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Forensic Engineering of Advanced Polymeric Materials

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EDITORIAL

Polymers are everywhere, also inside of the human body. Why polymers are so important?

The most general answer is: because they are solid. With the term “polymer” we describe long chains consisted with repetitive structure, and longer chains tend to be solid. Classical forensic polymer engineering concerns a study of failure in solid polymer products. This area of science comprises fracture of plastic products, or any other reason why such a product fails in service, or fails to meet its specification. Environmental stress cracking (ESC) is one of the most common causes of unexpected brittle failure of thermoplastic (especially amorphous) polymers. The rate of ESC is dependent on many factors, including, for example, the polymer’s chemical composition, bonding, crystallinity, surface roughness, molar mass and residual stress. It also depends on the chemical nature of liquid media and the temperature of the system.

The most familiar synthetic polymers include nylon, polyethylene, polyvinyl chloride, polytetrafluoroethylene and polyesters, whereas proteins, nucleic acids, cellulose, starch, glycogen, silk, wool and aliphatic biopoliesters (PHA) are the polymers occurring in nature.

So far, most of the reported forensic polymer engineering case studies concern ex-post investigations of traditional polymeric materials or their thermoplastic composites. (Bio)polyesters are recently of particular importance due to their biodegradation opportunity and potential medical applications. When the development of biodegradable polymers was in its infancy the most crucial features were concentrated on the effect of macromolecular architecture, new monomer systems, polymerization mechanisms, and different polymerization techniques on the final biodegradable properties. Significant eforts have been directed towards specific areas, such as mechanisms of biodegradation, biocompatibility, processing conditions and potential applications in medicine, protection of environment and agro chemistry. However, such aspects like bio-safety of such advanced polymers or nano-safety of their composites were and still are frequently neglected.

The knowledge and impetus for development of forthcoming advanced polymeric materials comes from identification of problems before they arise. This novel viewpoint focuses on prediction, evaluation and indication on potential complications arising from the use of advanced polymers. Associations between polymeric materials’ structures, properties and behaviors before, during and after practical applications can be evaluated by the use of the methodology developed by Forensic Engineering of Advanced Polymeric Materials (FEAPM). Optimization and characterization of the polymers’ properties are very important for their production, usage and utilization. The connecting of all these elements in the FEAPM methodology constitutes the novelty of this approach. This should help to project new advanced polymeric materials, avoiding the product defects generated during production and usage.

In the FEAPM studies, testing advanced polymers in simulated environments is needed before they are rolled out. Due to the wide spectrum of their potential applications, e.g., in medicine, electronic devices, in the field of compostable polymer packages (especially of long-shelf life products such as cosmetics or household chemicals) as well as in agrichemical formulations, the FEAPM can provide basic knowledge and a valuable service by increasing understanding and helping prevent future problems. However, for polymer evaluation at the molecular level the dedicated analytical technique is needed. It opens up wide opportunities for polymer mass spectrometry.

Polymer scientists have been unfamiliar with the advances made in the field of modern mass spectrometry for a long time. Today mass spectrometry complements in many ways the structural data provided by NMR, IR and other polymer characterization methodologies. Development of soft ionization techniques in mass spectrometry have helped to solve the difficult question regarding the molecular structure of (co) polymerse. Taking part in the "Electrospray Revolution" we have concentrated on using polymer electrospray ionization multistage mass spectrometry (ESI-MS^n) for forensic engineering of advanced polymer materials. ESI-MS^n was successfully applied for example in the prediction study dedicated to evaluation of the effect of the solvent-free non-woven fabrics formation method on the release rate of lactic and glycolic acids from the tin-free poly (lactide-coglycolide), PLGA, nonwovens. The results of the ESI-MS^n sequencing of the PLGA samples remaining after hydrolytic degradation indicated that the hydrolysis of ester bonds reduces the degree of ordering of the macromolecules of the PLGA copolymer. Thus, ex-ante investigations as well as ex-post studies are needed in the area of FEAPM in order to define and minimize the potential failure of novel advanced polymer products before and after specific applications.

It may be expected that the economic and societal impact of FEAMP studies will be of great significance and enable to recognize safe advanced polymers in a forthcoming sustainable society.