Comment on "Giant Nernst Effect due to Fluctuating Cooper Pairs in Superconductors"

In a recent Letter, Serbyn *et al.* [1] studied thermomagnetic effects above T_c and generalized results of [2,3] for arbitrary magnetic fields. In the Gaussian model, using the Kubo method they calculated the "kinetic microscopic" heat current, $\mathbf{j}^h = T\beta(\mathbf{E}\times\mathbf{H})/H$, and found that the coefficient β diverges at $T \to 0$. To get rid of the contradiction with the third law of thermodynamics, they added to $\mathbf{j}^h$ the "thermodynamic circular magnetization heat current, $\mathbf{j}_M^Q = c(\mathbf{M}\times\mathbf{E})$," where $\mathbf{M}$ is the magnetization. In our opinion, dissipationless magnetization currents do not transfer the heat and $c(\mathbf{M}\times\mathbf{E})$ is the magnetization part of the Poynting vector. Thus, the heat current-electric current correlation function directly gives the coefficient β and no further corrections are allowed [4].

(i) First we prove the above statements. In a finite sample, besides the bulk currents, charge and energy are also transferred by surface magnetization currents. Circular electric and energy magnetization currents, $\mathbf{j}_M^e = c\nabla\times\mathbf{M}$ and $\mathbf{j}_M^\epsilon = \nabla\times(c\phi\mathbf{M}) = \phi\mathbf{j}_M^e + c\mathbf{M}\times\mathbf{E}$ (ϕ is the electric potential), are divergence-free and corresponding net (bulk plus surface) magnetization currents are always zero [5]. Energy magnetization currents are shown in Fig. 1. The surface energy current, $\mathbf{J}_s^\epsilon = \phi_A\mathbf{j}_A^s + \phi_B\mathbf{j}_B^s$, arises due to the transfer of the potential ϕ by the surface electric magnetization current $\mathbf{j}^s = c\mathbf{M}\times\mathbf{n}$ ($\mathbf{n}$ is the unit vector normal to the surface) [4,5]. The surface energy current $\mathbf{J}_s^\epsilon$ does not have a thermal component, because the thermal energy is counted from the electrochemical potential $\zeta = \mu + e\phi$ at the surface [4–6].

The bulk magnetization energy current $\mathbf{J}_b^\epsilon$, which compensates the surface current, also does not transfer the heat. As it is shown in Fig. 1, it may be calculated as $\mathbf{J}_b^\epsilon = -\mathbf{J}_s^\epsilon = c(\mathbf{M}\times\mathbf{E})w$, where w is the width of the sample. Therefore, the term $c(\mathbf{M}\times\mathbf{E})$ is the magnetization part of the Poynting vector (for details see [7]).

If the heat current is extracted from the energy current, $\mathbf{j}^h = \mathbf{j}^\epsilon - (\zeta/e)j_{\mathrm{tr}}^e - c\nabla\times(\zeta M/e)$ [5,7], where j_{tr}^e is the transport electric current, there are other important corrections besides $c(\mathbf{M}\times\mathbf{E})$. Thus, even if we assume that the "heat current" in [1] is in fact the energy current, it does not make [1] consistent.

(ii) It is not surprising that [1] contradicts to experimental data. While for noninteracting electrons thermomagnetic effects are proportional to the square of the particle-hole asymmetry (PHA) and very small, according to [1–3] the fluctuation thermomagnetic effects do not require PHA at all and, therefore, huge. The Gaussian model is fully applicable to ordinary superconductors, for which the works [1–3] predict the interaction correction to β to be at least $\epsilon_F/T \sim 10^5$ times bigger than β in the normal state. It is impossible that such giant effects have been overlooked by all groups measured β in ordinary superconductors (Al, In, Sn, Nb) [8]. Also, the calculations of [1] for superconductors with the negative interaction constant in the Cooper channel being generalized for nonsuperconducting metals with a positive constant will lead to giant effects even in ordinary metals. Certainly, such giant thermomagnetic effects are not known.

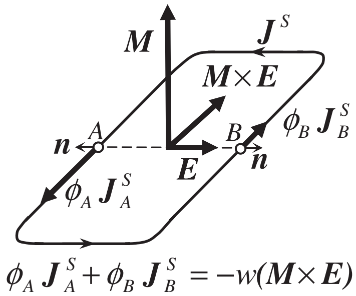

FIG. 1. Bulk and surface magnetization energy currents.

(iii) In [1] the microscopic calculations were supported by the phenomenological theory, where ∇T was introduced via $\nabla\mu(T)$. The authors claim that in this way they derived a general Einstein-type relation: $\nu_N \equiv \beta/(\sigma H) = (\sigma/ne^2c)(\partial\mu/\partial T)$, where σ is the conductivity and n is the electron concentration. According to textbooks [6], $\nabla\mu$ should be included in the effective electric field, i.e., thermomagnetic transport cannot be reduced to the thermodynamic quantity $\mu(T)$. Even with this wrong relation, to get the giant effect, the authors of [1] introduced the chemical potential of Cooper pairs: $\mu_{c.p.}(T) = T_c - T$. However, in equilibrium $\mu_{c.p.}$ is zero (see Eqs. 1.5–1.7 in Ref. [3]).

We did not touch microscopic aspects here; the related problem of gauge invariance is addressed in [9].

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Received 16 June 2009; revised manuscript received 6 May 2010 ; published 1 April 2011
DOI: 10.1103/PhysRevLett.106.139701
PACS numbers: 74.40.−n, 72.15.Jf, 74.25.F−

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