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Superconductor/ ferromagnetic insulator bilayers of arbitrary thickness with simultaneous display of superconductivity and spin-splitting fields

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Ferromagnetic insulators (FI) can induce a strong exchange field in an adjacent superconductor (S) via the magnetic proximity effect. This manifests as spin-splitting of the BCS density of states of the superconductor, an important ingredient for numerous superconducting spintronics applications and the realization of Majorana fermions. We show theoretically and experimentally[1] that a crucial parameter determining the magnitude of the induced spin-splitting in FI/S bilayers is the thickness of the S layer «d»: in very thin samples, the superconductivity is suppressed by the strong magnetic proximity effect. By contrast, in very thick samples, the spin splitting is absent at distances away from the interface. Through theoretical considerations we show that for d >3.0 ξ_s (ξ_s is the superconducting coherence length), the paramagnetic phase transition is always of the second order, in contrast to the first-order transition in thinner samples at low temperatures. Experimentally, we studied tunneling spectroscopy measurements in several EuS/Al/AlOx/Al samples of varying S layer thickness. We observed that if the Al film in contact with the EuS is thinner than a certain critical value, we do not observe superconductivity, whereas, in thicker samples, we find evidence of a first-order phase transition induced by an external field. The complete transition is preceded by a regime in which normal and superconducting regions coexist.

[1] (in print, Physical Review Research), A. Hijano, arXiv:2012.15549v2 [cond-mat.supr-con] (2020)