

Solution-Based Synthesis of Ultrathin Quasi-2D Amorphous Carbon for Nanoelectronics

Viet Hung Pham^{1,2}; Congjun Wang¹; Junseok Lee^{1,2}; Jennifer Weidman^{1,2}; Sittichai Natesakhawat^{1,2}; Christopher Matranga¹

¹National Energy Technology Laboratory, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA; ² NETL Support Contractor, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA

Research & Innovation Center

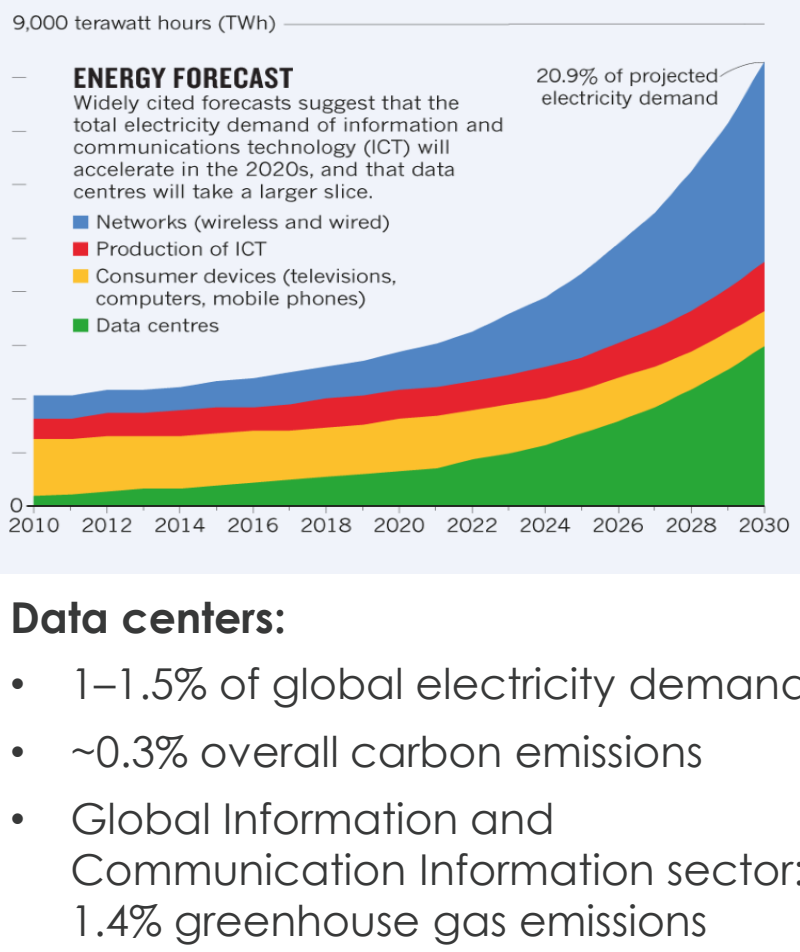
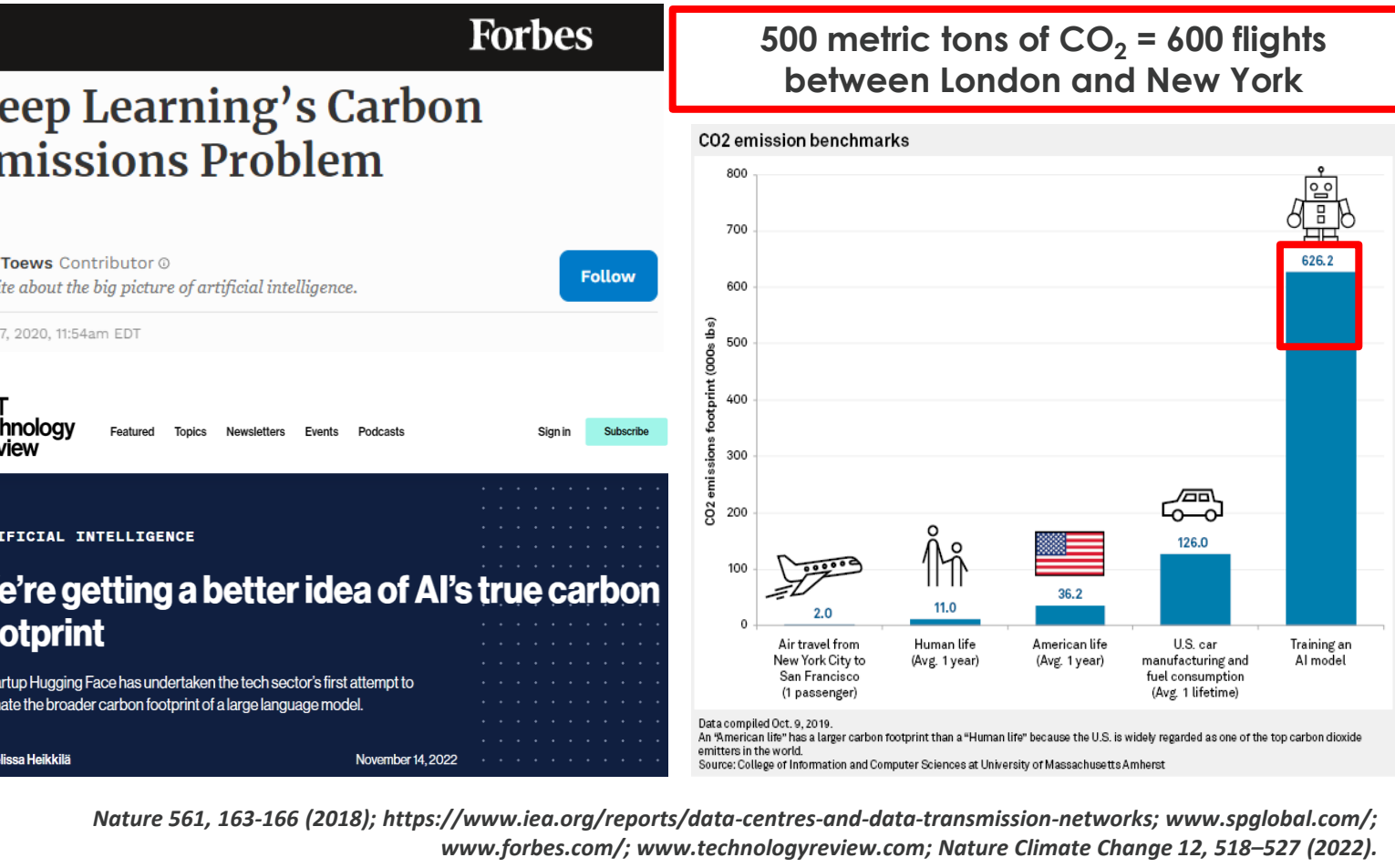


