Since the synthesis of the first polymers, synthetic materials have been constantly improved in terms of their mechanical and functional properties, strength, and resistance to weather conditions. Today, plastics are used in most industries. Just look around you to find at least a few examples. The properties of materials, including their mechanical and thermal strength, and transparency depend on the morphology, degree of crystallization, and organization of the structure.

Research on the influence of the conditions of obtaining the material on its structure requires the use of many advanced research measurement techniques. Full information about the structure of the material at the molecular level requires tracking chemical and structural changes simultaneously. Both types of information are provided by FT-IR microscopy using linearly polarized light in the mid-infrared range. If the material has a strongly oriented structure, as is the case with partially crystalline polymers (poly(lactic acid), polycaprolactone), the use of polarized infrared light provides new information about the structure of the sample. The four-polarization method (4P-2D) has been proposed, which enabled the study of the organization of macromolecules in complex biological systems. The application of IR imaging with 4P on heterogeneous structures, human tissue microarrays, was presented for the first time by our team in 2020[1]. The next level of difficulty is determining the orientation of molecules in three-dimensional space. The modified 4P-3D method using two bands of roughly perpendicular transition moment orientations was applied for the first time in practice in 2021, again by the Polish team to visualize the arrangement of polymer chains in spherulite, the basic crystalline form of polymers[2]. Thus, it was possible to obtain both chemical information and three-dimensional visualization of the structure. The project aims to implement the 4P-3D method to track changes in the molecular structure occurring during crystallization. This will allow the creation of a completely new tool providing an extremely wide range of information at the same time. One of the limitations of classical FT-IR microscopy is the low spatial resolution that does not allow the visualization of structural elements with dimensions smaller than a few micrometers, which limits its usefulness in the study of hierarchical structures and nanomaterials.

For years, work has been done on techniques that use infrared radiation to collect chemical information about nanometric objects. One such method is O-PTIR infrared microscopy. The technique allows the detection of IR radiation obtained as a result of the laser-induced local photothermal expansion of the sample. Spatial resolution reaches about 400 nm. The systems have already been successfully used to study single cells[3,4] and nanomaterials[5]. Another goal of our project is the improvement 4P-3D method for O-PTIR microscopy.

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