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Depth-resolved characterization of superconductor-superconductor bilayer properties beneficial for SRF applications

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Coating Nb with thin layers of one or more superconductors with longer penetration depths, λ, has been proposed to achieve accelerating gradients, E_{acc}, beyond Nb's fundamental limit. Such heterostructures can sustain the Meissner state above each layer's superheating field, B_{sh}, due to the strong suppression of the screening currents in the surface layers by a ''counter-current" in the substrate and the presence of interfacial energy barrier between material junctions. We infer the presence of interfacial energy barrier by measuring the first-flux-penetration field, $\mu_0 H_{\mathrm{vp}}$ in superconductor-superconductor (SS) $\mathrm{Nb_3Sn}$(2 μm)/Nb samples using muon spin rotation (μSR). Using thin Ag foils as energy moderators for the implanted muon spin probes, we profiled $\mu_0 H_{\mathrm{vp}}$ at sub-surface depths between 10 μm and 100 μm, finding that $\mu_0 H_{\mathrm{vp}}$ is depth-independent with a value of 234.5 ± 3.5 mT, consistent with Nb's metastable B_{sh} and a surface energy barrier preventing flux penetration. Similarly, evidence for current suppression in SS $\mathrm{Nb_{1-x}Ti_xN/Nb}$ samples was observed from nanoscale (depths
$lesssim$ 150 nm) measurements of their Meissner screening profiles in applied fields $\leq$ 25 mT using the low energy μSR. The observed bipartite form of the screening profiles quantitatively confirm the Meissner response predicted by the ''counter-current" model, which we use to identify the optimal $\mathrm{Nb_{1-x}Ti_xN/Nb}$ coating thickness for maximizing the $\mu_0 H_{\mathrm{vp}}$. Our results of strong suppression of the Meissner currents in the surface layer suggest that multilayered structures with several superconducting and insulating layers are necessary to reach the highest E_{acc}.

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