Haute école d'ingénierie et d'architecture Fribourg
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POLYAGE & POLYLIFE Projects

Lifetime prediction of polymers by physical and chemical characterization of their degradation and simulation of their ageing

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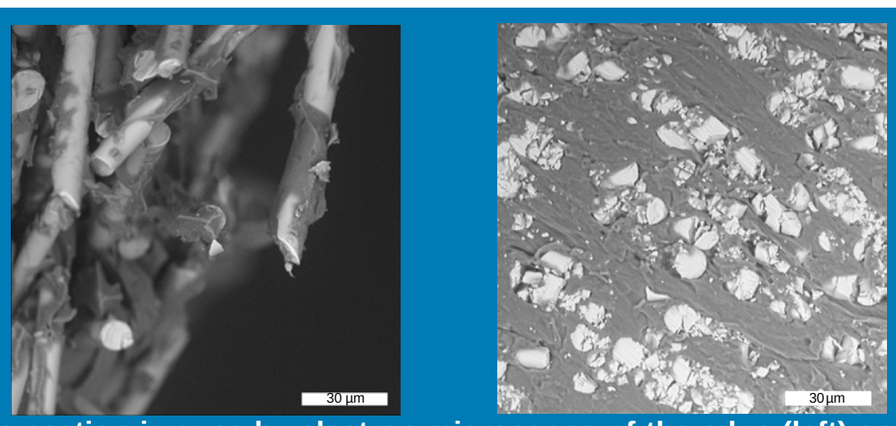
Context

For 2013 only, the European demand concerning plastics was up to **46.3 million tons** all areas included, the main demand coming from the **packaging, construction** and **car industries**. In practice, polymers are exposed to temperature variations, light radiation or chemical products which leads to faster ageing, a complex process that affects the predicted lifetime of the final product and that is mostly not know.

The POLYAGE and POLYLIFE projects, carried out in collaboration with 4 industries from Fribourg (Geberit, Jesa, Johnson Electric and Wago), study the **thermal and chemical ageing** of polymers used by our partners, in order to predict a realistic lifetime.

PlasticsEurope



Cross-section images by electron microscope of the edge (left) and the center (right) of a PPA sample reinforced with glass fibres after an ageing of 1000 hours at 240°C. These images shows that on the edge of the sample the PPA matrix has been degraded, as opposed to the center of the sample.

Results

In cooperation with 4 industrial partners, a list of 6 polymers was established with in top priority the study of the thermal and chemical ageing of 4 of them according to their specific applications:

Studied polymers

- Polyethylene (PE)
- Polyphenylene sulfide (PPS)
- Polyphtalamide (PPA)
- Polybutylene terephthalate (PBT)

Ageing of samples

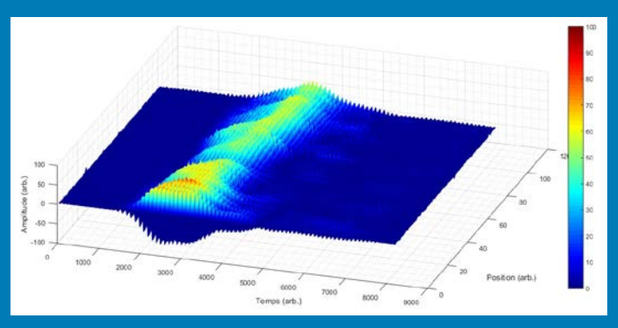
- Chemical ageing
- Thermal ageing, in maximal time scale of 4 months

Ageing detection methods

- Thermal analyses : DSC and TGA analyses
- Structural analyses: Raman and FT-IR (vibrational spectroscopy)
- Topographic analyses SEM-EDX (Scanning electron microscope and energy-dispersive X-ray)
- Chemiluminescence analyses
- Ultrasonic non destructive testing using Lamb waves and resonance method
- Nanoindentation

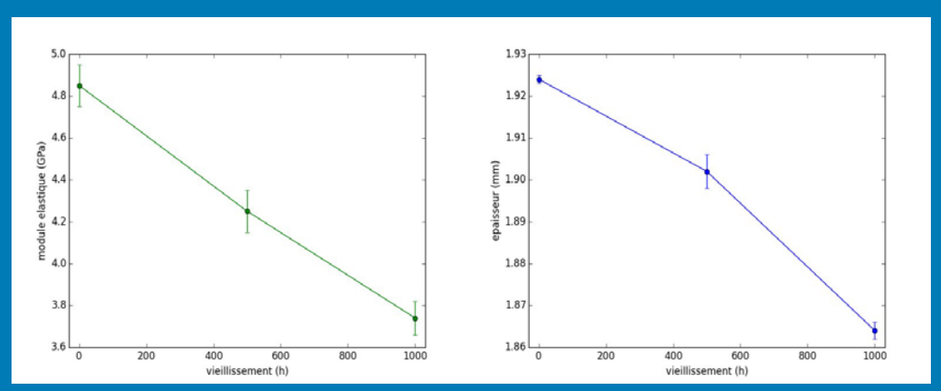
POLYAGE/POLYLIFE focuses on the effects of the thermal ageing. The samples were heated at high temperatures to accelerate the degradation or were already aged by our partners by their own industrial processes. These different tests allowed us to understand the degradation mechanisms and to develop models of artificial ageing in a reasonable time.

Measuring the ageing of plastic sample with ultrasonic non destructive methods



Propagation of the ultrasonic wave along a PBT piece by the Lamb method. The phase velocity of the wave allows to mesure the Young modulus.

In cooperation with the SESI institute (Sustainable Engineering Systems Institute, HEIAFR), some correlations were established between structural and mechanical properties. Ultrasonic was used to measure the tensile modulus of PBT samples. This one was then compared to the tensile modulus obtained by Nano-indentation measurement.



Left: tensile modulus variation of PBT samples in function of the ageing time at 200° C. Right: Thickness variation of the same samples in function of the ageing time.

Conclusion

☑ The lifetime prediction of PE was simulated. It takes around 50 years at 70° C and under atmospheric pressure before the oxidation takes place.

☑ The lifetime prediction of PPA was finalized. A lifetime of 15 years at 100° C under atmospheric pressure was found.

☑ The tensile modulus of PBT was determined by ultrasonic measurement. A result of 4.3 GPa after an ageing of 500 hours at 200° C was obtained while a tensile modulus of 3.75 GPa was measured after 1000 hours at the same temperature.

~ The tensile modulus measurement by ultrasonic wave on finished pieces is in progress.

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