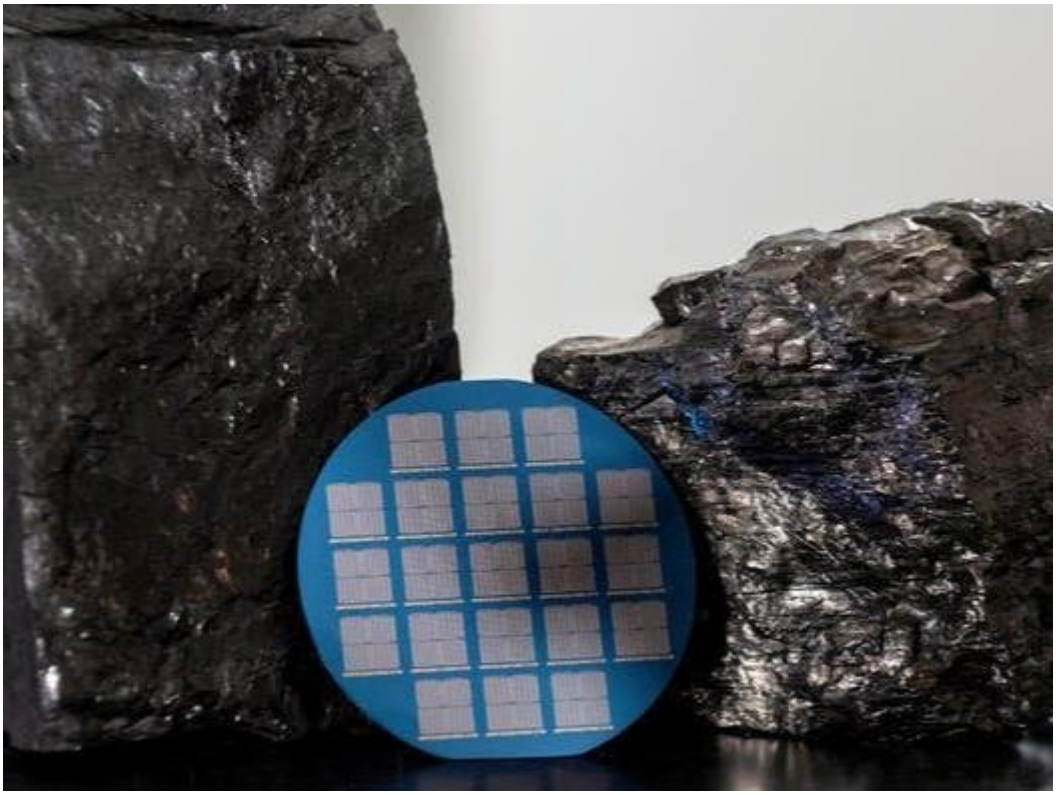
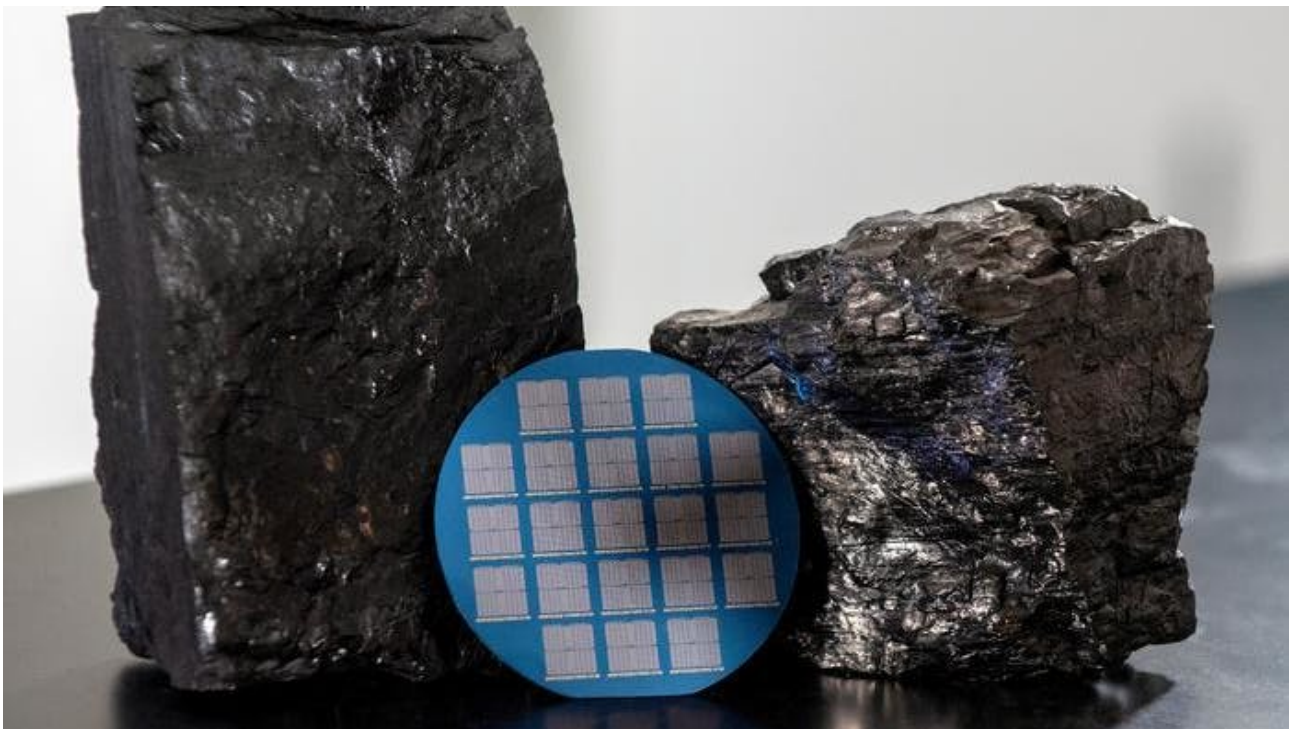
From Mines to Megahertz

