Influence of Inter-layer Contact Resistances on Quench Propagation in $YBa_2Cu_3O_x$ Tapes

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Introduction

In designing superconducting powered devices with YBCO tapes operating at high temperature around 70 K, the detection of the slow quench in the tapes remains a challenge. To address this issue, we built 2D and 3D tape models composed of multiple layers to study the physics which drive quench propagation. During a quench, current flowing in the YBCO layer redistributes to the stabilizer and substrate layers through the silver and buffer inter-layers. From simulations, we studied how the inter-layer electrical and thermal contact resistances affect the quench behaviors such as the voltages across layers, current sharing lengths, normal zone propagation velocity (NZPV) and peak temperature.

Experimental

The tape models were implemented in COMSOL Multiphysics, and have taken into account the thermal and electrical physics of all layers in real dimensions. A wide range of thermal and electrical conductivities on a generalized Ag layer (S-layer) and a substrate layer were considered in order to investigate their influences on the quench propagation behaviors. Initial tape temperature was set at 77 K. Cooling at 77 K was forced on the substrate surface and adiabatic conditions were assumed everywhere else on the tape surface.

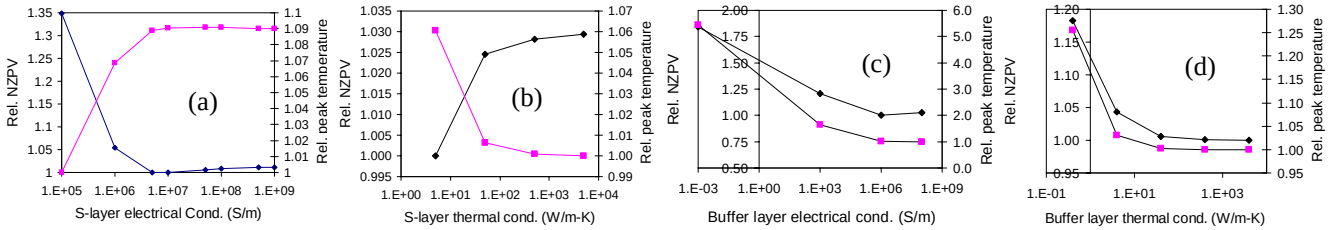

Fig. 1. Simulation results on tapes with no stabilizer on the sides. Figures show the relative NZPV (diamond) and peak temperature (square) vs. (a) Ag (S-layer) electrical conductivity, (b) Ag thermal conductivity, (c) buffer layer electrical conductivity, and (d) buffer layer thermal conductivity.

Results and Discussion

Our simulation results showed that for a tape with no stabilizer on the sides, a higher inter-layer contact resistance leads to longer current sharing length in the layer adjacent to that inter-layer. A higher Ag layer electrical contact resistance leads to a higher NZPV and a lower peak temperature (Fig. 1(a)). A higher Ag layer thermal contact resistance, however, always results in a lower NZPV and higher peak temperature (Fig. 1(b)). With respect to the variation of the Ag layer electrical or thermal contact resistance, the NZPV always behaves inversely in trend to that of the peak temperature. In contrast, the variation of buffer layer electrical or thermal contact resistance causes both the NZPV and peak temperature to vary in the same trend. Higher buffer layer electrical or thermal contact resistance results in higher NZPV and peak temperature (Fig. 1(c) to Fig. 1(d)).

Conclusions

Our high fidelity YBCO tape models showed qualitatively the influence of inter-layer contact resistances on quench behaviors. These behaviors are important factors for the design of tape architectures and in developing new approaches to quench detection.

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