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„Wytwarzanie i badanie nanodrutów metalicznych modyfikowanych powłokami tlenkowymi i organicznymi"

Silver nanowires (AgNWs) are among the most promising one-dimensional plasmonic nanostructures, due to their high aspect ratio, anisotropic optical response, excellent electrical conductivity, and compatibility with large-area fabrication techniques.

This doctoral dissertation, titled "Fabrication and Characterization of Metallic Nanowires Modified with Oxide and Organic Coatings," addresses the issue of consciously controlling the properties of AgNWs through appropriately selected surface modification methods. The main thesis of the thesis assumes that both the plasmon resonance position and the colloidal and environmental stability of silver nanowires can be effectively regulated using controlled inorganic and organic functionalization. This approach allows for tailoring the studied nanomaterials to specific technological applications. The aim of the research was to achieve controlled tuning of the physicochemical and plasmonic properties of AgNWs by employing two complementary modification strategies: oxide coatings and organic functionalization.

The experimental section begins with the optimization of AgNWs synthesis, which forms the foundation for subsequent functionalization and application steps. The polyol method, widely recognized as an efficient technique, was used, precisely controlling the precursor concentration, reaction temperature, growth time, and polyvinylpyrrolidone (PVP) content as a factor shaping the AgNWs structure. The obtained nanowires had a high aspect ratio, diameters of 40–80 nm, and lengths of tens of micrometers. Their dispersions were stable, and their fabrication procedure was reproducible. This last feature is particularly important in applications requiring uniform, large-area conductive layers.

The first modification route involved the fabrication of core@shell structures—silver nanowires with a tin(IV) oxide layer—leading to the formation of hybrid AgNWs@SnO_2 structures. The motivation was both to protect silver from oxidative degradation, ensuring increased chemical stability, and to enable the shifting of the plasmon resonance position through controlled changes in the local dielectric environment. SnO_2 coatings were obtained by hydrolysis of stannates, and their thickness was adjusted within a range of several to several dozen nanometers. Analysis of optical properties revealed a clear relationship between the oxide layer thickness and the maximum localized surface plasmon resonance (LSPR), confirming the possibility of precise tuning of optical properties.

The resulting control over the resonance maximum was then utilized in the development of photonic anti-icing coatings. In this approach, laser light at a wavelength matched to the LSPR maximum of the hybrid nanostructures caused local plasmonic heating, resulting in rapid melting of the ice layer. The coatings deposited on the substrates demonstrated effective deicing, and additional functionalization endowed them with superhydrophobic properties, facilitating ice detachment and water runoff. This multidimensional approach—combining oxide stabilization and organic functionalization—enabled the creation of durable and multifunctional coatings.

The second line of research involved organic functionalization, achieved using sodium 2-mercaptoethane sulfonate (MESNa) and mercaptopolyethylene glycol (PEG). These molecules, bound to the silver surface via thiol–Ag interactions, provided colloidal stability, hydrophilicity, and the potential for further chemical modification. Stable, aggregation-resistant aqueous dispersions of AgNWs were obtained using FEM. Furthermore, the effective surface area of nanowires available for modification was determined for the first time, significantly contributing to our understanding of their surface chemistry. AgNWs@MES structures have potential applications in biological applications (biosensors, antimicrobial coatings, ion detection systems) and electrochemical applications (flexible electrodes, energy storage).

The presented results confirmed that surface modification is a key factor in determining the properties and applications of silver nanowires. SnO_2 coatings allow for controlled tuning of the LSPR and increase resistance to environmental degradation, and their practical importance is demonstrated in the example of photonic coatings with anti-icing properties. Organic functionalization using FEM and PEG opens up new possibilities for stabilizing aqueous colloids of silver nanowires and using the material in electronic applications. For the first time, functionalization of one-dimensional nanowires using FEM has been described, quantifying their surface area available for modification. From an application perspective, oxide-coated AgNWs are presented as active components of photonic coatings, demonstrating the utility of plasmonic heating in practical environmental applications. The combination of tunable plasmonic properties, high electrical conductivity, and compatibility with a variety of chemical modifications makes silver nanowires a versatile building block for future technologies in electronics, optics, and biomedicine. This dissertation therefore makes both fundamental and application contributions. The presented results provide a solid foundation for the further development of hybrid AgNW systems and their integration into devices where controlled surface interactions determine their ultimate functionality.