Experimental evidence for counter current flow in superconductor-superconductor bilayers

Md Asaduzzaman,[1,2,*] Ryan M. L. McFadden,[2] Anne-Marie Valente-Feliciano,[3] Andreas Suter,[4] Zaher Salman,[4] Thomas Prokscha,[4] and Tobias Junginger[1,2]

[1] *Department of Physics and Astronomy, University of Victoria, 3800 Finnerty Road, Victoria, BC V8P 5C2, Canada*

[2] *TRIUMF, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, Canada*

[3] *Thomas Jefferson National Accelerator Facility, 600 Kelvin Drive, Newport News, Virginia 23606, USA*

[4] *Paul Scherrer Institute, Laboratory for Muon Spin Spectroscopy, CH-5232 Villigen PSI, Switzerland*

(Dated: September 8, 2022)

ABSTRACT

We report evidence for counter current flow in superconductor-superconductor (SS) bilayers from depth-resolved measurements of their Meissner screening profiles using the low energy muon spin rotation (LE-μSR) technique. In these experiments, the implantation depth of the muons can be tuned/adjusted/controlled between $\sim$10 nm and $\sim$150 nm below the surface, wherein their spin-precession reveals the field distribution inside the material (communicated via their radioactive decay products). Here we studied two prototypical SS bilayers [Nb$-$Ti$-$N(50nm)/Nb and Nb$-$Ti$-$N(80nm)/Nb] and compared the Meissner screening profiles obtained from LE-μSR against Kubo's counter current flow model, as well a naive (bi)exponential model. From fits to Kubo's model, we obtain a magnetic penetration depth for the thin Nb$-$Ti$-$N layers of $\lambda_{\mathrm{Nb-Ti-N}} = (201 \pm 4)$ nm, in good agreement with literature values. In contrast, a naive exponential model overestimates the $\lambda_{\mathrm{Nb-Ti-N}}$ value by a factor of two, suggesting that it is inappropriate for quantifying $\lambda_{\mathrm{Nb-Ti-N}}$ in the SS bilayer. This also indicates that the surface current is suppressed by the counter current flow in the bottom superconductor. Our result suggests that SS bilayers are a viable means of overcoming the theoretical field limit of Nb.

* E-mail: asadm@uvic.ca