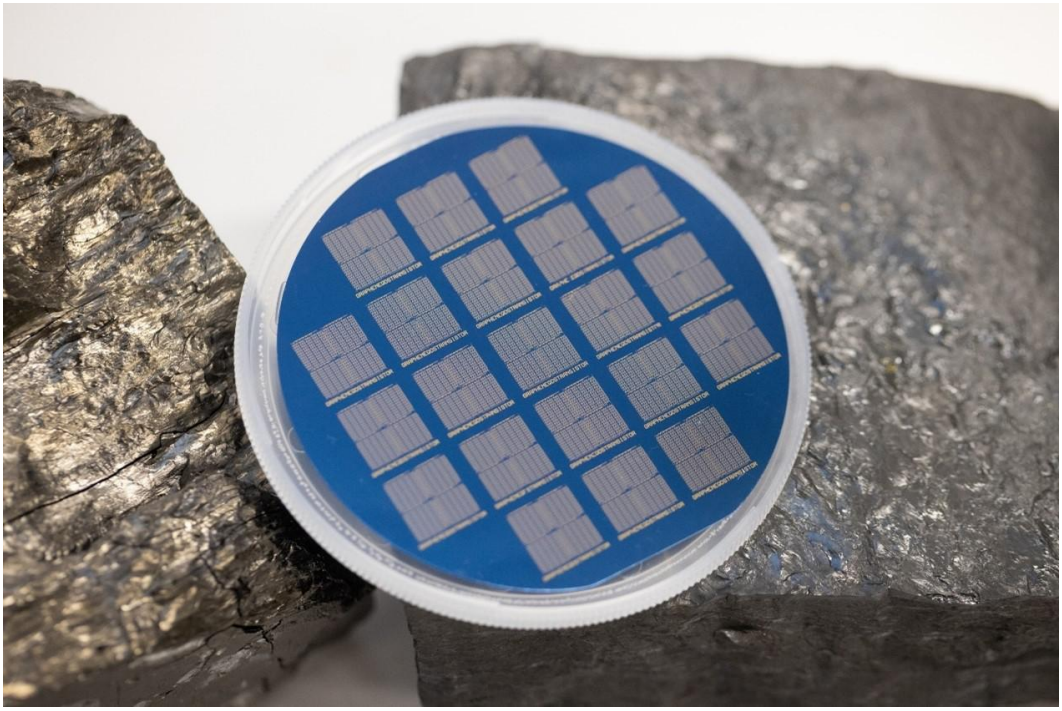
Coal-derived Carbon Material Improves Performance and Efficiency of Computer Microelectronic Devices

netl.doe.gov/node/13199



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

The modern economy is increasingly data-driven and dependent on advanced computing at a time when the traditional semiconductor materials used for computers are reaching their absolute performance limits. This gap in materials performance is pushing researchers to develop new materials for computing microelectronics with better performance characteristics and higher energy efficiency that can also ensure supply chain security and improve sustainability.

To this end, researchers at NETL, the University of Illinois at Urbana-Champaign, Oak Ridge National Laboratory and TSMC have developed ways 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.

Utilizing coal as a manufacturing feedstock creates business, economic and societal benefits for the U.S. Among the technologies created by the researchers is a thin carbon material used to reduce the size of computer devices, improve their performance, and enhance their

energy efficiency. The team used this carbon to fabricate a memory device called a “memristor” which stores data, as well as a field effect transistor which processes data in computers.

Memristor computer memory will enable machine learning and artificial intelligence by making data storage and processing devices smaller, faster, and more energy efficient. The memory devices made by the team reduce energy consumption by 5-20-fold over conventional memristors and overcome device variation issues that have plagued the field.

Transistors were invented over 75 years ago and enabled a renaissance in computing technology. The first transistor was about ½ inch in size but today billions of transistors are packed into the same space. The team’s carbon material will allow future transistors to run more than two times faster and with reduced power consumption compared to current technology.

These carbon-based devices are made with domestic coal and simple processing technologies, lowering the barrier for U.S. firms to enter this market and innovate in a manner that cannot be achieved with conventional materials and manufacturing methods.

“The unique arrangement of atoms in the carbon material is what makes these devices perform so well,” said Congjun Wang, a NETL researcher who helped develop the material. “It’s really exciting to manufacture a material with such extraordinary properties and ultrahigh purity from a feedstock that cannot be more ordinary: coal.”

“Currently, the best way to make this carbon material is by using a coal-based feedstock.” said NETL’s Christopher Matranga. “Who would have ever guessed coal could be used inside a computer?”

This groundbreaking research was featured in the journal Communications Engineering. The feature shows that the greater research community is taking notice of this technology’s potential. With patents filed last spring, the carbon material is available to outside entities through licensing and cooperative research and development agreements.

Communications Engineering is a selective open access journal from Nature Portfolio publishing high-quality research, reviews and commentary in all areas of engineering. Research papers published by the journal represent significant advances for a specialized area of research and development.

NETL is a U.S. Department of Energy national laboratory that drives innovation and delivers technological solutions for an environmentally sustainable and prosperous energy future. By leveraging its world-class talent and research facilities, NETL is ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while developing technologies to manage carbon across the full life cycle, enabling environmental sustainability for all Americans.