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Microwave Spectroscopy of Wigner crystals in 2DES and Bilayer Systems: Many-body correlation in electronic quantum solids[1]

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It is generally known that in high quality two dimensional electron systems (2DES, similarly for 2D hole systems and bilayer systems) under sufficiently large perpendicular magnetic field B, the quantum Hall (QH) states terminate into an electronic solid — a Wigner crystal (WC) pinned by disorder. After a brief review of solid phases in QH systems (including several recently discovered ones [1]) as known from microwave spectroscopy (measuring a characteristic pinning mode resonance of the solid), I will discuss two of our experiments that highlight the importance of many-body quantum correlation in the high-B WC. In one experiment [2], we measured the *melting* temperature (T_c) of the high-B WC at many different B and densities n and in multiple 2DES samples. The data show unambiguously that in a given sample, T_c is controlled by Landau filling ν=nh/eB instead of by n. This demonstrates the quantum nature of the high-B WC and that its melting is dependent on many-body quantum correlation (via ν). Such behavior contrasts with any other known solids (in particular, a classical electron solid), whose T_c are determined by n. In addition, we found that stronger pinning disorder in samples with tighter vertical confinement led to an enhancement of T_c. In another experiment [3], we studied *bilayer* WC (BWC) in bilayer hole systems (in low inter-layer tunneling limit). We found that in samples with a bilayer exciton condensate (BEC) QH state at ν=1, the pinning mode frequency of the BWC ($\nu \ll 1$) is systematically enhanced from what would be expected from two classically interacting single-layer WC. The enhancement decreases with increasing effective layer separation and is not observed for samples without the ν=1 state. We suggest that our results give evidence for a pseudospin (layer index) ferromagnetic BWC, which possesses interlayer quantum correlation and long range in-plane phase coherence similar to that in the ν=1 BEC state and can experience enhanced pinning [4] in the presence of interlayer spatial correlation of disorder.
[1] Yong P. Chen *et al.*, Phys. Rev. Lett. **93**, 206805 (2004); Phys. Rev. Lett. **91**, 016801 (2003); [2] Yong P. Chen *et al.*, Nature Physics **2**, 452 (2006); [3] Z. Wang *et al*, submitted; [4] Yong P. Chen, Phys. Rev. B **73**, 115314 (2006).

[1]Work done at Princeton University and National High Magnetic Field Laboratory.