Comment on "Observation of Negative s-Wave Proximity Effect in Superconducting UBe_{13}"

In a recent Letter, Han *et al.*[1] reported that the critical current I_c of a point-contact junction between Ta and an ingot of UBe_{13} decreased below the superconducting critical temperature of bulk UBe_{13}. This result, which was interpreted as a "negative proximity effect," was taken as evidence of a triplet superconducting state in UBe_{13}. We point out here that the basis for this conclusion, a proximity-induced Josephson effect[2] between Ta and UBe_{13}, is questionable in its neglect of fundamental nonequilibrium effects. Although the well-known proximity effect between a superconductor and a normal metal may be treated with use of the equilibrium Ginzburg-Landau (GL) equation, the extension of the problem to include current flow across such a superconductor-normal interface[3] with or without an insulating tunneling barrier requires the consideration of nonequilibrium relaxation processes. This is because the spatial conversion of supercurrent J_s into normal quasiparticle current J_n generates quasiparticle charge imbalance near the interface, which in turn induces a voltage and resultant time-dependent effects.

Specifically, Eqs. (1) and (2) of Ref. 2 treat the proximity effect in the weak-coupling limit within equilibrium GL theory. A resulting supercurrent $J_s(\phi)$ proportional to η is derived, where ϕ is the phase difference and η the overlap parameter. This solution is incomplete, however, in that ϕ is treated as an independent variable, whereas in fact it is an internal variable of the same degree as the magnitude ψ_{n0} of the induced order parameter. Completing the minimization yields $\phi=0$ and $J_s=0$. The solution to the corresponding time-dependent problem has in fact been obtained (see Kadin and Goldman and Ferrell and Scalapino[4]) and yields only a second-order Josephson current $J_s \sim \eta^2 \sin 2\phi$, where $\phi = \tan^{-1}(2eV\tau_{GL}/h)$, $\tau_{GL} = \pi h[8k_B(T-T_c)]$ is the GL relaxation time in the weak induced superconductor, and V is the voltage across the barrier. Thus, contrary to the usual first-order effect, J_s is nonzero *only* for nonzero V. This J_s is time dependent and is not the average of some oscillating current. In this case an ac voltage will not induce Shapiro steps. Then the apparent contradiction of this result with usual ac Josephson relaxation can be reconciled by use of the concept of charge imbalance.[4] Furthermore, experimental measurements of the pair-field susceptibility[5] have provided a direct quantitative confirmation of a second-order Josephson effect of this form.

The Josephson effects observed experimentally in Refs. 1 and 2 certainly appear to be of the conventional first-order type. Given the above discussion, we suspect that a model involving phase slip within the strongly superconducting tip may possibly account for the data more correctly than the postulated "proximity Josephson effect." Specific observations on UBe_{13} may also reflect a disordered normal layer on its surface. A further discussion of these alternative possibilities will be presented in the future. In any case, while it may turn out that electron pairing in UBe_{13} is not singlet and s-wave in character, we do not believe that the interpretation of the experiments contained in Ref. 1 provides a critical test that rules out more conventional explanations.

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