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Editorial

Advances in Topological Materials

Artem V. Pronin

1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany; artem.pronin@pi1.physik.uni-stuttgart.de

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Materials with electronic bands that possess nontrivial topology have remained a focal point of condensed matter physics since 2005, when topological insulators were theoretically discovered by Kane and Mele [1,2]. In parallel to this remarkable discovery, Haldane and Raghu [3] realized that topological phases are a universal phenomenon of waves in periodic media. Thus, topological concepts can also be applied, for example, to electromagnetic waves in photonic crystals [4], magnons in magnetic materials [5], and sound waves in different periodic structures [6]. This Special Issue of *Crystals* represents a collection of 11 papers devoted to different aspects of experimental and theoretical studies on topological materials.

Five papers from the Special Issue focus on the theory side. Gao and Wang [7] propose a new design for an ideal photonic Weyl metacrystal ("ideal" means that there are no additional states at the Weyl-node energy). The Weyl nodes of this metacrystal are stabilized by the screw rotation symmetry of space group 19. The authors argue that this design might be advantageous for further experimental studies of photonic Weyl materials. Cheng and Gao [8] study a non-interacting Λ/V-type dice model composed of three triangular sublattices. By considering certain nearest-neighbor and next-nearest-neighbor hopping terms, as well as a quasi-staggered on-site potential, they acquire the full phase diagrams for different energy band fillings. They find abundant topologically nontrivial phases with different Chern numbers and a metallic phase in several regimes. Nikolaev et al. [9] study the influence of uniaxial deformation on the band structure and topological properties of the multifold semimetal CoSi with large topological charges. The $\mathbf{k}\cdot\mathbf{p}$ Hamiltonian, which takes the deformation into account, is constructed from symmetry considerations near the Γ and R points of the Brillouin zone. The transformation of the multifold band crossings into nodes of other types with different topological charges, their shift in energy and in reciprocal space, and the tilt of the dispersion around the nodes are studied in detail, depending on the direction of uniaxial deformation. Polatkan and Uykur [10] present a theoretical study of the band structure and optical conductivity for another multifold semimetal, PdGa. They identify several characteristic features in the optical conductivity and relate their origin to the band structure. Yaresko and Pronin [11] calculate the *ab*-plane optical conductivity of the Weyl semimetal TaP and compare it to the experimental data. Based on these calculations, they propose an explanation of the strong low-energy peak observed in the experimental spectra: this peak originates from transitions between the almost parallel non-degenerate electronic bands split by spin-orbit coupling.

The other papers in this Special Issue report experimental findings. Dally et al. [12] present small-angle inelastic neutron scattering measurements of Fe_3Sn_2. Fe_3Sn_2 has recently been discovered to host room temperature skyrmionic bubbles and is known to have competing magnetic exchange interactions, correlated electron behavior, weak magnetocrystalline anisotropy, and lattice anisotropy. The results of Dally et al. reveal that, at elevated temperatures, there is an absence of significant magnetocrystalline anisotropy and that the system behaves as a nearly ideal isotropic exchange interaction ferromagnet. Hatnean et al. [13] report on the growth of large high-quality Ce-substituted SmB_6 crystals via the floating zone method. The topological properties of SmB_6 are currently being intensively discussed in relation to Kondo physics. Hence, the investigation of substituted

SmB_6 samples is of interest. The structural, magnetic and transport properties of single crystals with different Ce contents are investigated by Hatnean et al. using X-ray diffraction techniques, electrical resistivity and magnetization measurements. The authors find that the substitution of Sm with magnetic Ce does not lead to long-range magnetic ordering.

The remaining experimental reports focus on optics. Shuvaev et al. [14] present sub-terahertz measurements of the quantum anomalous Hall effect (QAHE). In the static regime, the QAHE is observed as a step in Hall resistivity. At optical frequencies, it is transformed into a step in the polarization rotation, with the size of this step being equal to the fine structure constant, $\alpha \approx 1/137$. The authors measure the polarization rotation in thin films of the topological insulator $(Bi,Sb)_2Te_3$ doped with Cr and observe the expected steps at temperatures below 20 K. However, due to material issues, the size of the steps only reaches up to 20% of the theoretical value (at 1.85 K). At millikelvin temperatures, full-size steps are anticipated. Kamenskyi et al. [15] perform magneto-optical measurements of the topological insulator Bi_2Te_3 in the terahertz frequency range in magnetic fields up to 10 T. They report on the observation of a cyclotron resonance mode and ascribe it to free bulk carriers. The width of the mode demonstrates a non-monotonous behavior in the magnetic field. The authors propose that the mode width is defined by two competing factors: impurity scattering and electron–phonon scattering, which exhibit opposite behaviors in applied magnetic fields. Another topological insulator, Bi_2Te_2Se, is investigated by Zhukova et al. [16] by mid- and near-infrared optical measurements. The optical conductivity of Bi_2Te_2Se is found to be dominated by bulk carriers and shows a linear-in-frequency increase at 0.5 to 0.8 eV. This linearity might be interpreted as a signature of the three-dimensional (bulk) Dirac bands; however, the band structure-based calculations performed by the authors show that transitions between bands with complex dispersions contribute instead to the inter-band optical conductivity at these frequencies and, hence, the observed linearity is accidental. These results warn against oversimplified interpretations of optical conductivity measurements in different Dirac materials. Finally, Schilling et al. [17] investigate the broadband optical conductivity of the two-dimensional Dirac material $CaMnBi_2$. They find that both components of the intraband conductivity follow a universal power law as a function of frequency at low temperatures. This conductivity scaling differs from the standard Drude-like behavior and might point toward quantum criticality in this system.

Overall, this Special Issue represents a few recent developments in the broad and growing field of topological material studies.

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