Abstract

The doctoral dissertation is focused on a novel nitride-based nanomaterials obtained by chemical synthesis and their physicochemical characterization. In the literature chapter, classification of metal nitrides, their properties, applications, and methods of synthesis are presented. In particular review is oriented on copper nitride (Cu_3N) properties in relation to the crystal structure. The optical, electrical, and physicochemical properties were examined in detail. The copper nitride synthesis methods including: ammonolysis reactions, solution-based reactions, and solid-state reactions are compared and discussed. Subsequently, applications of Cu_3N in, optoelectronics, energy storage, catalysis of electrochemical and organic reactions, and gas detection were reviewed.

The literature study revealed unique structural properties of copper nitride, that allow the doping of transition metal atoms into its crystal structure, resulting in alteration of structure and leading to a promising new materials for applications in optoelectronics and catalysis. The following research hypotheses were formulated: (1) the synthesis method and its experimental parameters impacted the physicochemical and morphological properties of copper nitride; (2) the modification of copper nitride structure, doped with transition metals, by chemical synthesis methods is possible; (3) doped Cu_3N can reveal better catalytic activity in electrochemical reactions, including CO_2 reduction.

The experimental part presents materials and research methods used in dissertation. Results of Cu_3N thin-film fabrication in ammonolysis reaction of oxide precursors are described. The modified method of copper nitride synthesis via reduction, using organic amines, with conventional or microwave heating was discovered. The impact of the synthesis conditions on properties of the obtained material was analysed. Subsequently, copper nitride nanostructures modified with silver(I), zinc(II), nickel(II), and palladium(II) ions were fabricated and characterized by SEM, TEM, SEM/EDX, STEM/EDX, PXRD, IR, and XPS methods. The copper nitride nanostructures properties such as: morphology, chemical composition and optical properties were discussed. In the last chapter electrocatalytic activity of selected materials, in reduction reaction of CO_2, O_2, and nitrate was analysed using CV, CA, LSV, and NMR techniques.

The most significant results of the dissertation include: (i) development of new Cu_3N chemical synthesis methods, yielding structures of various shapes (cubes, wires) and sizes (from 10 nm to several μm), (ii) the fabrication of novel multicomponent nanomaterials based on Cu_3N, (iii) discovery of Cu_3PdN electrocatalytic activity in CO_2RR. The new knowledge presented in the dissertation thesis confirms scientific significance of the conducted research in the field of inorganic, materials chemistry and nanotechnology. Application potential of the copper nitride based materials is highly probable in fabrication of nanostructures, for optoelectronic devices and in eco-friendly technologies.