**LASER ASSISTED TRANSFORMATION OF PHENOLIC AND BIOMASS PRECURSORS TO HIGH-QUALITY TURBOSTRATIC GRAPHENE-LIKE CARBONS FOR ENERGY STORAGE APPLICATIONS**

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**ABSTRACT**

Utilization of graphene-based active materials in energy storage electrochemical cells (supercapacitors, batteries) is constantly growing, despite the fact that synthesis of high-quality graphene in a consistent and environmentally friendly way is still elusive. Laser irradiation of suitable precursors is known to produce high-quality graphene materials [1], avoiding the high production costs and environmental impact and low product quality of conventional synthesis routes. In the present work, we propose a single-step method to produce high-quality turbostratic graphene-like powders from biomass (Corinthian raisins) and a phenol-based resin under ambient conditions utilizing a laser source used widely in the industrial sector (welding/marking lasers). In the first case, a representative example of carbohydrate biomass was successfully transformed to a graphene-like powder (BGRL) with one of the highest reported C/O ratios of ∼19 (in relation to similar studies) and an extremely low sheet resistance value of ∼10 Ω·sq−1 [2]. In the case of the resin precursor, instead of the high-cost kapton (Polyimide) precursor [1], an inexpensive phenol-based resin was selected for irradiation [3]. In this case, the first successful example of laser-assisted turbostratic graphene-like growth in powder form from a phenol-based resin (PGRL) was achieved. Unlike previous phenol-based laser-transformation studies [4-6], the transformation is possible without the need of the addition of a promoter compound prior to irradiation. The final product is highly conductive with sheet resistance of 40 Ohm sq-1, and has a specific surface area of 124 m2 g−1. Both of these graphene-like powders were investigated as electrode materials for supercapacitors. Testing of symmetric supercapacitor cells revealed an electrode gravimetric specific capacitance of 8-10 F g-1 and 11-16 F g-1 for BGRL and PGRL electrodes, respectively.

**KEYWORDS:** Laser-assisted grahene, turbostratic graphene, supercapacitors, biomass.

**REFERENCES**

1. Lin, J. *et al.* Laser-induced porous graphene films from commercial polymers. *Nat. Commun.* **5**, 5714 (2014).

2. Athanasiou, M. *et al.* High-quality laser-assisted biomass-based turbostratic graphene for high-performance supercapacitors. *Carbon N. Y.* **172**, 750–761 (2021).

3. Samartzis, N., Athanasiou, M., Dracopoulos, V., Yannopoulos, S. N. & Ioannides, T. Laser-assisted transformation of a phenol-based resin to high quality graphene-like powder for supercapacitor applications. *Chem. Eng. J.* 133179 (2021). doi:10.1016/j.cej.2021.133179

4. Sopronyi, M. *et al.* Direct synthesis of graphitic mesoporous carbon from green phenolic resins exposed to subsequent UV and IR laser irradiations. *Sci. Rep.* **6**, 39617 (2016).

5. Zhang, Z. *et al.* Visible light laser-induced graphene from phenolic resin: A new approach for directly writing graphene-based electrochemical devices on various substrates. *Carbon N. Y.* **127**, 287–296 (2018).

6. Hawes, G. F., Yilman, D., Noremberg, B. S. & Pope, M. A. Supercapacitors Fabricated via Laser-Induced Carbonization of Biomass-Derived Poly(furfuryl alcohol)/Graphene Oxide Composites. *ACS Appl. Nano Mater.* **2**, 6312–6324 (2019).