8. Abstract

This doctoral dissertation presents the research results conducted to design and obtain new materials doped with nitrogen heteroatoms for various applications. The research focused on searching for alternative catalysts for oxygen reduction reactions and as electrodes for supercapacitors. The works included optimization of the method of synthesis of carbon materials using microwave radiation, the use of hard templates ($CaCO_3$ and Na_2CO_3), as well as the use of orthophosphoric acid (V) to increase the specific surface area and develop the porosity of carbon materials. The obtained materials were fully characterized using physicochemical techniques using methods such as nitrogen sorption analysis, Raman spectroscopy, and microscopic methods (HRTEM, SEM, AFM). The enrichment of the graphene structure was possible thanks to natural nitrogen carriers (gelatine, chitosan, green algae) and organic chemical material azodicarbonamide (ADC). To determine the percentage content of nitrogen and other elements contained in the carbon structure, elemental analysis was used, and additionally, X-ray photoelectron spectroscopy (XPS) was used to identify nitrogen functional groups enriching the graphene structure.

Obtained materials were subjected to electrochemical verification in order to determine their potential application. The obtained carbon materials doped with nitrogen were tested in the oxygen reduction reaction and used as electrodes in a supercapacitor. Electrochemical studies for the oxygen reduction reaction included cyclic (CV) and linear (LSV) voltammetry, as well as tests of the stability of carbon materials in an alkaline environment. Using electrochemical methods, the mechanism of the oxygen reduction process was determined. In addition, the influence of the presence of nitrogen functional groups on the catalytic properties of the ORR reaction was determined. Electrochemical tests of supercapacitors electrodes included cyclic voltammetry, galvanostatic charge and discharge cycles (GCD) and impedance spectroscopy (EIS) for a two electrodes system. For the obtained carbon materials, the influence of morphology, specific surface area and the presence of nitrogen functional groups on the specific capacity of the obtained materials was determined.