Forum Inżynierii Materiałowej

Materials Engineering Forum

➢ The Materials Engineering and Metallurgy Committee of the Polish Academy of Sciences
➢ Polish Materials Science Society

Determining the structure-property relationships using AFM techniques: from fossil-derived to sustainable polymers

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Polymers are materials without which today's world cannot function. The majority of them are derived from petroleum-based materials because these resources are the primary source of the carbon and hydrogen necessary for their synthesis. However, these resources are finite, and their use in polymer production is associated with, among other things, greenhouse gas emissions. The physical durability and chemical resistance of polymers are their strengths, but they also pose challenges in terms of recycling and degradation. This, in turn, leads to environmental pollution, including microplastics. These factors drive ongoing research aimed at synthesizing polymers based on renewable resources, such as plants, and those that undergo accelerated biodegradation.

The macromolecular structure of polymers consists of long chains or networks of repeating monomeric units, giving rise to a wide range of materials with diverse properties. Understanding the connection between structure and properties is crucial for a comprehensive grasp of polymers. Studying the relationships between structure and properties in polymers enables the precise design and optimization of polymer materials for various applications, ensuring they meet specific performance and safety requirements while promoting sustainability and reducing environmental impacts. This relationship is especially significant at nanometre to micrometre scales. Fortunately, Atomic Force Microscopy (AFM) is the ideal tool for examining this relationship at these scales.

During this lecture, I will present selected research results for both 'traditional' synthetic polymers like polyurethanes, polyureas, and polysiloxanes, as well as polymers of renewable origin, such as lignin or plant oils, and their modifications. I will primarily focus on the heterogeneous nature of these materials, including phase separation, filler dispersion, and physicochemical differences in layers of 3D printed samples. For most of the findings presented, AFM will be the primary tool for gaining insights into the relationship between polymer structure and properties.

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Self-lubricating surface layers and composite materials produced by laser alloying and powder metallurgy

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The search for new materials with unique properties, including tribological properties, is very important from the point of view of practical and economic applications. Tribological wear is one of the most common causes of material wear, leading to damage to machine parts or tools. It is estimated to be responsible for 80% of their breakdowns. Approximately 30% of energy is used to overcome frictional resistance. Annual economic losses due to frictional wear account for almost 2% of national GDP. Therefore, studies on friction and the search for new materials, including lubricating oils, greases, and solid lubricants, are a topical issue of important social and economic benefits. With developing industry and modern production technologies, requirements for wear resistance in demanding operating conditions, such as high speeds, high loads, high vacuum, radiation, and operating temperature range, are increased. This means a need to search for new materials, and modification of their surfaces by appropriate treatments. Conducting effective lubrication of the contact surfaces of moving parts is an effective method to counteract friction and reduce their wear. Lubrication oils, plastic greases, and solid lubricants can be distinguished. The lubricating oils, used on a large scale, pollute the environment during their production and, practically, at all the stages of their use: during transport to users, long storage, during work, as well as collection and disposal at the end of the service life. Oils and plastic greases can pose a serious problem in some applications, for example, at high temperatures, when they may evaporate. In addition, they cannot be used for a long time in a high vacuum greater than 10–1 Pa. The solution may be to use solid lubricants. The production of wear-resistant self-lubricating surface layers containing solid lubricants can be one of the most effective and economical methods to increase the durability of machine parts and tools. During the presentation, the results of research on self-lubricating layers produced by laser alloying and self-lubricating materials produced by powder metallurgy will be presented. Wear mechanisms in dry friction conditions of materials containing solid lubricants in their structure will also be presented.

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