Abstract

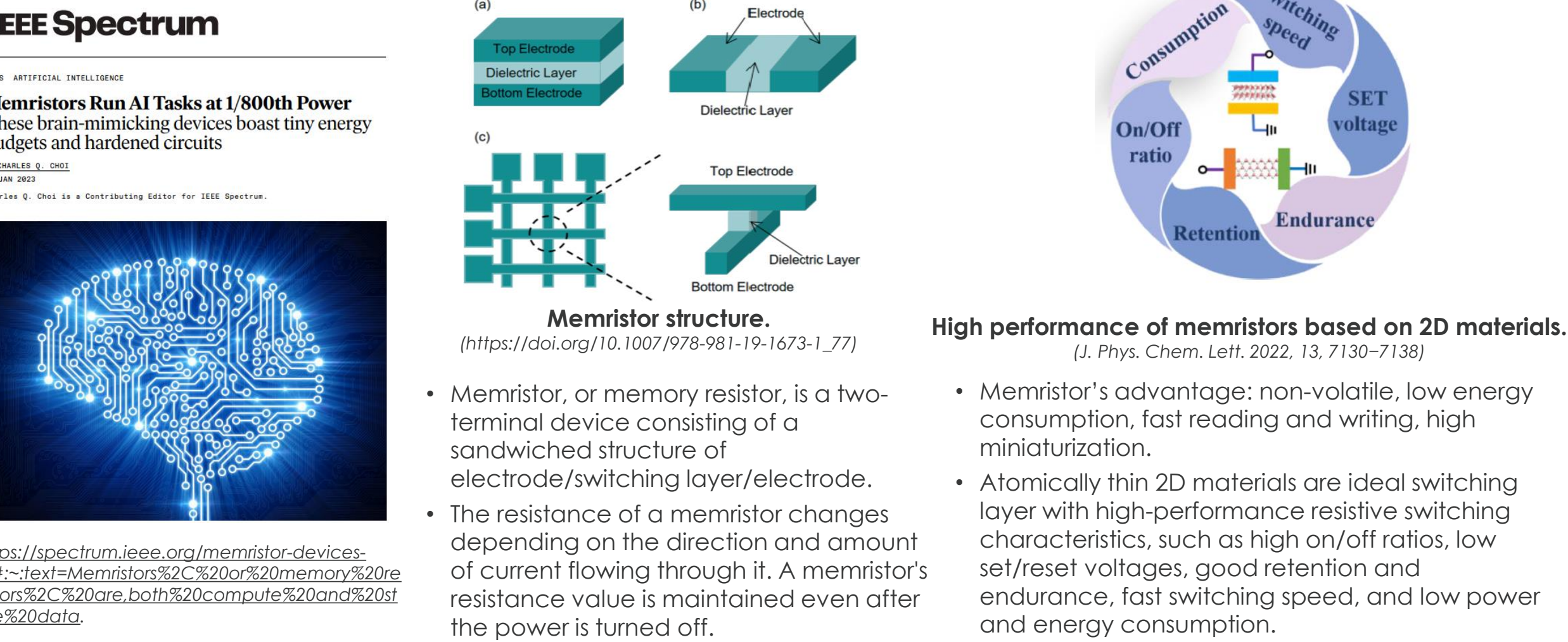
The synthesis of ultrathin 2D amorphous dielectric film represents a major challenge due to the metastable nature of amorphous phases. We describe a scalable and solution-based strategy to prepare wafer-scale 2D amorphous carbon with thickness down to 1–2 atomic layers from coal-derived carbon quantum dots as precursors. The prepared atomically thin 2D amorphous carbon can be suspended over cavities as freestanding membranes with high modulus of 400 ± 100 GPa and demonstrate robust dielectric properties with dielectric strength above 20 MV cm^{-1} and leakage current density below $10^{-4} \text{ A cm}^{-2}$ through a scaled thickness of three atomic layers. When implemented as ultrathin gate dielectrics in 2D transistors or ion-transport media in memristors, they enable exceptional device performance and spatiotemporal uniformity, resulting from their amorphous form, intrinsic ultrathinness, and 2D atomic structures.

