Comment on ”Observation of 2D Polarons and Magneto-Polarons on Superfluid Helium Films”

A recent letter by Tress et al. [1] found agreement between electron mobilities on a helium film and the theoretical mobility of a ripplonic polaron. We point out that this agreement results from an incorrect determination of the holding field and application of formulas for the isolated polaron to the case where the polaron radius $R$ and scale of electron localization $L$ are limited by the Wigner-Seitz radius $r_{WS}$. We show that the experimental results are in disagreement with the theory of the binding energy and dependence of polaron mobility $\mu_p$ on film thickness and magnetic field.

The holding field is written as $E_0^* = E_\perp + E_d$. Here $E_d$ is the sum of the fields of all primary image charges of strength $\delta e$ in the substrate. $E_\perp$ includes the applied field and the field of all polarization charges excluding the primary images, $\delta e + \delta_i e$, beneath each electron. For a saturated electron density $n$, $E_\perp$ is

$$E_\perp = (1 - \delta - \delta_h)ne/2e_o. \quad (1)$$

Here $\delta = (\kappa - \kappa_h)/(\kappa + \kappa_h)$; $\delta_h = (\kappa_h - 1)/(\kappa_h + 1)$; $\kappa = 4$ and $\kappa_h = 1.057$ are dielectric constants of the substrate and helium, respectively.

The main cause of discrepancies with the results of Ref. [1] lies in this expression. An overestimate of $E_\perp$ leads to errors in the binding energy and $\mu_p$. An underestimate of $L(0) \propto (E_0^*)^{-1}$ leads to an incorrect variation of $L(B)$ [Eq. (2) of Ref. [1]] and hence mobility with magnetic field. We have calculated the image field by taking into account the suppression of the film by the electron pressure and finite separation of the electron from the surface of the film.

The characteristic binding energy is given by $B_0 = (eE_0^*)^2/4\pi\sigma$. Here $\sigma$ is the surface tension. Binding energies are smaller for the case $r_{WS} < \kappa^{-1}$. Calculated values of $B_0$ for the densities used are in the respective ranges 20 - 60 mK, 40 - 80 mK, and 190 - 240 mK for $n = 2.1, 3.0$, and $6.6 \times 10^{13}$ m$^{-2}$ and are much less than $T = 1.3$ K. For $n = 6.6 \times 10^{13}$ m$^{-2}$ the system is in the crystal phase.

The calculated polaron mobilities [1] are plotted versus the suppressed film thickness $d$ and compared with experiment in Fig. 1. Vapor scattering is included by using Matthiessen’s rule as an approximation. The capillary constant $\kappa_c$ is replaced by $2\kappa^{1/2}$ in the expression for $\mu_p$ [1] since $k_c^{-1} > r_{WS}$. We have not corrected for $L > r_{WS}$ which holds for some of the data. Theoretical curves terminate at the limiting film thickness.

We compare the calculated conductivity ratio with experiment for $n = 5 \times 10^{13}$/m$^2$ in Fig. 2. The transition from $L(0)$ to the cyclotron radius is shifted to smaller values of $B$ because of the larger value of $L(0)$. The expression for $L(B)$ does not include electron diffusion within the dimple which results in diffusion of the cyclotron orbits and an increase in $L$. Data for $d = 40$ nm are within 2 percent of the melting temperature.

In summary, these results cannot be taken as conclusive evidence of the polaron state.

Supported by NSF grant DMR-REU-94-02647.

N.A. Rubin and A.J. Dahm
Department of Physics, Case Western Reserve University, Cleveland, OH 44106-7079

PACS numbers: 67.40.Rp, 71.38.+I, 73.20.Dx, 73.50.Fq

---

[1] O. Tress, Yu.P. Monarkha, F.C. Penning, H. Bluyssen, and P. Wyder, Phys. Rev. Lett. 77, 2511 (1996).
[2] K. Kajita, J. Phys. Soc. Jpn. 52, 372 (1983).
[3] X.L. Hu and A.J. Dahm, Phys. Rev. B 42, 2010 (1990).
[4] Eq. (1) of Ref. [1] should be divided by $e^2$.
[5] Yu.P. Monarkha and V.B. Shikin, Fiz. Nizk. Temp. 8, 563 (1982) [Sov. J. Low Temp. Phys. 8, 279 (1982)].
