## Coal to Play a Vital Role in Next-Generation Electronics

SECURITIES.O

**January 11, 2024 -** Researchers and scientists around the world have been working on making smaller, faster, and more advanced electronics. This means devices made with materials that are only one or two atoms thick operate much more quickly and consume far less energy.

Towards these devices, a lot of studies have been done regarding ultrathin **semiconductors**, but now there needs to be extensive research done on atomically thin insulators in order to construct working electronic devices like transistors and memristors.

When it comes to materials, they are divided into conductors, semiconductors, and insulators based on their ability to conduct an electric current. Materials like copper, brass, steel, gold, and aluminum that easily conduct electricity due to low electrical resistivity are called conductors.

Insulators are materials such as glass, air, wood, plastic, and rubber, which do not readily conduct electricity. Meanwhile, materials like silicon (Si), germanium (Ge), and selenium (Se), as well as compounds like gallium arsenide (GaAs) and indium antimonide (InSb), have an electrical conductivity value that falls between that of a conductor and an insulator.

A semiconductor's resistance falls as its temperature rises, while the conductivity of a semiconductor rises as the temperature increases.

Insulators have a wide range of applications, including wall insulation to regulate the heat flow, furnace insulation for thermal and dielectric barriers, sound insulation to prevent disturbances, and electrical insulation in household circuitry and capacitors in commercial and consumer goods. Semiconductors are also all around us, such as tiny transistors that are in almost every gadget we use and solar cells used in solar panels to turn sunlight into electricity.

In insulators, the energy gap between valence and conduction bands is very large (about 15 eV) while in a semiconductor, this gap is very small (about 1 eV).

As per the latest study, atomically thin layers of carbon with disordered atomic structures can function as an excellent insulator for constructing 2D devices, which the team created from coal char-derived carbon dots.

Now, to show the potential of coal-derived carbon layers, the researchers used them as the gate dielectric in 2D transistors. Built on semiconductor molybdenum disulfide, the team created a device operating speed over two times faster with lower energy consumption.

These coal-derived carbon layers do not have “dangling bonds,” which are abundant on conventional 3D insulators' surfaces. By effectively functioning as “traps,” they alter 3D insulators' electrical properties, slowing down the transport of mobile charges resulting in the transistor switching speed.

However, the new coal-derived carbon layers, unlike other atomically thin materials, are amorphous, and the undesired electrical currents flow through the insulator, leading to substantial additional power consumption during device operations. Mr Qing Cao said:

> **“It's really quite exciting, because t
> the first time that coal, something w
> normally see as low-tech, has been
> directly linked to the cutting edge o
> microelectronics.”**

Yet another application demonstrated by the researchers is memristors, electronic components that can store and operate on data, significantly improving the implementation of Artificial Intelligence (AI). These devices store and represent data by modulating a conductive filament.

By using carbon layers that are ultrathin as the insulator, the researchers were able to have the fast formation of such filament with low energy consumption that enabled the device to operate at high speed with low power. Additionally, atomic size rings in these coal-

derived carbon layers trap the filament to improve the reproducible device operations for more data storage reliability.

These new devices demonstrate that coal char-derived carbon layers can be used in 2D devices. In the next step, the collaborative effort will move towards developing a “fabrication process for coal-based carbon insulators” that can be applied on a large scale.

**Back**