Introduction

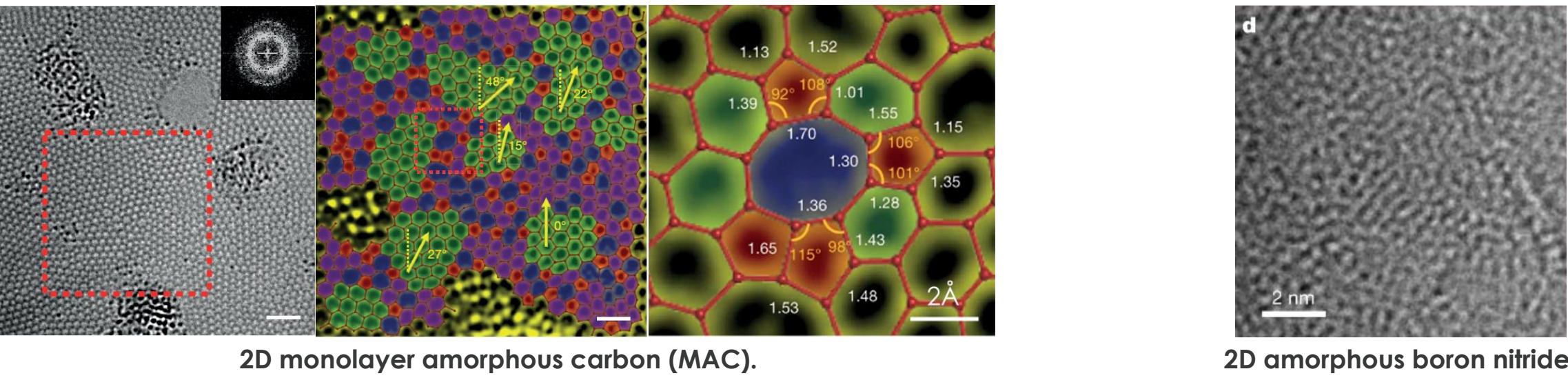
Efficient Microelectronic Devices Needed to Reduce Energy Consumption & Emissions



