Incipient Formation of Wigner Crystal in Strongly Interacting 2D Holes

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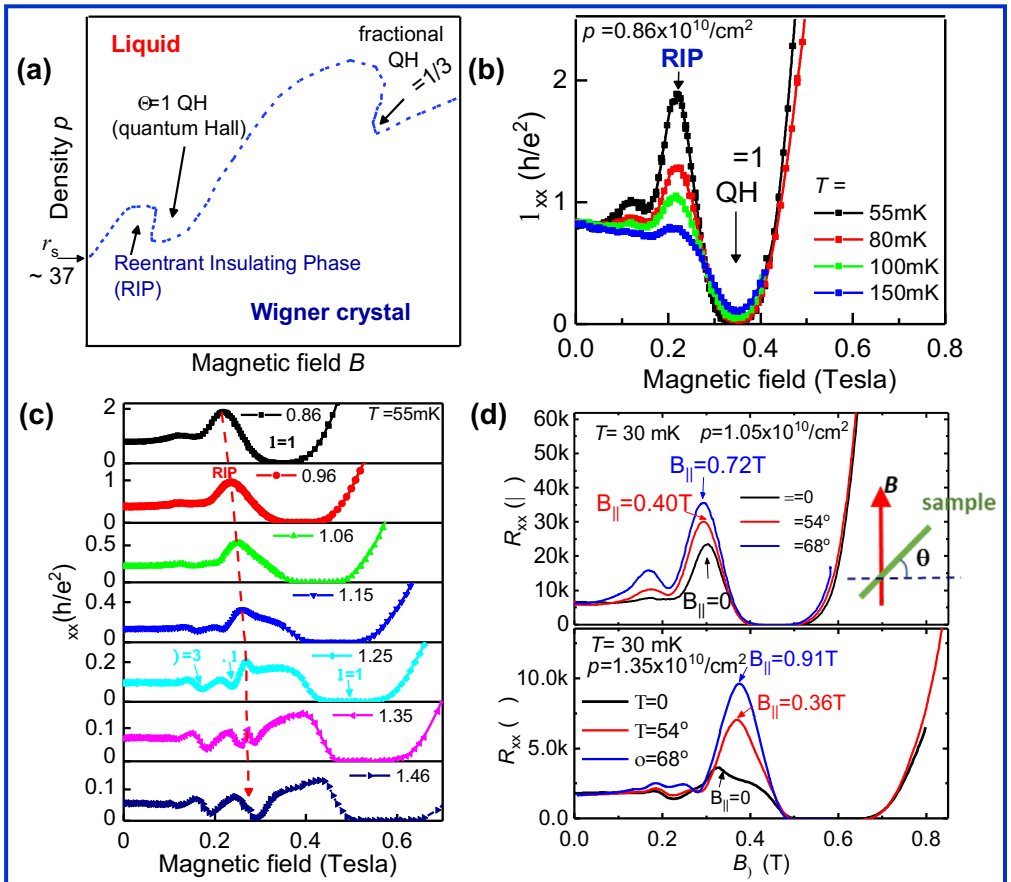
In two-dimensional (2D) electron systems, the ground state is expected to be an ordered electronic crystal, the Wigner crystal (WC), when the Coulomb repulsion energy is sufficiently strong. Identifying the 2D WC and understanding how the electron liquid transforms to the WC remain long-standing challenges in condensed matter physics.

Low density 2D holes in high mobility GaAs quantum wells were used to increase the Coulomb to Fermi energy ratio r_s to 20-30, approaching the WC transition expected at r_s ~37. Users of the MagLab's High B/T facility used a specially designed rotator stage for measurements in a tilted magnetic field at ultra-low temperatures to separately control the perpendicular and parallel magnetic fields to investigate the spin and orbital effects on the interaction driven Wigner crystallization of 2D holes. The 2D WC was observed as a reentrant insulating phase (RIP) from magneto-resistance data. The WC transforms gradually through an intermediate state where it mixes with the liquid phase. *Most intriguingly, spin polarization is found to enhance the WC formation*.

This research provides evidence that the liquid to 2D WC transition is not a direct first order transition, suggesting that an intermediate mixture phase formation may be a general aspect of strongly interacting low dimensional systems, providing insights to other quantum phase transitions in many-body electronic systems.



(a) Schematic phase diagram of interacting 2D electrons or holes. **(b)** Wigner crystallization appears as a reentrant insulating phase (RIP) in the magneto-resistance traces of 2D holes at low temperatures and **(c)** gradually mixes with the quantum oscillations and quantum Hall (QH) state. **(d)** Magneto-transport in tilted field shows that the RIP or Wigner crystal phase is enhanced by the parallel field.

Facilities and instrumentation used: MagLab High B/T facility, University of Florida, Gainesville, FL.

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