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Turbostratic Carbon Films: A Scalable Carbon Material for Advanced Energy Storage Applications

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ABSTRACT

Securing reliable and sustainable anode material supply is becoming a critical challenge for the continued scale-up of lithium-ion battery technologies. Natural graphite, which currently dominates the anode market, suffers from low conversion efficiency from mined material to battery-grade product, typically around 20%, due to extensive purification, shaping, and coating processes. Synthetic graphite provides improved purity and consistency, but its production requires graphitisation at temperatures above 2800°C, resulting in high energy demand, increased cost, and significant CO₂ emissions. These constraints, combined with the geographic concentration of production, create supply risks for rapidly expanding battery industries in regions including Australia, Japan, Europe, and the United States. Global demand for anode materials is projected to increase by approximately 25-fold by 2040.

This study introduces turbostratic carbon film (TCF) as a potential alternative carbon material platform. TCF is synthesised from coal tar pitch and forms a semi-ordered carbon structure with intrinsic electrical conductivity and mechanical flexibility. The material is produced as a continuous, self-supporting film, eliminating the need for polymer binders and conductive additives commonly used in conventional powder-based electrodes. This structural configuration enables more efficient electron transport and improved utilisation of active material.

Electrochemical performance evaluation demonstrates that TCF maintains stable capacity under high-rate charge and discharge conditions, indicating its suitability for fast-charging applications. In addition to its use as an anode material, TCF exhibits characteristics that support broader functional applications. These include electrodes for supercapacitors, conductive coatings on substrates such as ceramics, metals, and quartz, functional surface coatings including superhydrophobic layers, and catalyst or catalyst-support systems. The material also presents potential for integration into solar and photocatalytic technologies.

From a manufacturing perspective, TCF offers a scalable production pathway using readily available carbon precursors, with the potential to reduce both cost and environmental impact compared to conventional graphite processing routes. The development of such materials contributes to the diversification of battery material supply chains and supports the advancement of resilient, low-emission energy systems.

KEY WORDS

Lithium-ion batteries, Anode materials, Turbostratic carbon, Free-standing Carbon film, Binder-free electrodes, Fast charging

BIOGRAPHY

Dr Mehrdad Parsa is a materials scientist and Senior Research Fellow at the University of Melbourne, specialising in carbon materials and electrochemistry for energy storage applications. His work focuses on the development, scale-up, and commercialisation of advanced anode materials, including carbon-coated graphite and silicon-graphite composites, with an emphasis on cost reduction and emissions minimisation. He has led research within the Future Battery Industries CRC and is currently advancing turbostratic carbon film (TCF) technology under the Australia's Economic Accelerator program. His experience spans laboratory research, pilot-scale production, and industry collaboration, supporting the translation of materials innovations into commercial battery technologies.

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