Memristors for Modern Computing



2D Amorphous Dielectrics as Switching Layers for Memristors

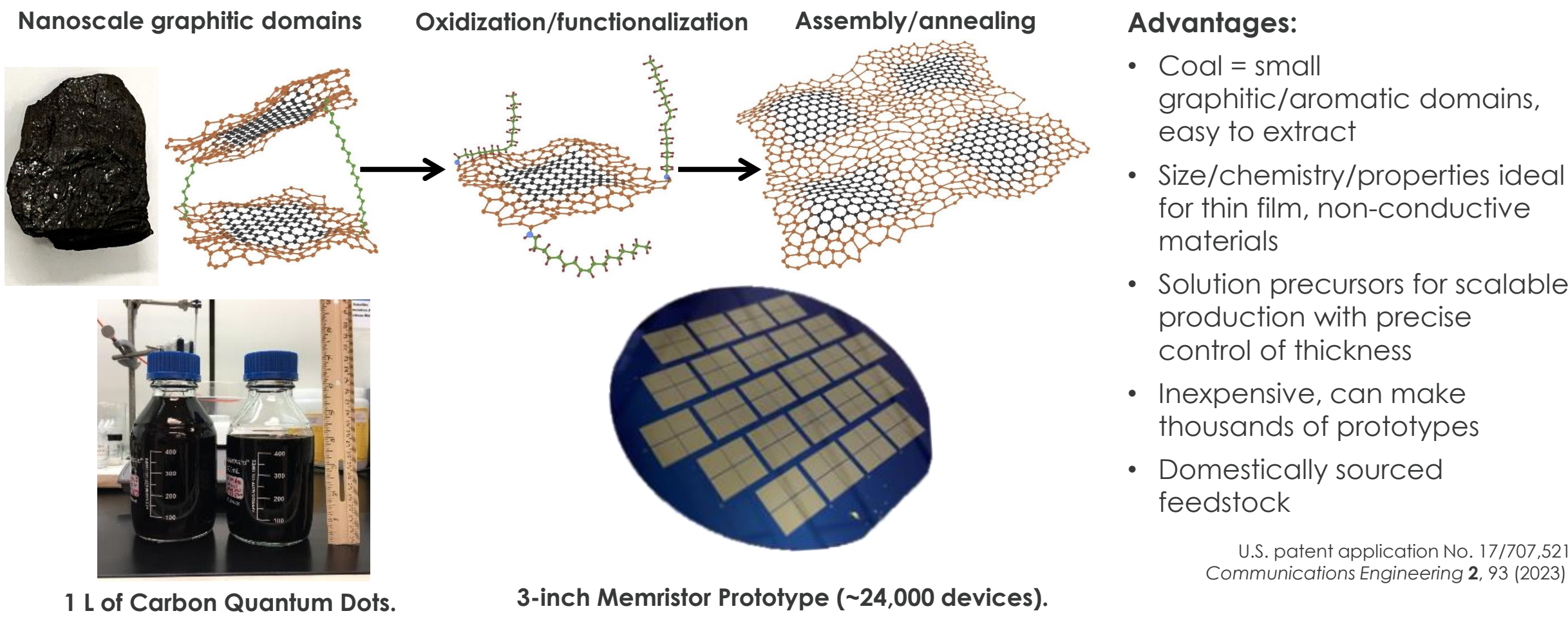


Significant limitations of existing vacuum deposition methods:

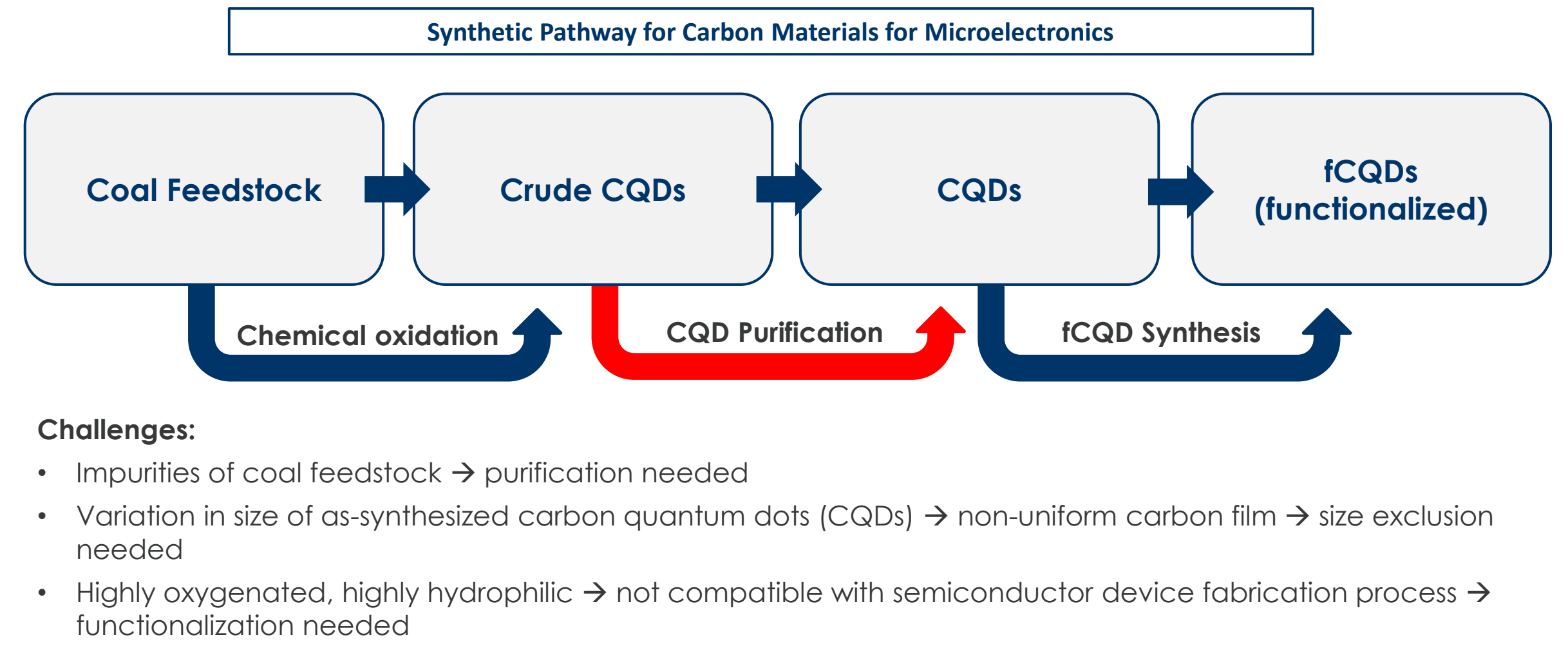
- Limited spatial uniformity and area coverage
- No precise control of film thickness, especially beyond first monolayer
- Limited demonstration for device applications

Experimental

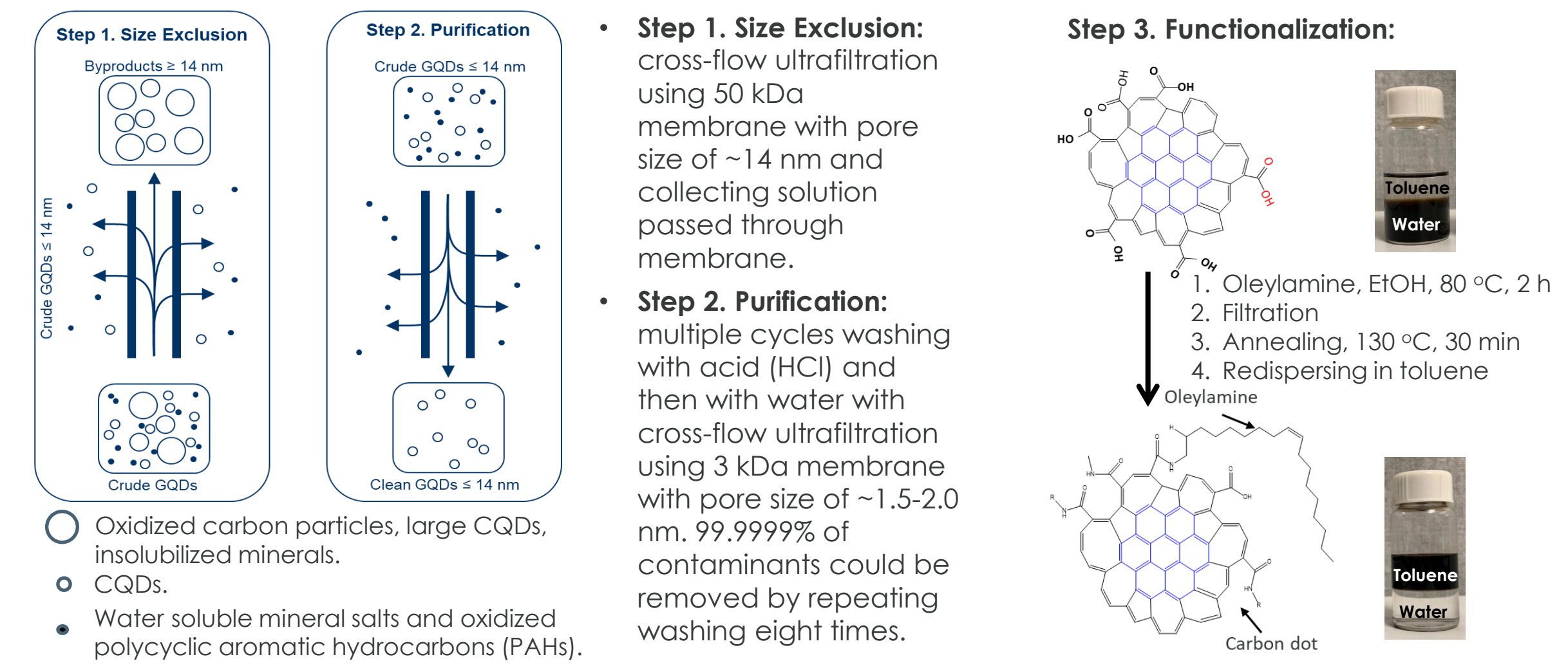
Coal as Feedstock for Low-Cost, Scalable Production of 2D Dielectrics