Nick Bild ⋮⋮ 1/4/2024



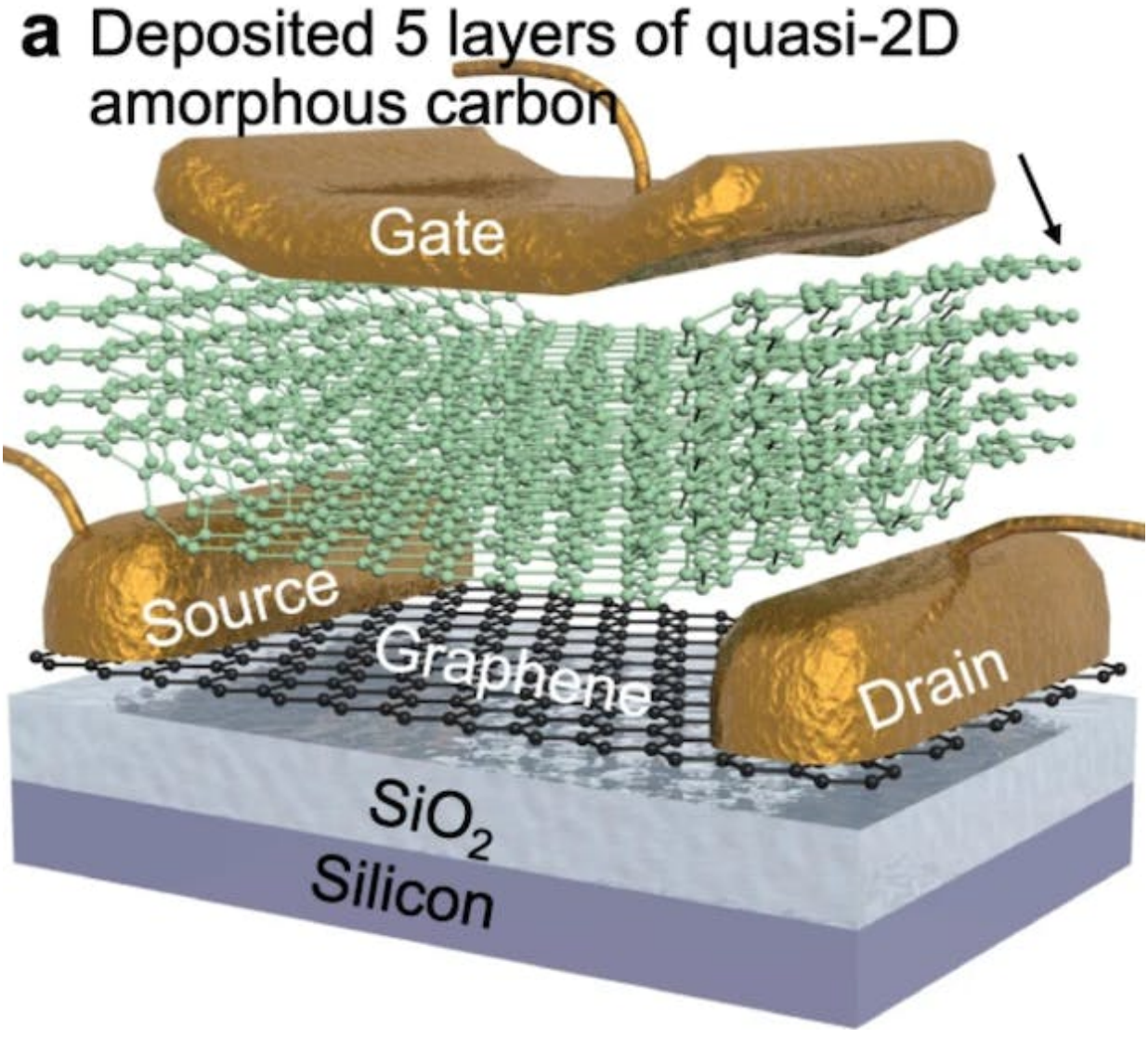


The wafer contains memristors fabricated with thin coal sheets (📷: University of Illinois Urbana-Champaign)

