Characterizing thin extrusion-coated polymer films through combined in-situ tensile testing and X-ray scattering

Tetra Pak® is one of the world's leading companies in the food packaging sector. Thin films of polyethylene are a key component of this packaging technology. Tetra Pak ® came to PETRA III at DESY to study the morphology of their polyethylene (PE) films using high-brilliance synchrotron X-rays. Synchrotron radiation sources offer much higher brightness compared with lab-based X-ray sources. This allows the dynamics of thin polyethylene films to be studied.

CHALLENGE

Thin films of PE used as packaging materials are produced by extrusion coating lines, in which molten PE is pressed through a forming die at high flow speeds, high pressures and high temperatures and afterwards quickly cooled. Due to the quick cooling, the polymer molecules do not have the time to arrange themselves in the energetical favored equilibrium structure. In fact, the structures formed are far from being at equilibrium and it is impossible to predict the resulting structures. For companies like Tetra Pak® this also means they cannot predict the mechanical properties of the PE films. Understanding the structure of these thin films which undergo mechanical deformation, e.g. during the production process, would help improve the quality of packaging products. A suitable method for characterizing the structures is small-angle scattering (SAXS). However, lab-based SAXS is not suitable for observing the unknown structures as it lacks the scattering intensities needed for such thin films.

METHOD

Tetra Pak® and the Niels Bohr Institute, Copenhagen/Denmark, teamed up to characterize PE thin films using SAXS measurements at PETRA III on the P03 beamline in combination with time resolved in-situ tensile stress testing (TST). The Research Institutes of Sweden (RISE) helped with the planning of the experiments. During TST, the films are extended and the applied force is measured and compared with the elongation of the film, allowing mechanical material properties such as Young's modulus to be determined.

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INSIGHTS & ANALYSIS

The high flux of PETRA III synchrotron X-rays allowed information about the thin film structure during the TST to be gathered with a time resolution of 1s. Stretching and relaxation processes observed in real time could be compared with the polymer structure deduced from the SAXS data, thanks to its sufficiently high intensity. As mentioned above, PE thin films experience such deformation during the production process, linking the findings to real-world applications and problems.

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BENEFITS

The combination of SAXS measurements and TST in real time was vastly improved by the use of synchrotron radiation. As a consequence, changes in the polymer morphology and in the mechanical properties could be connected, giving Tetra Pak® new insights into an integral part of their packaging products and the extrusion coating process. Also, Tetra Pak® learned about the opportunities that synchrotron facilities like PETRA III can offer companies and how important synchrotron characterization methods will be in developing and optimizing any polymer product, especially in the context of a sustainable future. The team of Tetra Pak®, NBI and RISE acknowledged that the next generation of synchrotrons, like PETRA IV, will have an even better potential for solving

> “The methodology developed allows us to characterize and compare the morphology, structure and material orientation of thin extrusion coated polymer films after manufacturing and during mechanical deformation.”
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> Anna Svensson, Tetra Pak

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