Summary

The dissertation focuses on the production and study of polymer microtips formed at the end of a multimode optical fiber. The possibilities of their use for shaping the optical beam emerging from the fiber are the basis for their applications in optical technology, both as transducers of optical fiber sensors and lenses for diverging or focusing the light beam.

Initially, a technology for producing 3D microtips on the end-face of multimode optical fibers was developed. The free radical photopolymerization process employed to produce microtips, required the use of appropriately selected light sources: from UV or VIS spectrum, as well as specially selected polymers, widely used in photonics, which were an alternative to traditional functional materials. Most microtips were produced on standard multimode fibers, which, due to their larger core diameter compared to single-mode fibers (SMFs), allowed for obtaining a larger adhesion surface between the optical fiber`s end-face and the fabricated tip. The description of the technology for shaping the microtip geometry includes an analysis of the influence of technological parameters on the shape and size of these elements. The most critical factors were identified as spectral characteristics of the light source and its optical power, enabling the formation of microtips with the desired geometry.

Based on the conducted research, it was found that a microtip made at the end of a multimode optical fiber can be used as a specific transducer for a fiber optic sensor. The characteristics of such a sensor exhibited a minimum at the point where the refractive index (RI) of the surrounding material closely matched the RI of the mixture used. In the ranges above and below this minimum, the transducer has linearly proportional return losses as a function of variations in the RI of the surrounding material. The sensitivity of this transducer, determined through a linear approximation of the sensor response, was the highest for the optimized microtip geometry at he optical fiber with outer diameter 105μm fiber, for microtip manufactured using VIS LED. Within the RI range of 1.35 to 1.48, the achieved sensitivity was -186 ± 2.2 dB/RIU, with the dynamic range 33 dB.

The described RI sensor was the basis for design of a threshold sensor to detect volatile organic compounds (VOCs). Several selected VOCs were tested: trimethyl phosphate (TMP), 1,4-thioxane (THX), acetone, toluene, and a 25% aqueous ammonia solution. Condensed chemical compounds deposited on the transducer caused changes in the refractive index of its surroundings. The level of these changes turned out to be similar for all VOCs tested. Additionally, the cyclic exposure of the sensor to the selected VOCs

demonstrated its capability for repeated use with the same substance within a specific timeframe. The VOC sensor can be used in places where harmful chemical compounds occur, which are easily subject to evaporation and condensation processes.

Using a microtip to couple standard optical fibers with antiresonant optical fibers resulted in modifying the spectral characteristics of the latter. It induced additional transmission bands by exciting oscillations in the capillaries. Microtips, acting as lenses, could, depending on their size and shape, converge or diverge a beam of light and cause a change in the numerical aperture and the number of modes. Furthermore, microtips can be appropriately adapted and adjusted to obtain parameters mentioned above.

Using the proposed fiber optic elements enabled design of sensors capable of operating across a wide temperature range while offering resistance to electromagnetic interference. Other advantages include simple design and compact size, which make it possible to use them in hard-to-reach locations.

The benefits of using this type of elements and the results obtained so far are the basis for further research aimed at advancing the applications of these microelements in optical measurements and sensor technology. The discussed polymer materials and microtips, fabricated on their basis, can be successfully used in applications requiring precise control of optical beam parameters.

The most important goals to be achieved in future research will be: improving the sensitivity of the described RI sensor, increasing the number of volatile compounds detected by the threshold VOC sensor and appropriate functionalization of the transducer material, to enable the determination the type of compound and its concentration.. Additionally, various concentrations of nanomaterial based mixtures will be tested to enhance transmission in selected spectral ranges.