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Flexible, lightweight and paper-like supercapacitors assembled from nitrogen-doped multi-dimensional carbon materials

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Flexible supercapacitors have shown great potential to fulfill the increasing demand on wearable, miniature, lightweight, thin and highly efficient power supply systems for advanced portable electronics. Owing to its superior supercapacitive performances as well as high chemical stability and excellent mechanical flexibility, graphene (GR) based flexible supercapacitors have received much research attention in recent years. However, GR-based supercapacitors often suffer from GR restacking leading to capacitance attenuation. Therefore, some macromolecules, polymers and zero-dimensional/one-dimensional (0D/1D) nanomaterials have been tested as spacers to prevent GR sheets (GRSs) from restacking for constructing three-dimensional (3D) porous electrodes. Besides, heteroatom doping of GRSs could further improve their specific capacitance by introducing pseudocapacitive characteristics and increasing hydrophilicity. In this work, a facile approach is developed to prepare nitrogen-doped carbon based flexible and free-standing paper electrodes (N3CPs) built from three types of representative carbon materials in different dimensions (0D: carbon black nanoparticles (CBNPs); 1D: carbon nanotubes (CNTs); 2D: GRSs) with melamine as the nitrogen doping source. The N3CP electrode has demonstrated several advantages, such as enhanced porosity, improved electrical conductivity and high nitrogen doping level. Electrochemical tests have shown that thanks to the synergistic effects of hybrid-dimensional optimized carbon materials, 3D hierarchical porous nanostructure and effective nitrogen doping, a N3CP based flexible supercapacitor has shown the combined advantages of high capacitance, high rate capability and long cycling life (>20,000 cycles). The results hold promising prospects towards practical applications of such flexible supercapacitors in portable electronics.

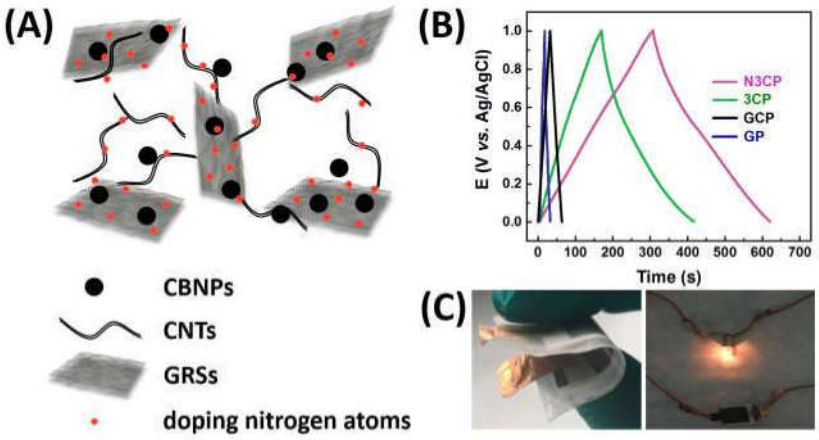

Fig.1 (A) Schematic for the heterostructure of the prepared nitrogen-doped multi-dimensional carbon materials. (B) Charge-discharge curves of different paper electrodes at 1 A·g^{-1}. (C) A lab-made N3CP based flexible supercapacitor (left) and a miniature bulb is lightened up by such a flexible supercapacitor (right). Not drown to scale.

Acknowledgments

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