Development of a (Nb,Ti)$_3$Sn multifilamentary wire with ZrO$_2$ APCs for high $J_{c}$, high $B_{c2}$, and low AC loss

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Introduction

$\text{Nb}_2\text{Sn}$ performance improvement is needed for projects like the Future Circular Collider (FCC)

- Maximize $J_{c}$ at 16 T
- Maximize pinning force $F_p$ at high B
- Refinement of grain size increases $F_p$ at high B

Next step is to produce a Ti-doped ternary wire to increase $B_{c2}$

<table>
<thead>
<tr>
<th>Table 1. Current state of $\text{Nb}_2\text{Sn}$ strands from various production routes</th>
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<tbody>
<tr>
<td>Internal Sn,</td>
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<td>12 T; 4 A/mm$^2$</td>
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<tr>
<td>Stability</td>
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<td>Loss</td>
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Externally-Oxidized Subelement

We started with a proof-of-concept ternary strand consisting of a Cu-$\text{Sn}$-$\text{Ti}$ rod inside a $\text{Nb}$-$1\%\text{Zr}$ tube. The wires were heat treated in a vacuum-sealed quartz tube containing varying amounts of CuO pellets.

Observations:

- Grain refinement to ~50 nm
- Ti incorporation in $\text{Nb}_2\text{Sn}$ layer
- Improvement of $J_{c}$ (calculated from PPMS M-H curve)

Initial Multifilament Development

Ternary hybrid wire

- Inner ring of filaments contain Sn/SnO$_2$ powder
- Remainder contain Sn-2%Ti rods

$\text{Sn}$-$1\%\text{Zr}$ tube

$\text{Cu}$-tubed $\text{Nb}$-$1\%\text{Zr}$ tube

Additional wire architectures are currently in production

Conclusions

- We have demonstrated grain refinement by a factor of 3 and a doubling of 12 T $J_{c}$ in monofilaments
- Internal oxidation can be used in many $\text{Nb}_3\text{Sn}$ strand types, including Tube (demonstrated) PIT (proposed), RRP/RT (proposed) etc.
- Ternary strands under development: Possible to inject Ti into internally oxidized $\text{Nb}_3\text{Sn}$ layers
- Sn contents remain high with Ti additions, but $B_{c2}$ increase not yet seen — may need to add more Ti
- Multifilamentary strands have been demonstrated with refined grains and enhanced $J_{c}$ values.
- New designs which have push non-$\text{Cu}$ fraction to above 50% and reaction fraction to above 30% are demonstrated (measurements underway) These need (1) To be optimized, and (2) To be demonstrated for a ternary alloy with the ternary alloy $B_{c2}$
- This route is very promising for future $\text{Nb}_3\text{Sn}$ development

References


Acknowledgments

This work was supported by the U.S. Department of Energy, Office of Science, Division of High Energy Physics, under SBIR phase I DE-SC0013949 and University Grant DE-SC0017125.

2017 CEC / ICMC Conference
July 9 – 13, Madison, Wisconsin, USA