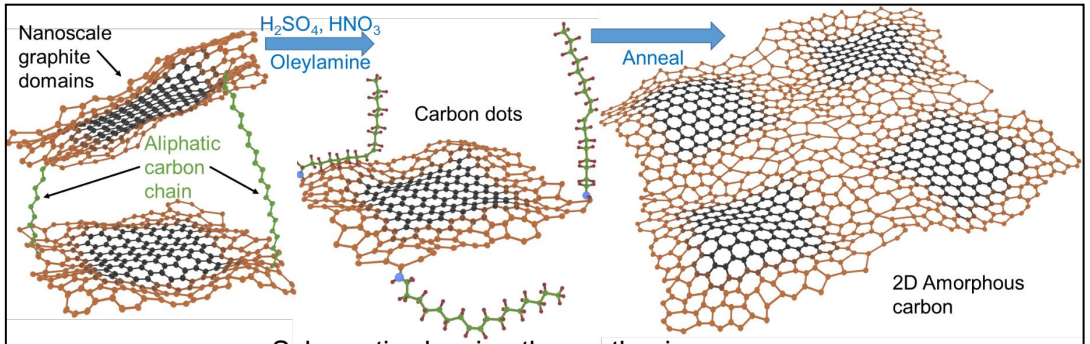
Two-Dimensional Amorphous Carbon with Tunable Atomic Structures As A Novel Dielectric Material for Advanced Electronic Applications

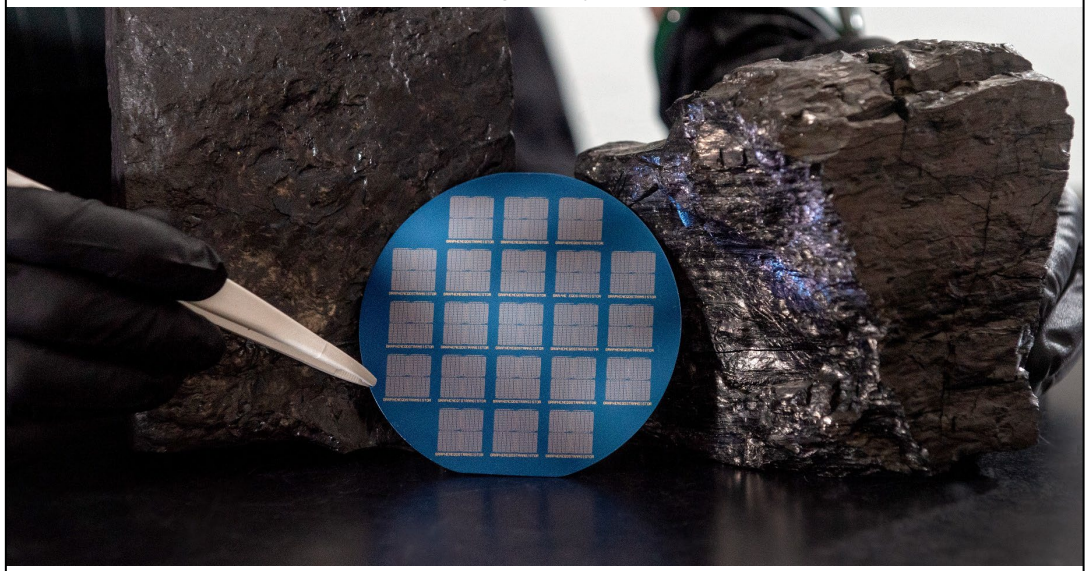
Qing Cao, University of Illinois at Urbana-Champaign

We developed a new process to create ultrathin microelectronics components from coal.

- First convert coal char into nanometer-size carbon dots.
- Such carbon dots were further connected to form atomically thin membranes, which is an excellent insulator.
- The coal-derived carbon layer is adopted as the ultrathin gate dielectric in transistors to improve device operating speed and reduce power consumption.
- It is also adopted as the switching medium in memristors, a new type of memory device for information storage and machine-learning accelerators, enabling faster writing with lower energy consumption and improved device uniformity.
- A new approach to use coal that doesn't involve burning it and releasing greenhouse gases, but rather uses it as a manufacturing feedstock for high-tech products such as computer microelectronics.
- A joint effort with DoE National Labs and Taiwan Semiconductor Manufacturing Company (TSMC).



Schematic showing the synthesis process



A 3-inch wafer with over 15,000 field effect transistors fabricated with the carbon nanomaterial derived from coal.

"Atomically Thin Amorphous Carbon Films Synthesized from Solution Precursor for Nanoelectronics," by F-F. An, C.-J. Wang, V.-H. Pham, A. Borisevich, J.-C. Qian, K.-J. Yin, S. Pidaparthy, B. Robinson, A.-S, Chou, J. Weidman, S. Natesakhawat, J. Lee, H. Wang, A. Schleife, J.-M. Zuo, C. Matranga, and Q. Cao, *Communications Engineering*, in press, 2023;

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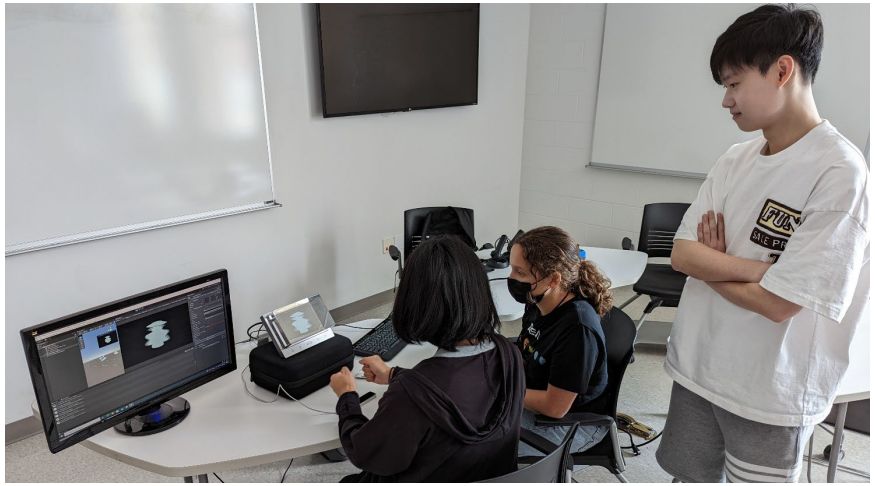
Organized workshop on "*Emergent Opportunities for Data-Driven Electron Microscopy in Materials Science*" on June 8-9, 2023 at UIUC

- More than 65 participants from Universities, National Laboratories and Industry, including students from under-represented groups.
- Brought together researchers working in the fields of instrument developments, 4D-STEM, data science, modeling
- Identified emergent opportunities and forge collaborations in this future form of electron microscopy for materials research and addressed the challenges from the unprecedent large volumes of data.

Outreach activity using HoloLens to visualize the 3D isosurface of electron densities

- Implemented in the UIUC GEMS Camp (Gender Equity in Materials Science), offered to local high school students with focus on support and empowerment of traditionally excluded populations in STEM.
- Interactive system allowing students to rotate and zoom the electron density by moving their hands in air, using a LeapMotion hand tracking device.

Group photo of invited speakers and participants attending our workshop on "Emergent Opportunities for Data-Driven Electron Microscopy in Materials Science"



Campers learning the electronic structure of molecules using the virtual reality system