Abstract of doctoral dissertation

Fabrication, optimization and application of hybrid photonic microcomponents based on 2D materials

This doctoral thesis presents the fabrication of photonic structures from a new material platform such as a sol-gel based on SiO_x:TiO_y oxides. The technological processes for producing photonic structures have been optimized to obtain the photonic microcomponents with low roughness and the best optical properties. The work presents the technology of fabrication waveguides and microlasers from the SiO_x:TiO_y sol-gel. The obtained structures are characterized by a high refractive index ($n \approx 1.80$ at a wavelength of 632.8 nm) and low roughness due to the sol-gel properties. Using the created system for the transfer of two-dimensional materials, such as monochalcogenides and dichalcogenides of transition metals, the integration of these materials with sol-gel waveguides was performed and demonstrated.

The first chapter contains an introduction to two-dimensional materials and the SiO_x:TiO_y sol-gel platform. The methods, which were used to obtain monolayers and thin flakes from van der Waals (vdW) crystals in work presented, where a special system was created for these purposes. Additionally, this chapter includes the described technologies for the characterization of thin flakes, such as Raman spectroscopy and photoluminescence.

The second chapter describes the preparation of electrical contacts for bulk VdW crystals and exfoliated thin flakes. A summary was presented containing information about the type of contact (Ohmic or Schottky) depending on the deposited metal. The obtained information will be a helpful source for further preparation of contacts for exfoliated two-dimensional materials.

Chapter three provides an overview of photonic microstructure fabrication techniques, such as optical and laser lithography, wet etching, and dry etching. In this work, photonic structures such as microdisks and planar waveguides were fabricated based on the integration of the SiO_x:TiO_y sol-gel platform with transition metal dichalcogenides. The spectroscopic measurements were performed and shown for the obtained photonic microstructures.

The fourth chapter presents experimental research that include the design and fabrication of photodetectors, where WS_2 and MoS_2 were used as active material, integrated with the obtained planar waveguides. The paper describes in detail the method of manufacturing a photodetector based on the WS_2 and MoS_2/ SiO_x:TiO_y sol-gel waveguide structure. For the electrical measurements of device, the special experimental system was created.

The first publication, included in the experimental part, contains the comprehensive research on the mechanism of degradation of materials from groups III (GaS, $GaS_{0.5}Se_{0.5}$) and IV (GeS, GeSe, SnS, SnSe) monochalcogenides in ambient conditions. The publication presents a systematic study of the mechanism of oxidation and degradation of mechanically exfoliated flakes in ambient conditions.

The second publication concerns the fabrication and characterization of a MoS_2-based photodetector on sol-gel waveguide. The obtained results from the measurements of current-voltage characteristics of the created photodetector were used for preparation a photodetector based on exfoliated WS_2 thin flakes.