High capacitance composite materials obtained by carbonization of MOF-5/polyaniline composites

Igor A. Pašti[1], Marjetka Savić[2], Aleksandra Janošević Ležaić[3], Nemanja Gavrilov[1], Bojana Nedić Vasiljević[1], Jugoslav Krstić[4], Gordana Ćirić-Marjanović[1]

[1]*Faculty of Physical Chemistry, University of Belgrade, Studentski trg 12-16, 11158 Belgrade, Serbia*

[2]*Vinča Institute of Nuclear Science, University of Belgrade, National Institute of the Republic of Serbia, P.O. Box 522, 11001 Belgrade, Serbia*

[3]*Faculty of Pharmacy, University of Belgrade, Vojvode Stepe 450, P.O. Box 146, 11221 Belgrade, Serbia*

[4]*Department of Catalysis and Chemical Engineering, Institute of Chemistry, Technology and Metallurgy, University of Belgrade, Njegoševa 12, 11000 Belgrade, Serbia*

Developing high-performance capacitive materials is of utmost importance for the rapidly growing field of electrochemical supercapacitors, which can offer complementary performance to batteries where short, high-power outputs are needed [1]. This study introduces a novel approach for synthesizing electroconducting composites, namely C-(MOF-5/PANI) composites, by carbonizing MOF-5/PANI composites [2], Figure 1. These composites, namely C-MOF/ES and C-MOF/EB, were derived from precursor composites with different forms of polyaniline (PANI) and varying ratios of MOF-5 to PANI. A comprehensive characterization of these composites was conducted using a suite of analytical techniques, including scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), thermogravimetric analysis (TGA), X-ray powder diffraction (XRPD), atomic absorption spectroscopy (AAS), Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, as well as measurements of electrical conductivity, nitrogen physisorption, and cyclic voltammetry. The results revealed that the composites exhibited excellent electrical conductivity (ranging from 0.08 to 0.24 S cm^{-1}), attributed to the formation of conducting graphitic structures during the carbonization process. Notably, despite having lower specific surface areas compared to precursors, the C-MOF/ES composites demonstrated remarkably higher specific capacitance (ranging from 146.3 to 238.2 F g^{-1}) compared to the C-MOF/EB composites (ranging from 91.2 to 136.2 F g^{-1}). This behaviour was ascribed to the higher content of covalently incorporated nitrogen in the C-MOF/ES samples, which facilitated enhanced wettability and pseudocapacitance. Furthermore, the composition and properties of these composites were found to be tunable based on the precursor composition, allowing for the production of composites with tailored properties suitable for various energy storage and conversion applications. Specifically, PANI component served as a source of nitrogen heteroatoms, with its emeraldine salt (ES) form enabling the production of the zinc sulphide (ZnS) phase. On the other hand, the MOF-5 component acted as a source of zinc ions and a template for the formation of zinc oxide (ZnO) and ZnS phases, contributing to the overall specific surface area of the final composite. Further increase of specific capacitance (to ~340 F g^{-1}) was achieved by acid etching treatment of C-(MOF-5/PANI) composite. In summary, this study presents a versatile synthetic approach for fabricating binary N,O-doped carbon/ZnO and ternary N,O-doped carbon/ZnO/ZnS composites with excellent electrical conductivity, specific surface area, and specific capacitance, thereby offering promising prospects for applications in supercapacitors and other energy storage and conversion devices.

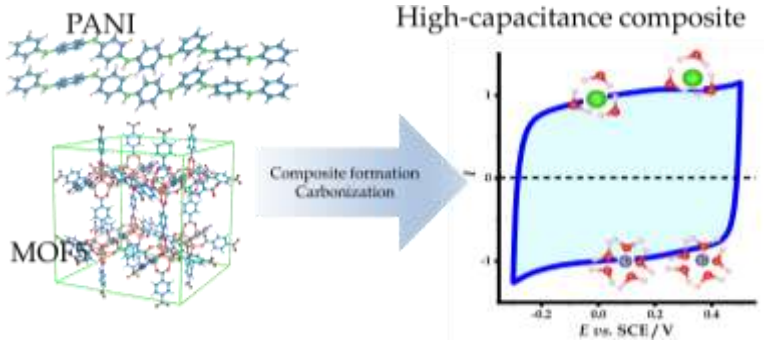

Figure 1. Composite formation between PANI and MOF5, followed by carbonization, leads to high capacitance binary and ternary carbon-based composites

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