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Editorial

Advances in Organic Conductors and Superconductors

Martin Dressel

1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany; dressel@pi1.physik.uni-stuttgart.de; Tel.: +49-711-685-64946

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Crystalline conductors and superconductors based on organic molecules are a rapidly progressing field of solid-state science, involving chemists, and experimental and theoretical physicists from all around the world. In focus are solids with electronic properties governed by delocalized π-electrons. Although carbon-based materials of various shades have gained enormous interest in recent years, charge transfer salts are still paradigmatic in this field. Progress in molecular design is achieved via tiny but ingenious modifications, as well as by fundamentally different approaches. The wealth of exciting physical phenomena is unprecedented and could not have been imagined when the field took off almost half a century ago.

Organic low-dimensional conductors are prime examples of Luttinger liquids; they exhibit a tendency toward Fermi surface instabilities, but can also be tuned across a dimensionality-driven phase diagram like no other system. Superconductivity comes at the border to ordered phases in the spin and charge sectors, and, at high fields, the Fulde–Ferrell–Larkin–Ovchinnikov (FFLO) state is well established. The interplay between charge and magnetic order is still under debate, but electronic ferroelectricity is well established. After decades of intense research, the spin liquid state was first discovered in organic conductors when the amount of geometrical frustration and electronic correlations is just right. They drive the metal and superconductor into an insulating Mott state, solely via electron–electron interactions. However, what do we know about the effect of disorder? Can we tune the electronic properties by pressure, by light, or by field? Research is still addressing basic questions, but devices are not out of reach. These are currently open questions, as well as hot and timely topics.

Although the superconducting transition temperature remains rather moderate for organic materials, the questions addressed are of fundamental importance, and for several topics molecular conductors are by far the best model system for detailed investigations. The spatial modulation of the superconducting order parameter in the Fulde–Ferrell Larkin–Ovchinikov state is certainly one of them [1,2]. The conceptional paper by Otsuka et al. reviews current ideas on the design of a spin-frustrated Mott insulator and points towards future developments in quantum spin liquids [3]. No question, this exciting research topic has placed organic crystals again at the forefront of solid-state physics. The class of β'-$Et_xMe_{4-x}Z[Pd(dmit)_2]_2$ with Z = P, As, Sb and x = 0, 1, 2 is a topic of the paper from Ueda et al. [4]. A completely new view on the structural properties of κ-$(BEDT\text{-}TTF)_2Cu_2(CN)_3$ is given by Foury-Leylekian and collaborators [5], who found that the compound contains two non-equivalent dimers in the unit cell and charge disproportionation between the dimers. Here, simple facts, assumed to be settled for decades, were revisited, such as the symmetry of a crystal; this laid new ground for the re-interpretation of numerous experimental observations. The low-temperature anomaly observed in the quantum spin liquid compound κ-$(BEDT\text{-}TTF)_2Cu_2(CN)_3$, however, remains an open issue [6]. In any case, the electrodynamic properties of these organic dimer Mott insulators appear to be fairly well understood by now [7,8]. The Mott transition observed in the two-dimensional organic κ-phase BEDT-TTF salts is the focus of

the detailed pressure-dependent measurements of the heat capacity [9] and thermal expansion [10]. Magnetic excitations were investigated by Raman scattering, suggesting intra-dimer charge degree of freedom for some salts [11]. The combination of a correlation-driven Mott transition and a disorder-driven Anderson transition has become more of an issue in recent years. The contribution of Rabaça et al. and Prokhorova et al. considers structural disorder [12–14]. The existence of Dirac-like electrons in α-(BEDT-TTF)$_2$I$_3$ is another topic that has attracted interest for more than a decade, from a theoretical side [15] as well as from the side of applications [16]. Pressure-dependent experiments are also important for the one-dimensional TMTTF salts, in order to study the charge and anion ordering [17,18].

In 2012, Reizo Kato edited a seminal collection of 45 contributions on various aspects of "Molecular Conductors" as a Special Issue of *Crystals*, which has been well received by the community. The present Special Issue on "Advances in Organic Conductors and Superconductors" may become a status report summarizing the progress achieved in the last five years.

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