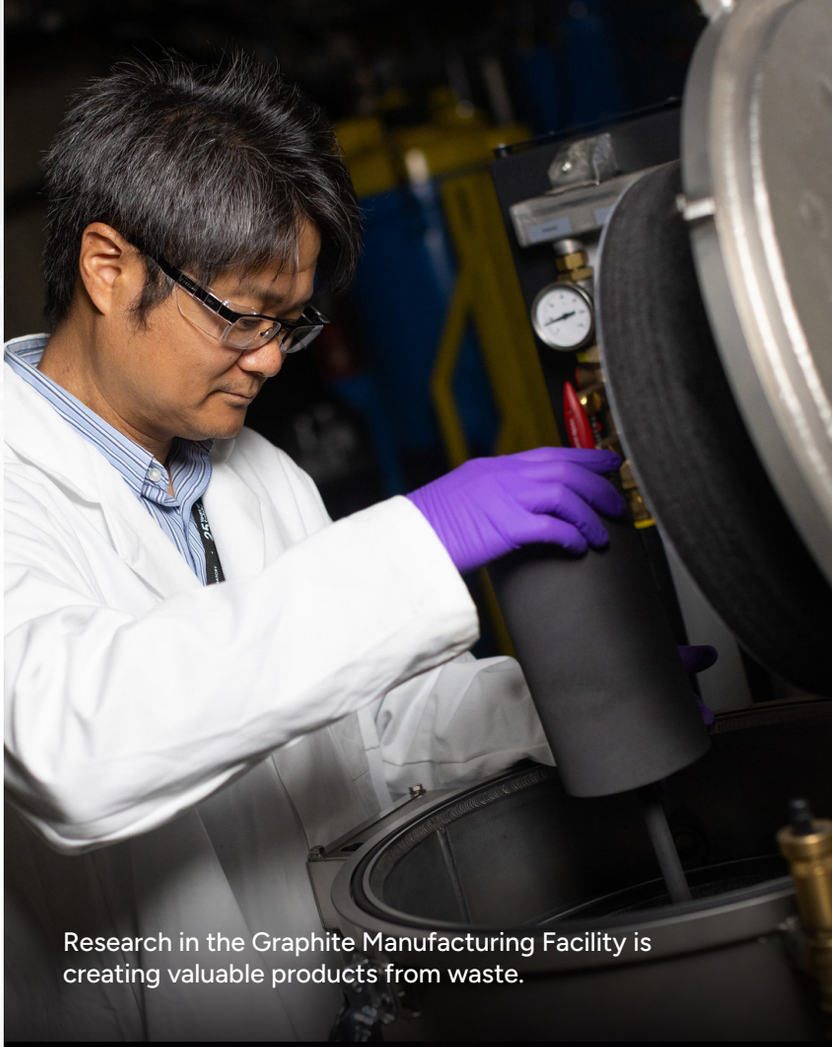
NATIONAL ENERGY TECHNOLOGY LABORATORY

Carbon Materials Manufacturing

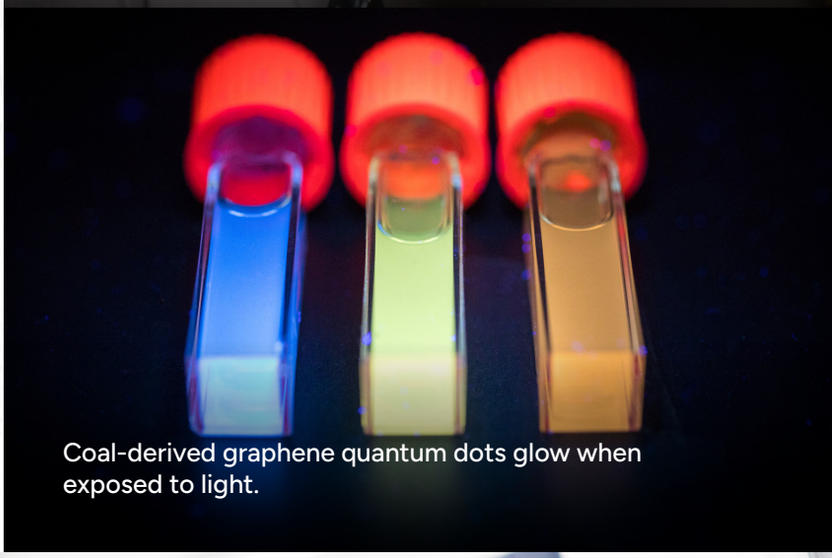
NETL develops carbon materials manufacturing technologies to transform how hydrocarbon resources are used to support U.S. energy security, manufacturing competitiveness, and supply chain resilience. Through innovations in materials science, chemistry, and process engineering, NETL is converting coal, coal refuse, sulfur-laden petroleum coke, biomass waste, and many other unconventional manufacturing feedstocks into high-value, high-tech carbon materials. These efforts enable the production of advanced products that strengthen domestic industries, enhance infrastructure, and contribute to a stronger energy economy.

