

Editorial

Organic–Inorganic Hybrids: A Class of Material with Infinite Opportunities

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The continuous research interest in organic–inorganic hybrid materials can be attributed to the synergistic or complementary interactions between their organic and inorganic components, which, in turn, opens up a wide array of potential applications. The study on the structural–property relationship represents a pivotal research direction for these organic–inorganic hybrids.

Metal–organic frameworks (MOFs) serve as the perfect platform to study the interactions between covalently bonded organic linkers and metal clusters and understand how the design and modification of organic ligands can tailor the resulting materials for specific applications [1,2]. In our Special Issue, Manos et al. reported two MOFs, namely MOR-1 and MOR-2, comprising 2-amino-terephthalic acid/2-((pyridin-1-ium-2-ylmethyl)ammonio)terephthalate organic linkers and zirconium (IV) oxide inorganic clusters. These two MOFs are used to remove pharmaceutical pollutants from water by sorption columns and exhibit high capacity, fast sorption kinetics, and high selectivity. The better sorption performance of the MOR-1 MOF than the MOR-2 MOF originates from its larger pore size, determined by the organic ligand, which benefits the insertion of the pollutant molecule into the MOF [3]. As a matter of fact, Zr-MOFs are considered to be the most promising MOF materials for real applications due to their diverse structures, high stability, and tunable properties. In 2020, Hong-Cai Zhou et al. summarized several methods to manipulate the pore size by modifying the structure of the linkers [4]. Omar Yaghi recently developed two series of amine-functionalized Zr-MOFs for carbon dioxide capture [5], and Karena Chapman suggested that a Zr-MOF can be used for single-site catalysts [6]. All of these very recent works indicate that the Zr-MOFs still exhibit fruitful research potential in both fundamental chemistry and state-of-the-art applications.

Wei Liu's group contributed two research articles to our Special Issue, reporting the light-emitting properties of several organic–inorganic copper halides. In one work, two zwitterionic types of zero-dimensional (0D) organic copper (I) bromide were presented, in which the cationic 1-((2-bromoethyl/chloroethyl)-1,4-diazabicyclo [2.2.2]-octan-1-ium) forms coordinating bonds with copper bromide anionic dimers [7], resulting in “all-in-one” structures, as suggested by the previous works of the authors [8–10]. These two compounds emit green photoluminescence, with internal quantum yields over 10%. According to the theoretical calculations, their emissions are attributed to the triplet cluster-centered excited states from the strong Cu–Cu interaction. In the other article from these authors, bidentate 5-chloropyrimidine was utilized to form a one-dimensional (1D) framework with copper (I) iodide, resulting in a red-light-emitting material with internal quantum yields of 6.5%. The theoretical calculation suggested a luminescence mechanism of combined halide-to-ligand charge transfer (XLCT) and metal-to-ligand charge transfer (MLCT), which implies that the emission could be manipulated by altering the organic ligand [11]. The unique “all-in-one” structure allows the coexistence of both ionic and coordinate bonds within a



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molecular cluster, which endows outstanding structural stability while maintaining the low-dimensional identity and its promising luminescence properties. Some recent advances highlight the potential applications of “all-in-one” organic–inorganic hybrids in rare-earth element-free phosphor [12], hypotoxicity photodetectors [13], and thin-film semiconductors for optoelectronic devices [14].

Another organic–inorganic hybrid material family, the halide perovskites, is extensively studied due to their excellent optoelectronic properties [15,16]. Structurally speaking, halide perovskites, including low-dimensional perovskites, are composed of ionically bonded organic and inorganic components, rendering them high dielectric constants and low exciton binding energies [17,18]. Halide perovskites are widely involved in optoelectronic applications, such as photovoltaics (PVs) [19,20], light-emitting diodes (LEDs) [21,22], field-effect transistors (FETs) [23,24], sensors [25,26], and lasers [27,28]. In our Special Issue, Hanlin Hu et al. reported a facile method to passivate the top interface of a two-dimensional (2D) perovskite solar cell. Instead of spin-coating the electron transport layer of [6,6]-phenyl-C61-butyric acid methyl ester (PCBM) after the formation of the 2D perovskite layer, they directly used PCBM solution as an antisolvent to assist in the crystallization of the perovskite layer. This method leads to better morphology of the PCBM layer and passivated interfacial defects, significantly improving the power conversion efficiency (PCE) from 8% to 12.8% [29]. They later summarized the commonly used two-step film fabrication method for perovskite solar cells, which possesses the advantages of good film morphology, easy fabrication, and good repeatability. Several two-step film processing methods have been reviewed, including spin-coating, immersion, and evaporation. Current strategies to manipulate the crystallization kinetics of perovskite films, such as additive engineering, compositional engineering, and solvent engineering, have also been discussed [30]. The two-step method has been widely applied to fabricate highly efficient perovskite solar cells [31,32], large-area modules [33,34], and perovskite tandem cells [35,36], which is considered to be a promising technical route for commercialization. Nevertheless, some critical issues of the two-step method should be addressed before it could surpass other approaches, which include the uncertain stoichiometric ratio of the perovskite film, the excessive and uneven distribution of PbI_2 in the film, and the efficiency loss for large-area devices [37,38]. Review articles revealing other applications of perovskites could also be found in this Special Issue [39,40].

In conclusion, research on the structural–property relationships of organic–inorganic hybrid materials has made significant progress in recent years. The Special Issue of “Organic-Inorganic Hybrids: Synthesis, Property and Application” provides the latest research milestones of organic–inorganic hybrid materials and reveals several research hotspots, including material design principle development, computational modeling and prediction, novel characterization techniques, and the expansion of their applications.

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