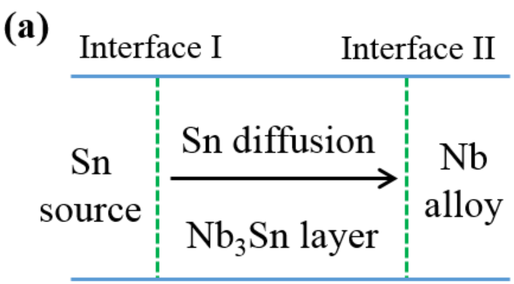
Other aspects for further improvement:
(1) Improving filament uniformity
(2) Heat treatment optimization

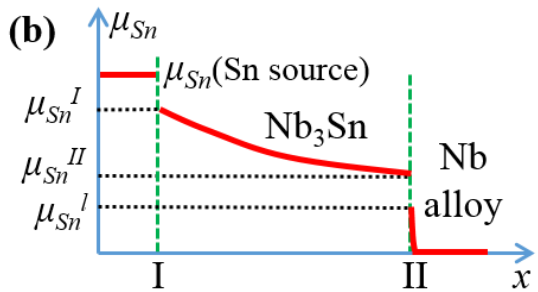
Conclusion: more work needed

- These results demonstrate improved J_c, but these APC wires are still in the prototype stage, and much more work is required: further optimization in recipe and heat treatment, fabrication of 217-restack wires, better fabrication for cabling, and other necessary tests.
- There are also other interesting ideas, like **the FSU Hf w/o O method, which the monofilament results show is promising.**
- **There still seems to be some room for Nb_3Sn conductors.**

Backup slide: a theory for the Nb_3Sn stoichiometry

Nb_3Sn layer grows in a Sn source/Nb_3Sn/Nb diffusion couple at reaction temperature:

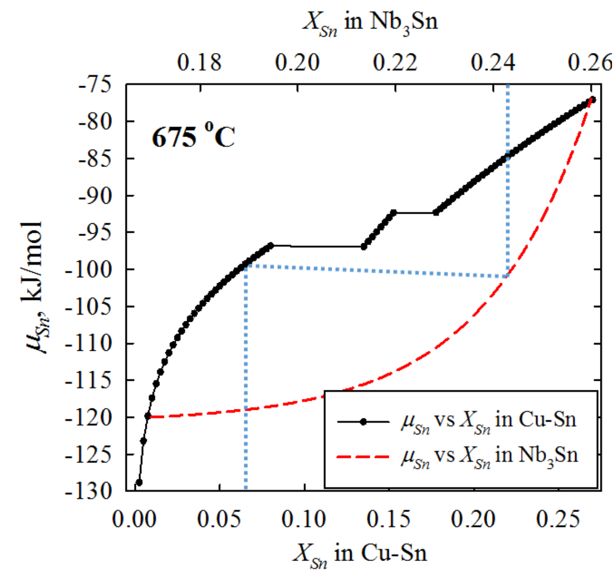




For details of this theory:

(1) Xu and Sumption, *Sci. Rep.* **6** 19096, 2016

(2) Xu, *Supercond. Sci. Technol.* **30**, 093001, 2017

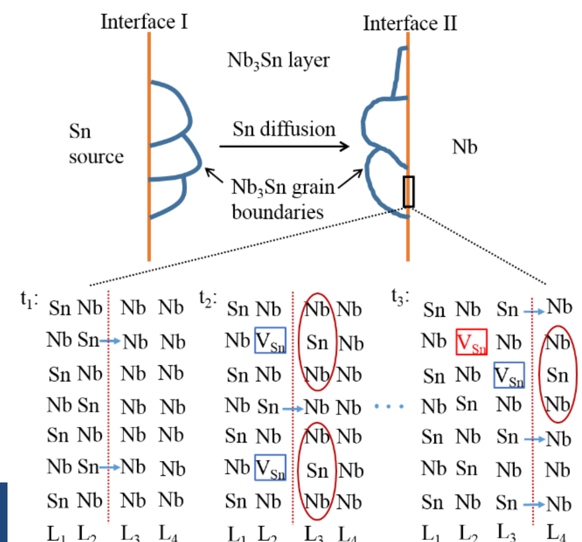


I. Thermodynamic part: chemical potential of Sn

The relation between $\mu_{Sn}(X_{Sn})$ of Cu-Sn and $\mu_{Sn}(X_{Sn})$ of Nb_3Sn is important. μ_{Sn}(Cu-7 at.% Sn) ≥ μ_{Sn}(Nb-24 at.% Sn); $\mu_{Sn}(X_{Sn})$ of Nb_3Sn must concave up.

II. Kinetic part: competition between diffusion rate and reaction rate

A competition between two processes determines the V_{Sn} fraction in the frontier Nb_3Sn layer: the reaction at the interface produces V_{Sn}s, while the diffusion of Sn along Nb_3Sn grain boundaries fills these V_{Sn}s. Higher diffusion rate relative to reaction rate benefits Nb_3Sn stoichiometry.



Why internal oxidation improves Sn content?

(1) Finer grain size ➔ higher diffusion rate.

(2) Lower reaction rate ➔ higher Sn content.

APC wires have slower layer growth rate.