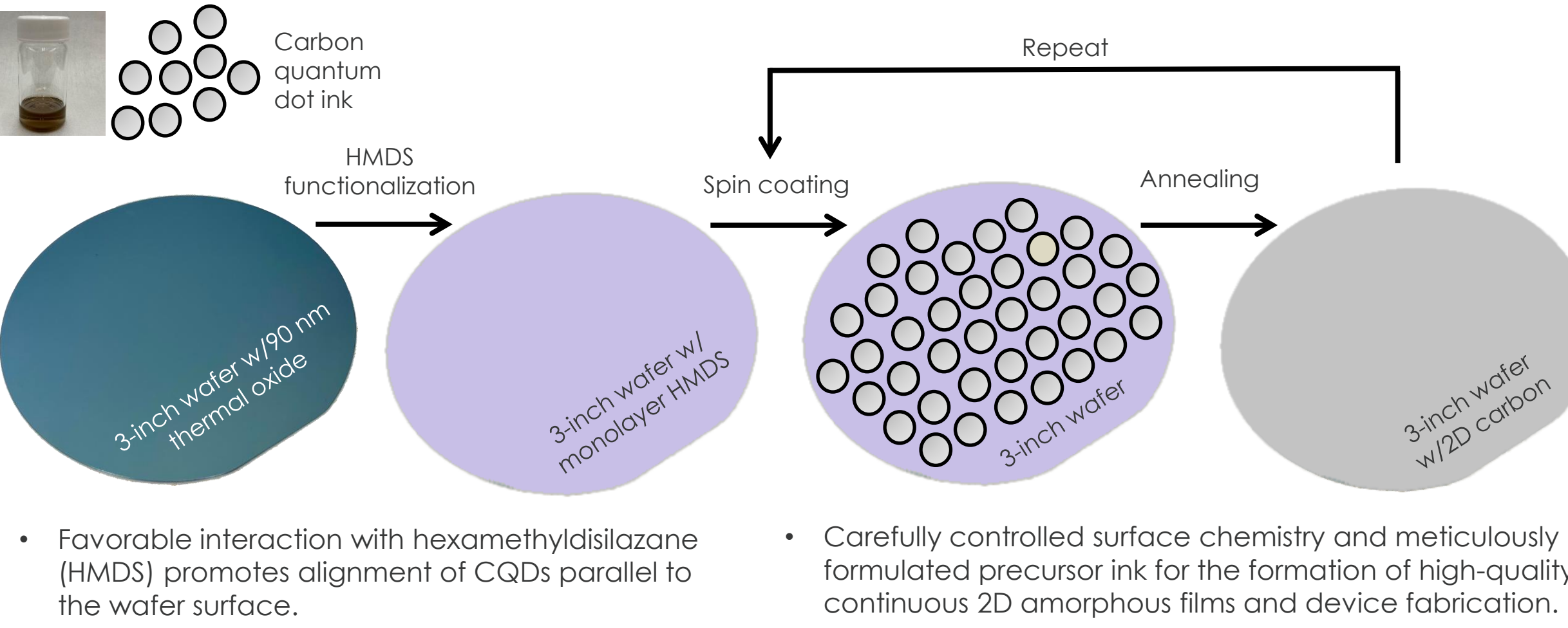
Synthesis and Functionalization of CQDs



Size Exclusion & Purification Using Cross-Flow Ultrafiltration, & Functionalization

