Evolution of Charge Carriers near the Mott Transition: Theory vs. Experiment in κ-(BEDT-TTF)$_2$X

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Despite the great amount of work devoted to the Mott metal-insulator transition (MIT), some key theoretical predictions in this field are still awaiting experimental verification. This is related, for example, to the quasiparticle coherence and the exact behavior of the effective mass renormalized by many-body interactions in the vicinity of the bandwidth-controlled first-order MIT. Here we explore these issues, employing the salts κ-(BEDT-TTF)$_2$X as exemplary quasi-2D Mott systems and gaining direct access to their charge carrier properties via magnetic quantum oscillations.

The X = Cu[N(CN)$_2$]Cl salt (κ-Cl for short) can be conveniently tuned very close to the MIT by means of precisely controlled pressure, see Fig. 1. Remarkably, we are able to observe the oscillations not only in the homogeneous metallic domain of the phase diagram but also deep in the transition region. This indicates the persistence of the large coherent Fermi surface even at the very edge of stability of the metallic ground state. At the same time, the oscillations reveal certain anomalies upon entering the phase-separated regime. This becomes evident when confronting κ-Cl with the X = Cu(NCS)$_2$ salt. Furthermore, the comparison between the two salts yields a clear evidence for the crucial importance of geometrical frustration for the difference in their ambient-pressure ground states.

The obtained experimental data provides a solid basis for explicit quantitative comparison with theory. In particular, we find that in the purely metallic state the effective mass m_c precisely follows the simple pressure dependence $m_c \propto (P - P_0)^{-1}$, seemingly consistent with theoretical predictions for the close proximity of the MIT. However, the slope of this dependence turns out to be strikingly, almost an order of magnitude, steeper than expected. Moreover, a comparison with some other, organic and inorganic Mott materials suggests a universal character of the detected inconsistency.

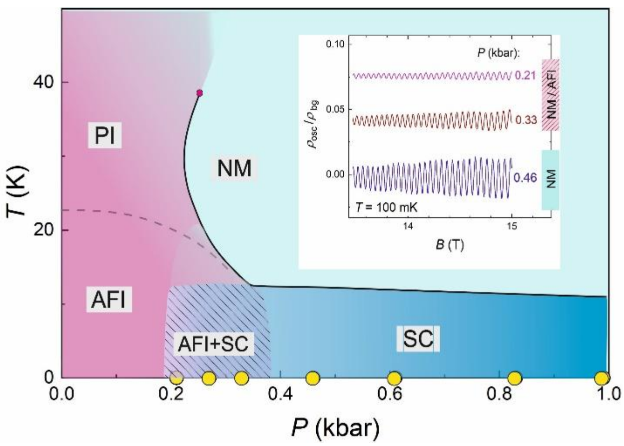

Fig. 1. Pressure-temperature phase diagram of κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl. Yellow circles indicate the pressures at which the measurements were done. Inset: Examples of the oscillatory magnetoresistance in the purely metallic state and deep in the phase-coexistence region.