Superfluid density in the ferromagnetic layers of superconductor-ferromagnet hybrid structures

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The Ohio State University — We have measured the areal superfluid density of superconductor-ferromagnet bilayers and trilayers. Samples are made by sputtering Nb and Ni films sequentially in an ultrahigh vacuum chamber with base pressure $<10^{-9}$ torr. Interfaces are cleaner when Ni is sputtered onto Nb for reasons related to disorder at the initial growth of Nb films. Superfluid density is measured using a low-frequency (50 kHz) two-coil technique with coils on opposite sides of the sample. These measurements provide the true $T_C$, i.e., the temperature below which superfluid exists. We find a nonmonotonic dependence of $T_C$ on ferromagnetic layer thickness, in agreement with resistive measurements of $T_C$. The superfluid density is also nonmonotonic. Even at large ferromagnetic layer thicknesses where $T_C$ is essentially constant, the areal superfluid density continues to increase, indicating that superfluid extends deeply into the ferromagnet layers. We will discuss these measurements in the context of theory of the superconductor-ferromagnet proximity effect.

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