ABSTRACT

Modern functional materials should have a number of properties that enable their multifaceted use in applications such as optoelectronics, biomedicine and textronics. The expected features include very good electrical conductivity, bioactive properties and photocatalytic properties. One of the unique materials are silver nanowires (AgNWs). When deposited on the substrate create a conductive and transparent network. Nanowires are an intensively studied nanomaterial that is being introduced to the production of transparent electrodes.

Since nanowires are typically thinner than 100 nm and also have a very high surface to volume ratio, instability and corrosion are becoming significant problems affecting their stability as the coating. In order to extend the time of AgNWs use, to protect them against degradation and harmful effects of external factors, it is necessary to effectively modify their surface. This can be achieved by covering the surface of AgNWs with a layer of other materials such as metals, metal oxides and polymers. Formed structure is called a core-shell type. The shell not only protects silver from degradation but also can change properties of the nanomaterial providing it with some additional functionality.

The aim of the research was to synthesize and study silver nanowires modified with tin oxides. To achieve it the specific objectives were planned like searching for factors determining the morphology of manufactured silver nanowires, developing effective methods for tin oxide shells on the surface of silver nanowires formation (SnO_2, Sn_3O_4) with controlled thickness, selection of appropriate characterization methods that can confirm the chemical structure and morphology of obtained materials and confirmation of the functionality of core-shell structures on selected examples.

In theoretical part of this thesis, a detailed analysis of the literature on the subject of silver nanowires, tin oxides (SnO_2 and Sn_3O_4) and core-shell structures especially silver@oxides has been shown. Analysis of state of the art knowledge has also indicated the current and potential areas of application of silver nanowires modified with tin oxides.

In the experimental part, research on the synthesis of AgNWs colloids via chemical reduction method in ethylene glycol has been conducted. Properly selected molar ratio of reagents and synthesis parameters gave silver nanowires with strictly defined morphology: diameter of 46 ± 2 nm, length of 8 ± 2 µm. A method of AgNWs separation from other forms of silver like nanoparticles was proposed and implemented as the colloid filtration on polycarbonate membranes under reduced pressure. An effective synthesis of colloid in larger scale up to 200 ml in one process was also optimized and carried out in laboratory conditions. The conductive properties of nanowires deposited on glass and PET film substrates were also tested, as well as corrosive effects of ammonia and hydrogen sulfide on AgNWs degradation.

The next part of the work presents research on nanostructural tin (IV) oxide and mixed (II-IV) oxide. Their synthesis and characteristics were crucial for the proper design and synthesis of silver nanowires modified with these oxides. SnO_2 was successfully prepared as a colloid of nanoparticles by

two methods: in aqueous solution at the boiling point of water and in a microwave reactor. A procedure for model metallic nanoparticles (gold and silver) of various sizes was developed to obtain core-shell structures. The influence of the SnO_2 shell on the stability of the core material has been demonstrated. The hierarchical mixed tin oxide Sn_3O_4 with a flower-like structure was also successfully synthesized by two methods.

As part of the research, core-shell structures with a metallic core of silver nanowires and an oxide shell of SnO_2 and mixed Sn_3O_4 were designed and synthesized. The presented materials are novel and have not been previously described in the literature. AgNWs coated with tin (IV) oxide completely or only partially were obtained in a controlled manner. In addition, shells of varying thickness were synthesized – from a single layer of SnO_2 crystals to several nm thick. Physicochemical characteristics and investigation of the impact of microwaves on nanosilver degradation have proved that tin (IV) oxide on the surface of nanowires protects silver against degradation. Filtrated Ag@SnO_2 nanowires deposited on glass or textiles create conductive materials. Modification of nanowires with mixed tin oxide Sn_3O_4 was also developed in a hydrothermal reactor and in an innovative manner in a microwave reactor to form the Ag@Sn_3O_4 NWs structure. Both methods ensured temperature and pressure control and high repeatability of the procedure. Studies on dye degradation under the influence of 395 nm light irradiation suggest that the obtained material has a potential for photocatalytic applications. Physicochemical characteristics of the obtained core-shell nanowires silver – tin (IV) oxide and silver – mixed tin (II-IV) oxide confirmed the effectiveness of the developed modifications including the nature and chemical composition of oxides on the silver surface and the bivalence of tin atoms in Sn_3O_4.

The author of dissertation hopes that knowledge obtained during the research proces will be helpful to future development of nanotechnology including areas such as chemistry and materials science. Synthesis methods can be characterized as an innovative approach to the subject and use of the latest laboratory preparation techniques. Silver nanowires modified with tin oxides are novel functional material with a wide application potential.