Comment on "Low-Density Spin Susceptibility and Effective Mass of Mobile Electrons in Si Inversion Layers"

In a recent Letter [1], the effective g factor and the effective mass, m, have been studied by Pudalov *et al.* in a dilute 2D electron system in silicon. By analyzing Shubnikov–de Haas oscillations in superimposed parallel and perpendicular magnetic fields, the authors reproduce the strong increase of gm with decreasing electron density previously reported in Ref. [2]. However, they contrast their data with the data obtained by our group [3] and claim that the spin susceptibility (or the product gm) "increases gradually with decreasing density," which "does not support the occurrence of spontaneous spin polarization and divergence of gm at $n_s = n_c$" (here n_s is the electron density and n_c is the critical density for the metal-insulator transition, MIT). The purpose of this Comment is to show that all available experimental data, including those of Pudalov *et al.*, are consistent with each other and are in favor of a spontaneous spin polarization in this 2D system and a divergence of gm at a finite electron density.

Spin polarization and spin susceptibility were recently studied by measuring the (parallel) magnetic field B_c, required to fully polarize the electrons' spins, using scaling of magnetoresistance [3] and magnetoconductivity [4]. To compare the data of the above two groups with the newer data of Pudalov *et al.* [1], in Fig. 1 we plot all three sets of data (two sets in the inset for better visibility). To convert gm from Ref. [1] into B_c, we use the condition for the full spin polarization: $g\mu_B B_c/2 = \pi\hbar^2 n_s/2m$, where μ_B is the Bohr magneton. (The factor of 2 on the right side of the equation reflects the valley degeneracy.) The agreement between all three sets of data is remarkable, especially if one takes into account that different groups used different methods, different samples, and different field/spin-polarization ranges. B_c is a linear function of n_s and extrapolates to zero at a *finite* electron density which we will designate n_χ. The linear fit of the data from Ref. [1] yields $n_\chi = 8 \times 10^{10}$ cm^{-2}, which is identical with ours suggesting that n_χ is sample independent.

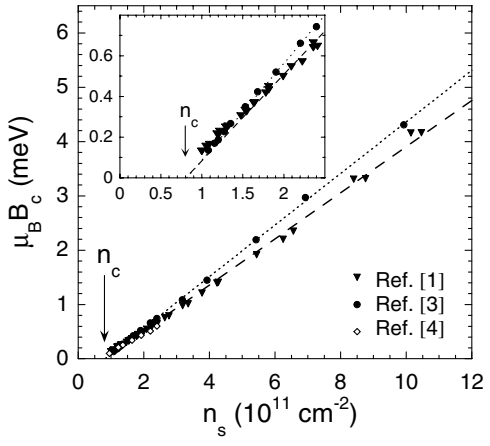

FIG. 1. $B_c(n_s)$ calculated using the data from Refs. [1,3,4]. The dashed and dotted straight lines are fits to the data from Refs. [1,3], respectively.

Contrary to the claim made in Ref. [1] of a *gradual* increase of χ with decreasing n_s, the linear dependence of $B_c \propto n_s/gm$ (Fig. 1) points to the *critical* behavior of the spin susceptibility: $\chi \propto n_s/(n_s - n_\chi)$. The divergence of χ should occur at the sample-independent electron density n_χ, which in the samples studied in Ref. [3] coincides with the critical density n_c for the MIT indicated by the arrow. In more disordered samples, however, n_c may be noticeably higher than n_χ. This is the case for the samples from Ref. [1] with $n_c \approx 1 \times 10^{11}$ cm^{-2} being well above the expected ferromagnetic transition point $n_\chi \approx 8 \times 10^{10}$ cm^{-2}. This explains why no divergence of gm is seen by Pudalov *et al.* at electron densities down to n_c in their samples. Note that even in the least disordered samples gm is still expected to be finite near n_χ, as it normally occurs for any ferromagnetic transition due to nonzero temperature, inhomogeneous broadening, etc.

Of course, for the spin susceptibility to diverge at $n_s = n_\chi$, the extrapolation of $B_c(n_s)$ to zero must be valid. To verify its validity, accurate data at lower densities, lower temperatures, and on much less disordered samples are needed. We emphasize that, in contrast to their claim, the method used by Pudalov *et al.* [1] certainly cannot be applied "down to and across the 2D MIT" because at $n_s \lesssim 10^{11}$ cm^{-2} (i) the amplitude of oscillations is too large (and even diverges as $T \to 0$) [5], which is inconsistent with the Lifshitz-Kosevich formula they use, and (ii) there are too few oscillations [5] to study the beating pattern. We also note that the Lifshitz-Kosevich formula was deduced for the case of weak electron-electron interactions, and its application to strongly correlated system is not justified.

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[1] V. M. Pudalov *et al.*, Phys. Rev. Lett. **88**, 196404 (2002).
[2] S. V. Kravchenko *et al.*, Solid State Commun. **116**, 495 (2000).
[3] A. A. Shashkin *et al.*, Phys. Rev. Lett. **87**, 086801 (2001).
[4] S. A. Vitkalov *et al.*, Phys. Rev. Lett. **87**, 086401 (2001).
[5] V. M. Pudalov *et al.*, Surf. Sci. **305**, 107 (1994).

