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Spectroscopic Features of Odd Frequency Triplet Pairing Components in F/S/F Trilayers

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We have studied the proximity effects in ferromagnet/superconductor/ferromagnet (F/S/F) trilayers. S is taken as a conventional *s*-wave singlet pairing superconductor like Nb and F is modeled in terms of the exchange energy. A particular focus is on the fingerprints of the odd frequency triplet pairing components in the trilayers induced by the exchange field and proximity effects. We solved the linearized Usadel equation near the critical temperature, T_c, and calculated the singlet and triplet pairing functions as a function of position, x, and the local density of states (LDOS) at selected positions within an F as a function of the energy. The LDOS may be probed by the tunneling spectroscopy. Three cases were considered where the field directions of the two F's in F/S/F trilayers are parallel, antiparallel, and perpendicular: (a) For parallel or antiparallel cases, the singlet and triplet pairing functions decay with the short length scale of $\xi_{ex} = \sqrt{D/E_{ex}}$ within F, where D is the diffusion constant and E_{ex} is the exchange energy. Then, LDOS at $x \geq \xi_{ex}$ away from the S/F interface within an F show no spectroscopic features at all. (b) For perpendicular case, the triplet pairing functions decay with the long length scale of $\xi_F = \sqrt{D/2\pi T_c}$. LDOS in this case show even for $x \geq \xi_{ex}$ the familiar U shape features. (c) Therefore, the unambiguous spectroscopic detection of the odd frequency triplet paring components will be, at $x \geq \xi_{ex}$, the U shape tunneling conductance for perpendicular case and null features for parallel or antiparallel cases. (d) For antiparallel case, LDOS at $x \leq \xi_{ex}$ show the reversed shape like that of the π – state in the S/F bilayers.

keywords : superconductor/ferromagnet proximity effects, odd frequency triplet pairing, Usadel equation, tunneling spectroscopy