2D-MIT as a Wigner-Mott Transition

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Introduction

Significant experimental advances [1] over the last ten years have provided beautiful and convincing evidence for the existence of a sharp metal-insulator transition (MIT) in two-dimensional (2D) electron gases (2DEG). This progress has sparked much renewed interest in better understanding the basic physical mechanisms that drive the MIT, a fundamental physical question that has remained poorly understood for many years. It should be emphasized, though, that the best evidence for a sharp MIT is found in the cleanest samples, where the diffusive regime is restricted to low densities and extremely low temperatures. Indeed, the experimental data [1] demonstrating strong effective mass m* enhancements have all been obtained in the ballistic regime, where diffusive processes are irrelevant. An important question then arises: How many of the key experimental features can be understood by deliberately disregarding disorder, and focusing on interaction effects alone as the main driving force for the transition? This question is the main subject of the work presented in Ref. [2], where we propose the quantum melting of a Wigner crystal as the fundamental mechanism for the MIT in a sufficiently clean 2DEG. Here, we presented a simplified description of a Wigner crystal, based on the idea that there exists a pronounced short range order in charge sector both on the metallic and insulating sides of the MIT. While this theory reproduced many aspects of the experiment, a more accurate description should explicitly include the dynamics of collective charge fluctuations which were phenomenologically treated in Ref. [2]. A more comprehensive theory describing both the charge ordering and the metal-insulator transition, which provides further support to the results of Ref. [2], has been presented in Ref. [3].

Results and Discussion

In Ref. [3], we show that strong correlations, normally expected only for narrow integer filled bands, can be effectively enhanced even far away from integer filling, due to incipient charge ordering driven by non-local Coulomb interactions. This general mechanism is illustrated by solving an extended Hubbard model using dynamical mean-field theory. Our findings account for the key aspects of the experimental phase diagram, and reconcile the early view points of Wigner and Mott. The interplay of short range charge order and local correlations should result in a three peak structure in the electron spectral function, which can be observed in tunnelling and optical spectroscopy. These experiments will discriminate between the Wigner-Mott scenario and the alternative perspective which views disorder as the main driving force for the 2D-MIT.

Conclusions

We presented the solution of a simple microscopic model which correctly captures the qualitative behavior near a Mott transition in the presence of a charge ordered background (Wigner-Mott transition). As in the conventional Mott scenario, this transition features the formation of a strongly correlated state on the metallic side. The magnetic field dependence proves to be dramatically different from what is expected in a one band Hubbard model at half filling but it is in favorable agreement with experiments on the 2DEG.

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