Shashkin et al. reply to cond-mat/0410409

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We show that the Comment by Reznikov and Sivan (cond-mat/0410409) is erroneous because the authors do not distinguish between Pauli and Curie spin susceptibility.

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The low-temperature behavior of the dilute electron system in silicon depends on a delicate interplay between kinetic energy, electron-electron interaction energy, and disorder. Any expansion of the strong localization regime to higher electron densities leads to a fading of the region in which the most pronounced many-body phenomena are observed. The spin susceptibility in silicon samples with different levels of disorder tends to diverge at a sample-independent critical density $n_{\chi} \approx 8 \times 10^{10}$ cm$^{-2}$, as was established in transport [1, 2] and thermodynamic [3] measurements. Rather than the absolute values of the electron density, it is the deviations from this critical point $n_{\chi}$ that matter. Due to the high level of disorder in their sample, Prus et al. [4] could only reach electron densities that are more than a factor of 2 (rather than by 20% mentioned in the Comment [5]) farther from $n_{\chi}$ as compared to our experiment. Of course, they could not see any critical many-body phenomena in their sample.

In our paper [3], we have studied the clean metallic regime characterized by the absence of a band tail of localized electrons. In contrast, Prus et al. have studied mainly the insulating regime in a highly-disordered sample, in which the band tail of localized electrons is present at all electron densities [4]. As a result, they have found Curie contribution to the measured magnetization, which is strongly nonlinear with a magnetic field, and the extracted spin susceptibility has a Curie temperature dependence. This is the case even at high electron densities, where metallic behavior might be expected instead. Such effects are absent in our samples: the spin susceptibility (in the partially-polarized system) has been found to be independent of the magnetic field and temperature. Therefore, there is no overlap between their data and ours (at least, in the crucial region of low electron densities) as they were taken in two opposite regimes, contrary to the claim made by the authors of the Comment [3]. Apparently, Reznikov and Sivan do not distinguish between the Pauli spin susceptibility of band electrons and the Curie spin susceptibility of local moments.

In Fig. 1, we plot the main data of Prus et al. One can easily see that the low-$B$ data points lie in the insulating regime, where the physics of local moments dominates [3]. (The $y$-axis is converted into electron density $n$ in accordance with the relation for the maximum magnetization $M = \mu_B n$ [4, 5], and the field $B$ corresponds to the onset of full spin polarization.) Based on the data obtained in the regime of strong localization, one cannot make judgments concerning the properties of a clean electron system. To this end, the attempt by Reznikov and Sivan to extend the analysis [4] to the clean limit is not justified.

The authors of the Comment are confused about the location of the point where the full spin polarization sets in and contradict themselves contrasting “maximal” and “full” magnetizations. Evidently, the onset of full spin polarization occurs at the point where $M(n)$ reaches a maximum (i.e., $dM/dn = 0$ for nearly anti-symmetric jumps in $dM/dn$), reflecting the beginning of the filling of the second spin subband. The method of extracting spin susceptibility, described in the Comment, which involves integration of $dM/dn$ from 0 to $n_m$ and use of the formula $\mu_B n_m(B)/B$, has nothing to do with the procedure we have used in our paper [3].

Concerning the possible influence of the diamagnetic shift, we have established experimentally that it is negligible in our case, as follows from the concurrence of results obtained by different methods including the magnetocapacitance method [3]. The attempt by Reznikov and Sivan to introduce their theoretical estimates of the diamagnetic shift into the experimental data makes little sense.

FIG. 1: Data of Prus et al. [4]. The onset of strong localization in $B = 0$ in their sample and the critical point $n_{\chi}$ are indicated by arrows. The data points obtained at low magnetic fields lie in the insulating regime, where the physics of local moments dominates.
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