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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.