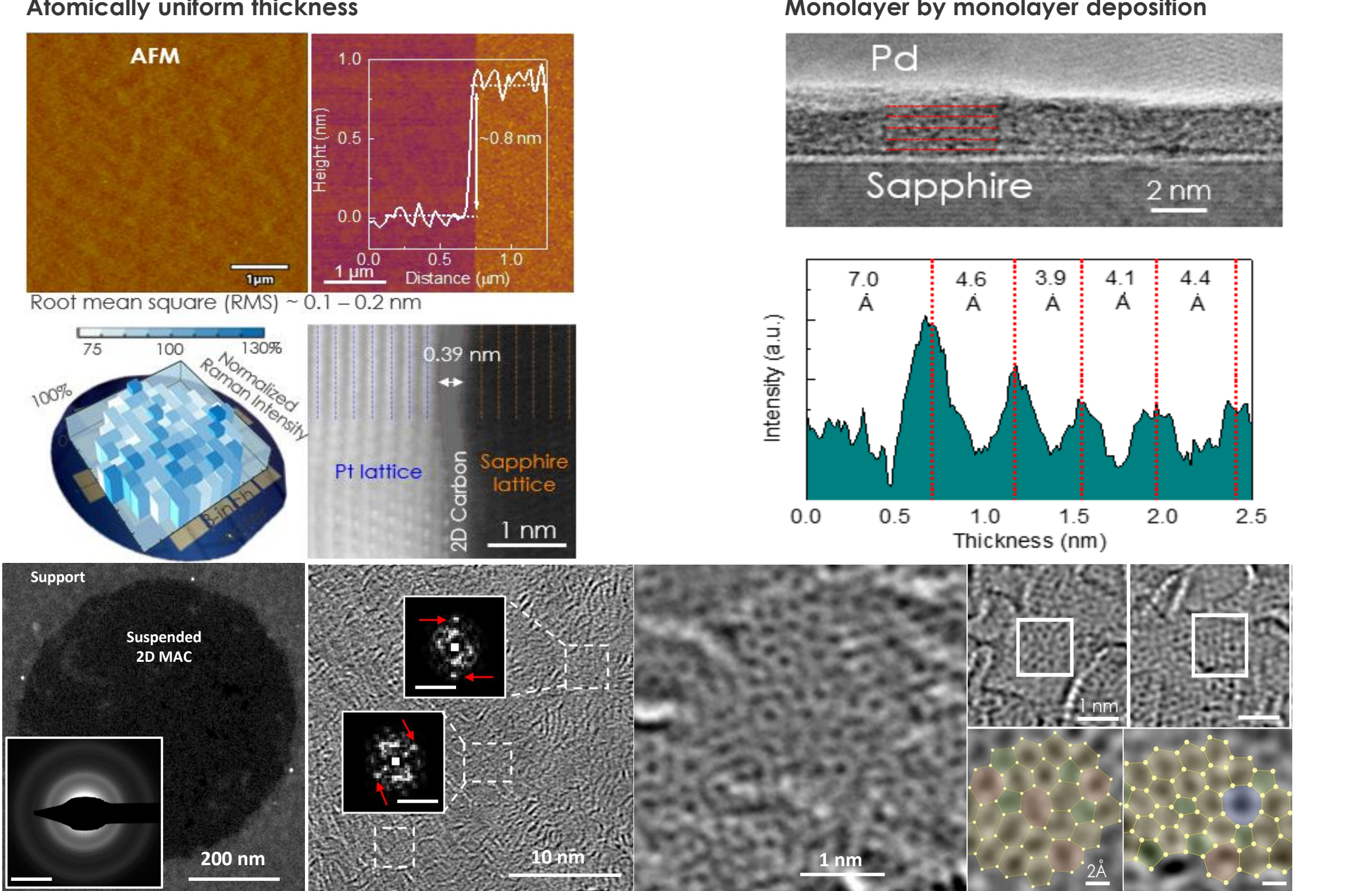


Low-Cost Fabrication of Large Area Continuous 2D Amorphous Carbon

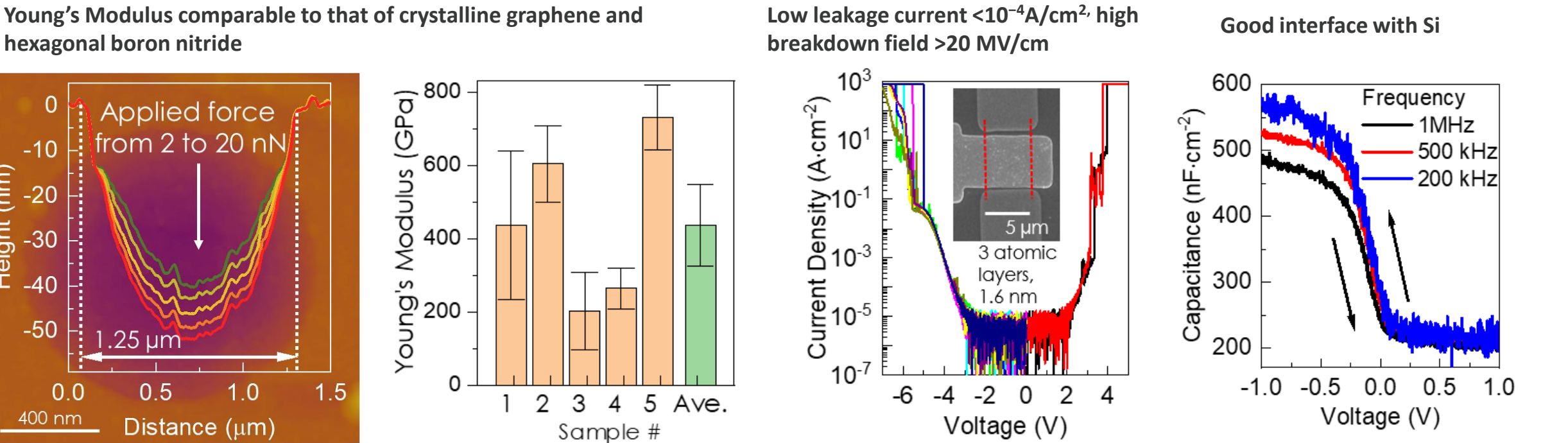


Result and Discussion

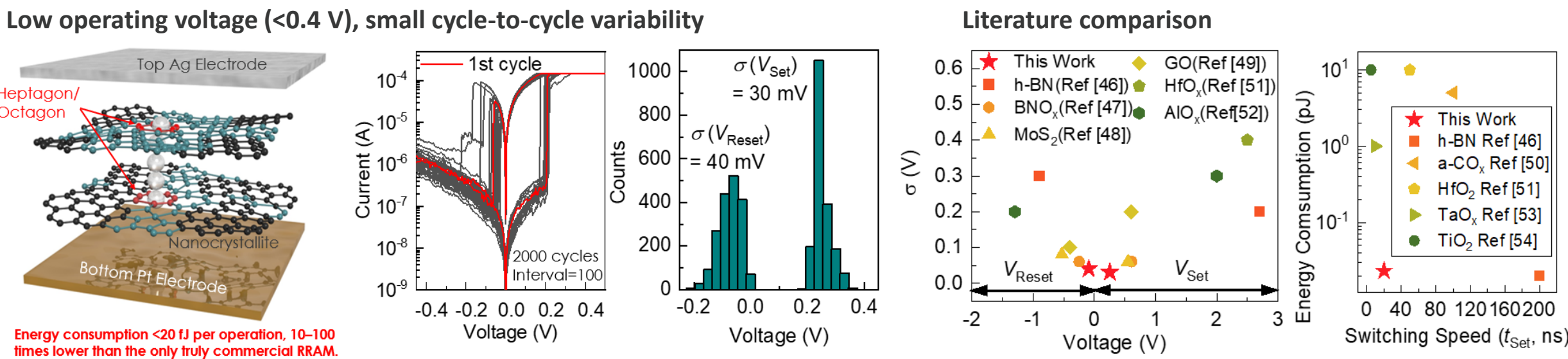
Morphology Characteristics of 2D Amorphous Carbon



Mechanical and Electrical Properties of 2D Amorphous Carbon



2D Amorphous Carbon as Switching Layer for Memristor



Summary

- Synthesis and control of surface chemistry enable the production of the ideal solution precursor for the scalable fabrication of high performance 2D amorphous carbon.
- 2D amorphous carbon exhibits extraordinary mechanical and electrical properties that can enable next generation solid state electronic devices beyond the limit of existing technology with dramatically improved performance and reduced energy consumption.
- When implemented as the switching layer in memristors, the 2D amorphous carbon enables one of the best performing memristors with ultrafast switching time, low energy consumption, robust endurance, stable data retention, and reduced device spatiotemporal variability.

Reference: Communications Engineering, 2023, 2, 93.

Disclaimer

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