Periodic Reporting for period 1 - IFR-CNS (Intumescent Flame Retardants Inspired Template-assistant Synthesis of N/P Dual-doped 3D Carbon Network for High-Performance Supercapacitors)

Reporting period: 2019-06-01 to 2020-05-31
With the development of renewable energy in recent years, supercapacitors - energy storage devices - have received global attention due to their high power density, short charging time and outstanding cycle stability. They hold great promise for future highly integrated, flexible and portable electronic systems, which are highly required by modern technological society. The limitation of the application of supercapacitors on a large scale comes from their low energy storage density and relatively high effective series resistance. Hence, it is of great importance to achieve high-performance supercapacitors via design and synthesis of novel electrode materials with rational structure and composition for meeting the requirements of ideal electrodes. Therefore, the overall objective of the project was to develop self-assembling and self-activation strategy to produce N/P dual-doped 3D carbon network by nano-CaCO3 template-assistant carbonization of intumescent flame retardants (IFRs) chosen for their interesting features such as presence of heteroatoms (N, P), tailored composition and easy carbonization to form porous char (2D carbon sheets).

Firstly, series of carbon materials have been successfully fabricated from N/P-containing IFRs as carbon precursors. In the next step of the research the obtained materials have been used on nano-CaCO3 template in order to create 3D carbon framework with desired morphology and structure. Various research methods such as transmission and scanning electron microscopy, nitrogen adsorption - desorption, X-ray photoelectron spectroscopy, etc. have been implemented in order to thoroughly characterize the received products. The characterization revealed high specific surface area of the as-prepared materials, hierarchical porous distribution with large pore volume, and heteroatoms co-doped carbon lattice. Also electrochemical properties of these carbon materials as supercapacitor electrodes have been tested. To further increase supercapacitive performance, the source of carbon has been changed to egg whites and coffee grounds to receive N/O/P co-doped 3D hierarchical porous carbon hybrids. The ultrahigh capacitance, high energy storage density and excellent cyclic stability have been achieved providing a cost-effective strategy for preparation of the multiheteroatoms co-doped carbon materials with potential application in common and flexible energy storage devices. The results of the research have been disseminated in international scientific journals with high impact factor and during scientific conferences and other international meetings.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

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Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The obtained results provide a novel, facile and efficient pathway for high-value utilization of natural biomass as well as propose its application as high-performance supercapacitors and flexible energy storage devices. The researcher plans to continue to further study the effect of template size on pore structure of carbon materials and their related electrochemical performances. Moreover, further research will also include extending this template method to synthesize porous carbon materials for other biomass systems and providing an in-depth scientific evidence/understanding on the evolution of dislocation-interface interactions ranging from micro- to nano-scales.