Towards Synthetic Two-Dimensional Soft Materials

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Two-dimensional (2D) materials possess a structure with a topographical thickness generally ranging from atomic/molecular level to few hundreds of nanometers while the lateral dimensions are one or several orders of magnitude larger than the thickness; in addition, the aspect ratios in the planar dimensions are usually smaller than 10. As an important member filling in the gap among zero-dimensional, one-dimensional materials, and three-dimensional bulk materials, 2D materials have attracted great interest in both academic and industry. Among them, 2D soft materials are flexible and show rich dynamics and self-assembly behavior determined by the subtle balance of energy and entropy. A typical example is graphene, a well-known 2D macromolecule, which is a single-layer graphite with close-packed conjugated hexagonal carbon lattices. Graphene possesses a large specific surface area along with exceptional electrical, mechanical, thermal and optical properties, and thereby shows great potential for applications in a variety of fields including energy conversion and storage, optoelectronics, catalysis, sensing, and biotechnology. In contrast to the extensive exploration of graphene and 2D inorganic materials such as metal dichalcogenides, metal oxides and nitrides, the study on 2D soft materials remains very limited.

In this lecture, we will present our recent efforts toward the chemical synthesis of novel 2D soft materials with structure control at the atomic/molecular-level or meso-scale. First, we will briefly demonstrate the latest efforts towards the synthesis of nanographenes and graphene nanoribbons with atomically precise structures. The synthesis strategy is based upon cyclodehydrogenation ("graphitization") of well-defined dendritic (3D) polyphenylene precursors with different topologies, in solution or on surface. Second, we will address the synthetic 2D conjugated polymers including 2D metal-dithienene/diamine coordination polymers at air-water and liquid-liquid interfaces. The resulting 2D conjugated polymers exhibit single-layer feature, good local structural ordering and with a size of mm^2. The first functional exploration of such 2D conjugated polymers for the efficient electrocatalytic water splitting will be demonstrated. Third, we will introduce the self-assembly of a host−guest enhanced donor − acceptor interaction, consisting of a tris(methoxynaphthyl)-substituted truxene spacer, and a naphthalene diimide substituted with N-methyl viologenyl moieties as donor and acceptor monomers, respectively, in combination with cucurbit[8]uril as host monomer toward monolayers of an unprecedented 2D supramolecular polymers at liquid-liquid interface. Finally, we will present the synthesis of 2D conducting polymers, such as polypyrrole and polyaniline with adjustable mesopores on various functional free-standing surfaces, including 2D graphene, molybdenum sulfide and titania nanosheets. The unique structure with adjustable pore sizes (5–20 nm) and thickness (35–45 nm) as well as enlarged specific surface area provides excellent specific capacitance and rate performance for supercapacitors.