R&D Applications

- High-Value Carbon Products
- Critical Minerals and Rare Earth Element Recovery
- Coal-Based Additive Manufacturing
- Coal-Derived Construction and Infrastructure Materials
- Remediation and Waste Valorization
- Hydrogen and Chemicals via Coal Gasification
- Coal and Coal Waste Processing
- Energy Storage Materials
- Structural Materials
- Graphite Manufacturing
- Carbon Microelectronics



Research in the Graphite Manufacturing Facility is creating valuable products from waste.



Coal-derived graphene quantum dots glow when exposed to light.

Computer Microelectronics from Coal

NETL is creating advanced microelectronic devices directly from coal, including memristors (memory devices) and field-effect transistors (current control devices). These coal-derived components are more energy-efficient and faster-performing than devices made with traditional semiconductor materials. NETL's ongoing research is expected to improve their performance by an additional 10% to 40% over the next several years.

Research Highlights

Thermal Synthesis of High-Quality 3D Graphene

NETL researchers have developed a simple, low-cost method of producing high-quality 3D graphene (3DG) that, when used as an electrode in supercapacitors, significantly enhances their performance. By employing simple thermal processing of coal-tar pitch or petroleum pitch, the resultant 3DG material has all of the characteristics necessary for peak performance in supercapacitors — high specific surface area, hierarchical pore distribution, and substantial electrical conductivity for electron transfer. As such, it increases specific capacitance, areal capacitance, and gravimetric energy density by 46% to 53%.

High-Quality Graphite from Coal

Researchers have developed a technology that converts every rank and type of U.S. coal into high-quality graphite for use in steel and aluminum production, batteries, rocket nozzles, and other advanced applications. Compared to conventional industrial methods, this process reduces processing temperature, time, and energy consumption by more than 40%. In the near term, NETL expects to improve efficiency and reduce costs by an additional 30% to 60%, while advancing new methods for coal-to-graphite conversion.

Supercapacitor and Hybrid Battery-Supercapacitor Energy Storage Devices from Coal

Through the development of a coal-derived carbon electrode material, NETL research has improved the performance of supercapacitors and hybrid battery-supercapacitors by 30% to 80%. This technology converts domestic coal into a high-performance material optimized for energy storage applications. These devices are essential for backup and emergency power systems in hospitals, data centers, metropolitan transit systems, and heavy equipment operations.

Cement and Concrete with Coal-Derived Additives

NETL has developed a technology for making, from coal, carbon additives that can be used in cement and concrete formulations to improve the strength of these materials by 15% to 35%. The coal additives also cause a densification of the cement and concrete, which makes these materials more resistant to weather-induced degradation. NETL's research in this area aims to increase the amount of coal used in these cement and concrete formulations to further improve strength and durability.

Publications and Patents

- An, F., Wang, C., Pham, V. H., Borisevich, A., Qian, J., Yin, K., & Cao, Q. (2023). Ultrathin quasi-2D amorphous carbon dielectric prepared from solution precursor for nanoelectronics. *Communications Engineering, 2, 9.* https://doi.org/10.1038/s44172-023-00141-9.
- Fan, S. H. I., Gray, M. L., Matranga, C., & Ji, T. (2022). *Production of Graphene-Structured Products from Coal Using Thermal Molten Salt Process*. (U.S. Patent No. 11,535,518). Washington, DC: U.S. Patent and Trademark Office.
- Gao, Y., Pham, V., Weidman, J., Kim, K., Spaulding, R., Wang, C., & Matranga, C. (2024). High-performance cementitious composites containing nanostructured carbon additives made from charred coal fines. *Scientific Reports, 14*, 8912. https://doi.org/10.1038/s41598-024-59046-y.
- Kim, K. J., Huynh, N. T., Lee, Y., Nguyen, T., Pham, V. H., Gao, Y., Li, Y., Bhandari, G., Wang, C., & Matranga, C. (2025). Highly crystalline, low-ash, graphite from coal using an Fe_2O_3-based catalytic process with recovery and reuse of catalyst and process acid. *Carbon*, 120920. https://doi.org/10.1016/j.carbon.2025.120920.
- Pham, V., Wang, C., Gao, Y., Weidman, J., Kim, K., & Matranga, C. (2024). Synthesis of microscopic 3D graphene for high-performance supercapacitors with ultra-high areal capacitance. *Small Methods, 8*, 2301426. https://doi.org/10.1002/smtd.202301426.

NETL is a U.S. Department of Energy (DOE) national laboratory dedicated to innovating and accelerating the nation's energy solutions in hydrocarbons, geothermal energy, and critical minerals production. The Lab further strengthens its impact by engaging with industry, academia, and other stakeholders through four strategically located Centers of Excellence: Coal, Critical Minerals & Advanced Alloys, Oil & Gas, and Geothermal. With research sites in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL operates as one laboratory to create advanced energy technologies that support DOE's mission and enable affordable, reliable and, secure energy to fuel human prosperity.

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