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Reply to "Coupled s- and d-Wave States in the Thorium-Doped Heavy-Fermion Superconductor UBe_{13}" by H. Pleiner and H. R. Brand

by

D. Sahu, A. Langner and Thomas F. George

Prepared for Publication

in

Physical Review B

Departments of Chemistry and Physics
State University of New York at Buffalo
Buffalo, New York 14260

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We discuss the points raised by H. Pleiner and H. R. Brand concerning our earlier work on UBe_{13} and thorium-doped UBe_{13}.

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Reply to "Coupled s- and d-Wave States in the Thorium-Doped Heavy-Fermion Superconductor UBe_{13}" by H. Pleiner and H. R. Brand

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Abstract

We discuss the points raised by H. Pleiner and H. R. Brand concerning our earlier work on UBe_{13} and thorium-doped UBe_{13}.

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In two recent papers[1,2] we examined the question of lowest-order coupling among even-parity superconducting states utilizing general symmetry considerations as guiding principles. Our approach was motivated by the work of Kumar and Wölfle (KW),[3] whose conclusions we generalized[1] and examined more closely.[2] Our works[1,2] have been criticized by Pleiner and Brand[4] (PB) who argue that we misinterpreted KW. Our response spells out why the criticisms of PB appears to us to be without foundation.

PB claim[4] that KW followed a two-step procedure for minimizing their free energy in Ref. 3: first KW minimized their free energy with respect to Δ_1 (the order parameter for $d_{x^2-y^2}$-state) and concluded that this must be zero for stability reasons. This enabled KW, in a second step, to write down their free energy involving Δ_2 (the order parameter for the axial $d_{2z^2-x^2-y^2}$-state) and Δ_0 (the order parameter for the isotropic s-state). Since this two-step procedure is never mentioned by KW in writing Eq. 1 of Ref. 3, the question of misinterpreting KW on this point does not arise.

In addition, we would like to comment on the claim of PB that a non-zero Δ_1 can never be an equilibrium state. Our detailed numerical work[2] suggests otherwise. We find that a transition from an s-wave state (state IV of Ref. 2) to a mixed state with both d-wave components of the two-dimensional representation non-zero (state VII of Ref. 2) is clearly favored over that of a transition to a mixed state with $\Delta_1 = 0$, $\Delta_2 \neq 0$ and $\Delta_0 \neq 0$ (state VI of Ref. 2). To account for the specific heat data, one clearly needs a non-zero Δ_1, as has been realized by KW[5] and by us.[6]

We are well aware of the required symmetry breaking to achieve second-order transitions to the various superconducting states. This point has been well addressed in Ref. 7. However, as is also mentioned in Ref. 7, the symmetry breaking is to a lower symmetry subgroup of the cubic group. Our analysis incorporates this progression. It should be noted that PB do not substantiate their claims by any detailed calculations as we have done in Ref. 2; they merely state in general terms that in the symmetry-broken phase "a given state can have lower symmetry than the crystal symmetry." The question as to whether state VI of Ref. 2 is stable or unstable with respect to the introduction of a Δ_1 perturbation is left unanswered by PB. Furthermore, their earlier work in Ref. 8, being based on the unsubstantiated points of Ref. 4, seems to us to be questionable.

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1. D. Sahu, A. Langner and T. F. George, Phys. Rev. B 38, 2466 (1988).
2. A. Langner, D. Sahu and T. F. George, Phys. Rev. B 38, 9187 (1988).
3. P. Kumar and P. Wölfle, Phys. Rev. Lett. 59, 1954 (1987).
4. H. Pleiner and H. R. Brand, preceeding Comment.
5. P. Kumar (private communication).
6. D. Sahu, A. Langner and T. F. George (unpublished)
7. I. A. Luk'yanchuk and V. P. Mineev, Pis'ma Zh.Eksp. Teor. Fiz. 47, 460 (1988) (JETP Lett. 47, 543 (1988)).
8. H. R. Brand, M. M. Doria and H. Pleiner, Phys. Rev. Lett. (Comment) 60, 2810 (1988).

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