

Carbon materials design using high-pressure toolkit

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Abstract

A rich variety of carbon-derived structural states originates not only from various hybridization motifs carbon atoms manifest, but also structural diversity of the precursors used in materials synthesis, including nanostructured molecular systems (fullerenes, nanotubes and graphene). These systems have been the focus of attention of the scientific community due to the rich assortment of outstanding chemical, optical, electrical and mechanical properties they exhibit [1]. High pressure provides a unique pathway to synthesize novel carbon-based materials that are unattainable under ambient conditions, transforming nanostructured van der Waals-bonded precursors into robust, covalently bonded networks.

In this talk, we review our recent results on the synthesis of a new class of carbon-based materials under high pressure from various precursors, including graphite nano-platelets, glassy carbon and fullerite C₆₀. These materials exhibit a remarkable combination of mechanical and electronic properties (ultra-hardness, superior wear resistance, and semiconducting behavior) [2-4]. They were characterized by multi-excitation Raman spectroscopy, SEM, XRD, high-resolution scanning TEM/EELS revealing the relationship between synthesis parameters and the resulting sp²/sp³ hybridized carbon frameworks. Application of torsion under high pressure to nano-graphite induces a phase transformation to hexagonal diamond allotrope (lonsdaleite) at ambient temperature, providing a unique alternative to the conventional high-pressure/high-temperature synthesis route [4-6]. Finally, we will discuss the potential of these materials for applications and present a viable route to the design of carbon materials with target mechanical and electronic properties.

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[3] Z. Li, et. al. Nature Materials (2023) 22:42.

[4] D. Chen, et al. Nature Materials (2025) 24: 513.

[5] L. Yang, et al. Nature (2025) 644: 370.

[6] S. Lai, et al. Nature (2026) 651: 621.