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Editorial: Progress on superconducting materials for SRF applications

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Editorial on the Research Topic
Progress on superconducting materials for SRF applications

Superconducting Radiofrequency (SRF) technology, which was originally used in discovery science and basic research within particle accelerators, has now expanded into diverse applications spanning energy, medical, security, and quantum computing domains. Superconducting bulk niobium (Nb) has traditionally been the primary material for constructing SRF cavities, with extensive efforts devoted to unraveling the material parameters' interplay with cavity performance. However, the SRF community is now exploring alternative superconductors like Nb_3Sn, NbTiN, and MgB_2, along with a superconductor-insulator-superconductor multi-layer approach, aiming to fabricate SRF cavities that are not only energy-efficient but also exhibit reduced cryogenic loss and extended energy reach.

Continuous research endeavors have pushed the performance of SRF cavities to their theoretical limits. Recent advancements in cavity processing techniques, including doping, infusion, and low-medium temperature baking, have yielded high-quality factors. Ongoing research aims to further elevate these quality factors toward achieving higher accelerating gradients. Additionally, thin-film superconductors could offer a cost-effective and high-performance alternative to bulk Nb in both accelerator and quantum information science applications.

Efficient SRF cavity development necessitates a thorough understanding of material characteristics governing cavity performance limitations. Techniques such as low-temperature scanning tunneling microscopy and spectroscopy, x-ray photoelectron spectroscopy, and secondary electron microscopy provide insights into regions of elevated RF loss within SRF cavities (Lechner et al. and Parajuli et al.) The degradation of superconducting properties, facilitating vortex nucleation or trapped flux settling during cavity cooling, is a critical focus. Advanced analytical methods like muon spin rotation and nuclear magnetic resonance offer precise measurements of magnetic field penetration in SRF materials (Junginger et al.). Multimodal cavities resonating at different TEM modes aid in comprehending frequency-, temperature-, and process-dependent performance variations across surfaces, mitigating ambiguity in comparative analyses (Kolb et al.).

Concurrent with experimental advancements, theoretical understanding of SRF cavity performance continues to evolve. The superheating critical field of niobium is believed to impose the ultimate gradient limitation, with multilayer superconductor-insulator-superconductor structures potentially offering higher superheating fields (Pathinara and Gurevich). In dirty superconductors with impurity diffusion, the non-monotonic dependence of quality factor on quasiparticle scattering rate reflects the pair-breaking effect of disorder, showcasing enhanced conductivity and frequency dips in impurity diffused SRF cavities (Zarea et al.).

The collection of manuscripts in this Research Topic provides a comprehensive snapshot of cutting-edge research, reflecting the collaborative efforts of an international array of researchers in the field.

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