Carbon Nanostructures by Design

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This is a chemistry-driven journey through the fascinating landscape of carbon nanostructures with size and dimensionality of molecules as guidelines. Two principles stand in the foreground: structural perfection even for ultralarge polymers and a powerful two-step protocol where dendritic 3D-polyphenylenes are flattened toward target 2D-graphenes. This reaction can be performed oxidatively in solution, but also thermally after deposition of the precursors on catalytically active metal surfaces.

From a functional point of view, the key breakthrough comes from unprecedented disc-type nanographenes and graphene nanoribbons (GNRs). The former include giant, but crystalline helicenes, the latter are quasi-1D-semiconductors which establish a unique generation of electronic materials. The most important features are i) the opening of an electronic band gap due to the geometric confinement, a requirement for field effect transistors, ii) the occurrence of stable high-spin systems with precise spin-spin interactions, a prerequisite for spintronics and iii) the occurence of exotic quantum states. All characteristics offer new concepts for electronic and energy storage devices, but also disruptive opportunities in complex, graphene-based electronic circuitry and quantum technology.

Equally important are 3D-polyphenylenes which are synthesized with atomic precision by way of a repetitive Diels-Alder cycloaddition. They are functional multitalents since they serve as carbon reservoirs for graphene synthesis, as efficient light-harvesting complexes, but also as carrier nanoparticles for biomedicine. DNA-transfection and disassembly of protein fibrils causing neurodegenerative diseases are fascinating applications.

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