Spin susceptibility near metal-insulator transition in 2D

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In very clean samples, practically universal metal-insulator transition is seen:

Klapwijk’s sample:  Pudalov’s sample:

(Note: samples from different sources, measured in different labs)
... in contrast to strongly disordered samples:

Suggested phase diagrams for strongly interacting electrons in two dimensions

Tanatar and Ceperley,

Attaccalite et al.
In clean samples, is it a phase transition, or just something funny happens to conductivity?

Measurements of thermodynamic magnetization


\[ i \sim \frac{d\mu}{dB} = - \frac{dM}{dn_s} \]
Magnetic field of the full spin polarization $B_c$ vs. $n_s$

$B_c = \pi \chi^2 n_s / |\mu_B|^2 n_p^* \mu$ for $B < B_c$

$M = \mu_B n_s B / B_c$ for $B > B_c$

Expected vs. measured $d\mu/dB = -dM/dn$
Sergey Kravchenko, Northeastern Univ. (KITP 1-21-05) Critical behavior of the Paul spin susceptibility near the 2D.

$\frac{d\mu}{dB}$ vs. $n_s$ in different parallel magnetic fields:

Magnetic field of full spin polarization vs. electron density:

Spontaneous spin polarization at $n_\chi$?
Measurements of the thermodynamic density of states

$$i \sim \frac{d\mu}{dn_s}$$

Jump in the density of states signals the onset of the full spin polarization

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Magnetic field of full spin polarization vs. electron density:

- Magnetization data
- Magnetocapacitance data
- Linear fit

Data become T-dependent, possibly due to localized band-tail

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Anderson insulator

Disorder increases at low density

Paramagnetic Fermi-liquid

Wigner crystal?

Liquid ferromagnet?

Density-independent disorder

Electron density

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Spin susceptibility exhibits critical behavior near the metal-insulator transition:

\[ \chi \sim \frac{n_s}{n_s - n_c} \]

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\[ n_c (10^{11} \text{ cm}^{-2}) \]

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g-factor or effective mass?
Critical behavior of the Paul spin susceptibility near the 2D...
Critical behavior of the Paul spin susceptibility near the 2D..
CONCLUSIONS:

- In strongly interacting 2D electron system in silicon, spin susceptibility sharply rises with a tendency to diverge at a sample-independent density $n_x$.

- We find no evidence of increasing g-factor: it must be the effective mass that is responsible for the effect.

- In clean samples, $n_x$ practically coincides with the metal-insulator transition.

Appendix:
Difference between our results and those of Prus, Reznikov, Sivan et al. (PRB 2003):
Only three data points are relevant to the metallic regime.

Indeed, the (inverse) spin susceptibility has a Curie form characteristic of local moments.