Globally, about 36% of electricity is still produced by coal. While this makes up a large fraction of the present electrical grid, the amount of coal used for this purpose is on the decline. Alternative and renewable sources of energy continue to replace coal as the years go by.

Because coal is often regarded as a relatively unclean source of energy, this reduction in its use is generally regarded as a positive development. However, we must be careful not to throw the baby out with the bathwater, so to speak. This abundant resource has many interesting properties that could make it useful in a number of ways as demand for its use in energy production diminishes.

In a somewhat surprising report, a team led by researchers at the University of Illinois Urbana-Champaign have shown that coal may be the ideal substance from which to produce a new generation of microelectronics components. As it turns out, coal can be processed into a form that is just a few atoms thick. In this form, it has a unique atomic structure and properties that could make it more performant than present state of the art materials in producing electronic devices.

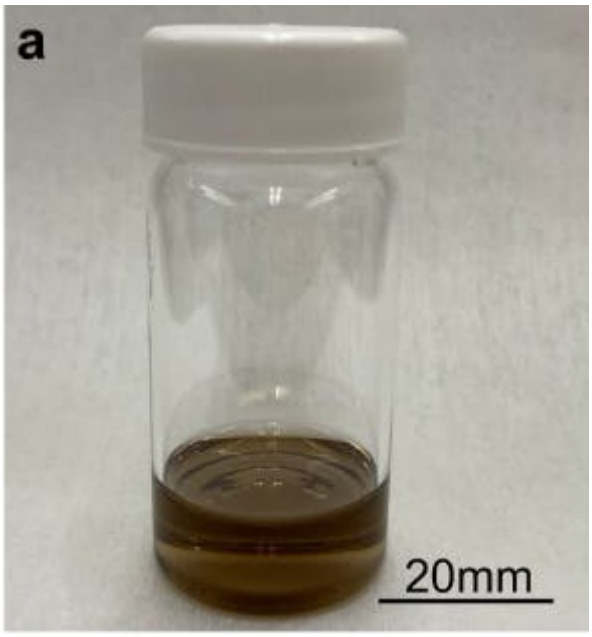


A schematic of the transistor (📷: F. An et al.)

Toward that goal, the team has developed a process that converts raw coal into what they call “carbon dots,” or nanoscale carbon disks. At just one, to a few, atoms thick, these carbon dots can be joined together into quasi-two-dimensional structures to compose components like transistors and memristors. These components are critical building blocks in designing more complex electronic devices, like computers.

In addition to serving as ultrathin semiconductors, the researchers demonstrated that coal-based carbon disks can also serve as insulators, which is essential in the development of electronic devices like transistors and memristors. By creating disordered atomic structures in the thin layers of carbon, it was shown that excellent insulation properties could be achieved.

Among the benefits of carbon dot technology should be faster operating speeds and reduced energy consumption. To test that theory, the researchers utilized their material as the gate dielectric in two-dimensional transistors. Because these nanoscale disks do not contain what are known as dangling bonds — or electrons that are not associated with a chemical bond — which under normal conditions slow down the transport of charges, these transistors were able to achieve switching speeds that are twice as fast as those found with traditional materials. Moreover, less energy was consumed by the devices.



A dispersion of carbon dots in toluene (📷: F. An et al.)

With their ability to offer memory and processing functions in a single component, memristors are getting a lot of attention lately from AI researchers. Accordingly, the team designed an insulating filament from their carbon dots that can be sandwiched between a pair of electrodes to serve as a key component in a memristor. This component was, like the transistors, found to operate using only very small amounts of energy — a critical factor in modern day AI applications. Moreover, the unique properties of the carbon sheet are well-suited to reproducible device operations and reliability.

While the team has been very successful in producing these proof of concept components, it still remains to be seen if their methods can be scaled up to produce large amounts of them in a practical manner. They intend to spend the next few years working toward refining their production process to make this possible and enable a new generation of faster, more energy-efficient electronic devices.

Nick Bild

R&D, creativity, and building the next big thing you never knew you wanted are my specialties.