Evidence for Different Dopant Site Behavior by EXAFS in High Critical Current Nb_3Sn Superconductor Wires

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Introduction

To meet critical current density, J_c, targets for the Future Circular Collider (FCC), the planned replacement for the Large Hadron Collider (LHC), the high field performance of Nb_3Sn must be improved, but champion J_c values have remained static for the last 10 years. Here we report our investigation on the site occupancy of the most commonly used dopants, Ti and Ta, to better understand their effectiveness in increasing H_{c2}.

Experimental

We performed EXAFS (extended x-ray absorption fine structure) characterization on several high-J_c Nb_3Sn wires doped with Ti, Ta or both elements. This technique is sensitive to the local environment of the dopant atoms and allows determination of their site occupancy. We combined those results with the microstructural and superconducting characterizations performed at ASC-NHMFL.

Results and Discussion

Because of the crystalline structure, a dopant sitting only on the Sn site should generate a single main peak in the Fourier transform of the EXAFS spectra, whereas a dopant sitting on the Nb site should have a three-peak structure in the ~2-3.5 Å range. The three-peak structure was observed for both Ta and Ti alloying cases indicating that they have a preference for Nb sites (Figure 1). However, by fitting the curves, we found that Ti is actually only on the Nb sites while a significant fraction of Ta (~21-32%) occupies the Sn sites. This means that previous hypotheses suggesting that Ta substitutes on the Nb site and Ti on the Sn site are incorrect. Since the two dopants introduce different levels of disorder and generate different charge doping in the system, their effectiveness in increasing H_{c2} varies. These considerations and the markedly sub-stoichiometric Sn composition of the best internal-Sn strands indicate that further investigation of global and local properties are needed.

Conclusions

Although improvements of J_c properties in the >16 T range at 4.2 K are likely still possible, especially using longer and higher temperature heat treatments to make the layers more uniform and more stoichiometric, more attention has to be paid to the effects of the dopants and their ability to increase H_{c2} and the high-field J_c.

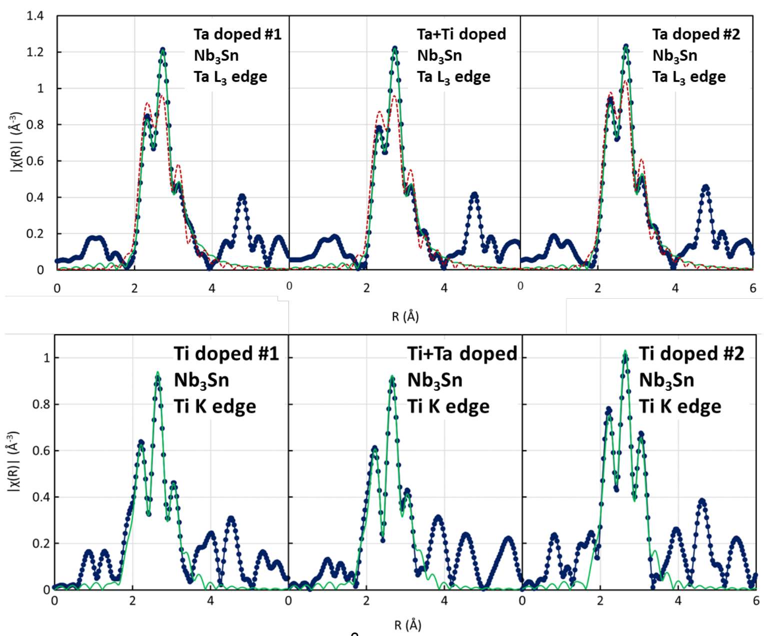

Fig.1 Fourier transforms of the k^2 weighted $\chi(k)$ data for the Ta L3 (top) and Ti K (bottom) edges of EXAFS spectra obtained on doped Nb_3Sn wires.

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