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Development of an active optical fiber with the plasmonic phenomenon

Abstract

The appropriate selection of glass-forming elements, rare earth elements, and transition metals in the proper molar concentration can lead to the thermochemical reduction of metal ions placed within the structure of the resulting glass. This makes it possible to obtain metallic nanoparticles directly during the glass synthesis. Moreover, with the right choice, high thermal stability and mechanical strength of the glass can be achieved, allowing for the creation of optical fibers when using suitable cladding material. Introducing dopants to the glass in the form of rare earth ions and noble metal ions enables the modification of luminescence through the plasmonic resonance of metallic nanoparticles.

The aim of this work is **to develop an optical fiber co-doped with lanthanide ions and noble metal nanoparticles exhibiting the plasmonic effect.**

The research work on the development of an active optical fiber utilizing the plasmonic effect has been divided into several areas of scientific and experimental research: production of optical glasses allowing doping with metal ions and lanthanides; studies on the effect of co-doping glasses with lanthanide ions and noble metal particles on structural, thermal, and spectroscopic properties; determination of the thermochemical reduction process of nanoparticles as a result of glass annealing; analysis of interaction mechanisms of nanoparticles in glasses doped with Eu3+ and Dy3+ ions; production and characterization of the optical fiber.

The completion of the above tasks influenced the definition of the main topicsaddressed in this work.

The first chapter concerns fiber optic cables. The author focused on the construction and propagation of radiation in the fiber optic structure. In addition, a characterization of the types of optical fibers was made based on their application.

The second chapter is dedicated to the spectroscopic properties of noble metals and contains subsections on the optical properties of silver nanoparticles, the influence of size and refractive index of the medium, and the effect of aggregation on optical properties.

The third chapter focuses on the fundamental phenomena of surface plasmon resonance and localized plasmon resonance. It illustrates the differences between these phenomena. The next part of the chapter is dedicated to the influence of the electric field on noble metal nanoparticles. It then introduces key mathematical models of light scattering and absorption by spherical metallic nanoparticles using Mie theory. Subsequently, we move to the analysis of nanoparticle coupling and discuss the Otto and Kretschmann configurations, ending with the Ostwald process, which describes the methodology for nanoparticle synthesis.

The fourth chapter describes energy levels and characterizes possible interactions between lanthanide ions and silver nanoparticles. Energy levels are analyzed in detail. This consideration not only provides a basic understanding but also delves into how these levels influence the behavior and properties of lanthanide ions and silver nanoparticles. Configurations of energy levels are presented, which determine the spectral characteristics of these elements and show their impact on interactions.

The fifth chapter describes the thesis and objective of the work, playing a key role in presenting the thesis and the goal of the work, thereby defining the path leading to the final research results.

The sixth chapter is a comprehensive analysis of the process of creating and evaluating core glasses doped with Ag+ and Au+ ions as well as selected lanthanide ions (Dy+, Eu+). This segment of the work consists of a series of steps that together present a complete picture of the procedure, from the selection of the chemical composition, through synthesis, and the description of thermochemical reduction. The latter part of the chapter includes descriptions of the test stations and measurement methods for studying material, structural, morphological, and optical properties.

The seventh chapter provides a discussion of the results of the research process, in which experimental data are presented, analyzed, and interpreted. It contains key elements that shed light on the essence of the studied glass

materials and their unique properties. This is a crucial part of the work, providing solid evidence to suport the formulated research thesis.

The eighth chapter describes the creation of an optical fiber doped with rare earth elements and noble metal nanoparticles, including the selection of technological parameters of the fiber drawing process and the analysis of the luminescent properties of the produced fibers.

The ninth chapter serves as a conclusion of the work, in which the main findings from the conducted analysis are presented. The chapter concludes the discussion, highlighting the key aspects of the study and emphasizing the most significant achievements, while also pointing out their implications.