Pinning and melting of a quantum Wigner crystal

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Introduction

The goal of this research was to test for an unambiguous demonstration of the transition within a two-dimensional electron system at ultra-low temperatures to an electronic solid state known as the Wigner crystal in which coulomb interactions cause the electrons to form a triangular lattice.

Experimental

The experimenters measured the differential electrical resistivity, dV/dI, of a low carrier density (n = 4 x 10^{-10} cm^{-2}) and high mobility (3 x 10^6 cm^2/Vs) electronic system in GaAs quantum wells. Electrons were cooled to 9mK and a perpendicular magnetic field was applied to quench the kinetic energy, thus enabling coulomb interactions to dominate in this regime of high B/T.

Studied low carrier density n =4 x 10^{-10} cm^{-2} and high mobility (3.0 × $10^6$$cm^2$/Vs) systems in a GaAs quantum well at low temperatures. The samples were cooled by immersion in liquid ^{3}He. A striking threshold behavior was observed for T ≲ 35 mK. The results are interpreted in terms the pinning of holes within a narrow range of ±5 pA (resistance > 1 GΩ).

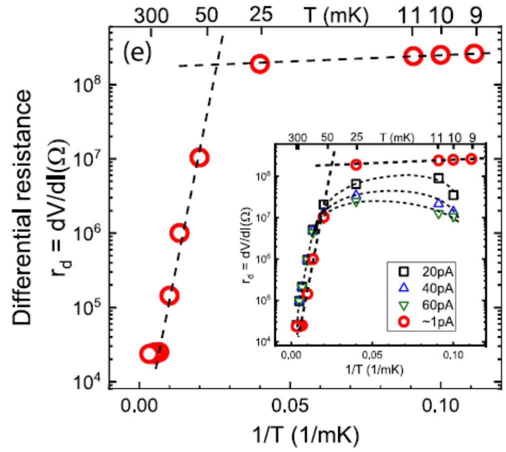

Fig.1 Temperature dependence of the differential resistivity, dV/dI, in the limit of V à0, plotted on a semi-logarithmic scale. Inset: comparison of the differential resistivity obtained with higher current drives.

Results and Discussion

The measurements revealed a striking threshold behavior for T ≲ 35 mK that is consistent with the formation of a Wigner crystal. The crystal is pinned (i.e. resistance > 1 G ohms) by disorder only at extremely low currents with magnitude < 5 pA. At currents just above the pinning threshold, the resistance plummets by more than an order of magnitude. The pinning is also destroyed by heating, consistent with the thermal melting of the Wigner crystal. The temperature dependence was found to be non-activated and piecewise, implying the existence of a pinned Wigner crystal undergoing a two-stage first-order transition upon heating.

Conclusions

Evidence has been obtained for a clear two-stage transition to a Wigner crystal state in a low carrier density two-dimensional electron system.

Acknowledgements

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References

[1] Knighton, T. *et al.,* Phys Rev B97, 085135 (2018).