Detection of degraded polymers via NIR hyperspectral imaging

C. Barretta[1], J. Geier[1], M. Messiha[1], M. Bredács[1], G. Koinig[2], E. Helfer[1], F. Arbeiter[4], C. Burgstaller[3], G. Oreski[1,4]

[1] Polymer Competence Center Leoben GmbH (PCCL), Sauraugasse 1, 8700 Leoben, Austria – chiara.barretta@pccl.at
[2] Montanuniversität Leoben, Chair of Waste Processing Technology and Waste Management (AVAW), Leoben, Austria
[3] Transferzentrum für Kunstofftechnik GmbH (TZKT), Wels, Austria
[4] Montanuniversität Leoben, Chair of Material Science and Testing of Polymers (WPK), Leoben, Austria

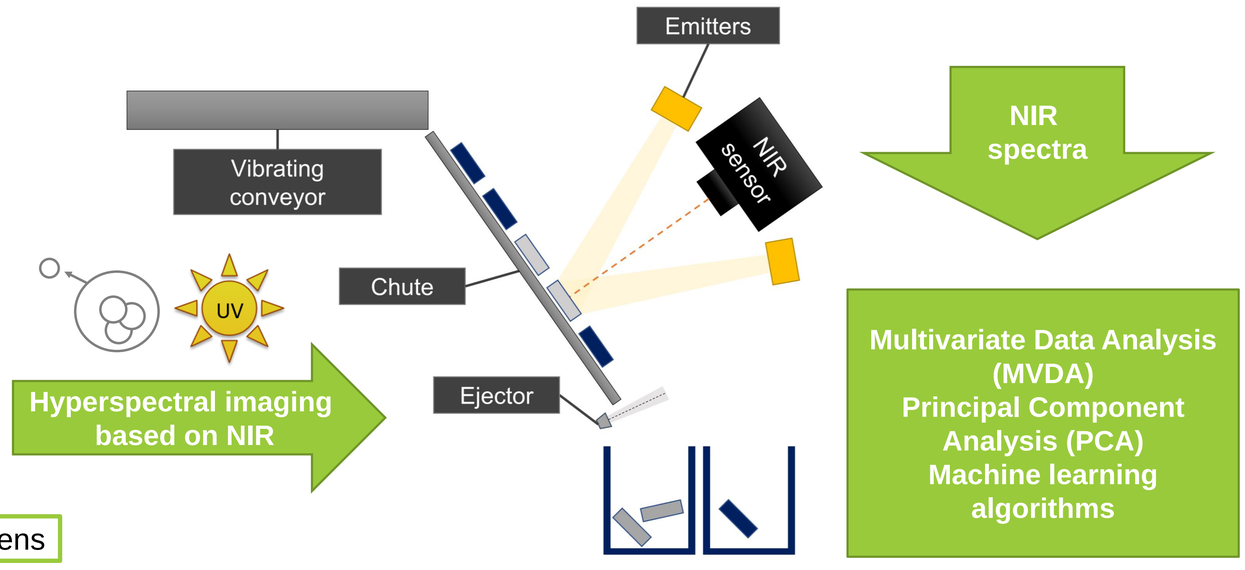
OBJECTIVES AND APPROACH

- Polymers undergo **chemical and physical degradation** processes during their lifetime. Those processes can have a significant effect on **changes of properties** of interest.
- Materials that are severely degraded might enter the recycling loop and it is not yet known which **effects** they might have on **production of recyclates with high quality**. Aged polymers might worsen properties of recyclates and require, for example, **higher amount of additives** to achieve target values.
- Main research question is: **can we detect degraded polymer in automated sorting systems?**
- **HDPE samples** were degraded using different **accelerated aging** protocols to produce mechanical failures. Data from the **NIR hyperspectral camera** of a lab-scale sorting device were used to determine whether degraded polymers can be detected and sorted out.

EXPERIMENTAL

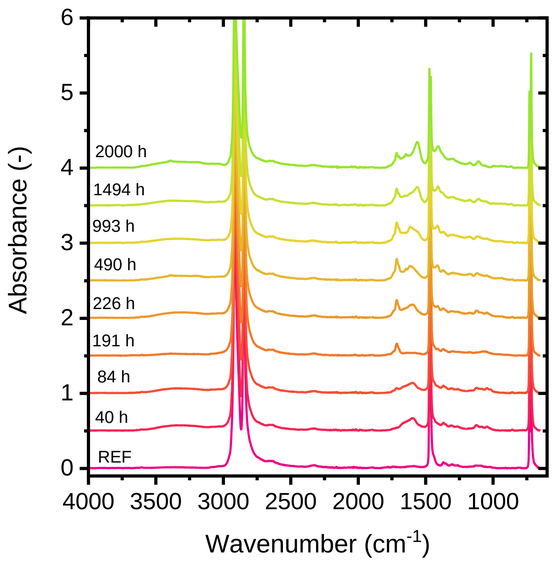
Thermo-oxidative	Highly oxidative medium	UV – photo-oxidation
55 °C	55 °C	55 °C
80 °C	ClO_2, 1 ppm	Fluorescent bulbs with peak at 340 nm, 0.8 Wm^{-2}
Duration: 8000 h (~11 months)	Duration: 2000 h (~ 2.7 months)	Duration: 4670 h (~ 6.5 months)

HDPE with blow moulding grade, 1 mm compression moulded plates, tensile test specimens



RESULTS AND DISCUSSION

- **No** significant signs of **chemical degradation** or worsening of mechanical properties for **samples exposed to high temperatures** (not shown here)
- Chemical degradation (**oxidation**) detected with FTIR for samples exposed to **ClO_2** (highly oxidative medium)
- **Strong embrittlement** and decrease of mechanical properties starting from 191 h of ClO_2 exposure
- Chemical degradation (**photo-oxidation**) detected with FTIR for samples exposed to UV test
- **Different chemical degradation mechanisms** between the two aggressive protocols, but **similar effects** on mechanical properties
- **Strong embrittlement** and decrease of mechanical properties starting from 150 h of exposure upon UV exposure
- Slight decrease of crystallization temperature from DSC thermograms (not shown here)



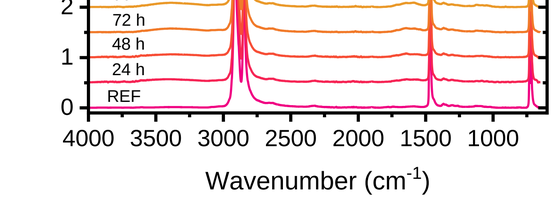
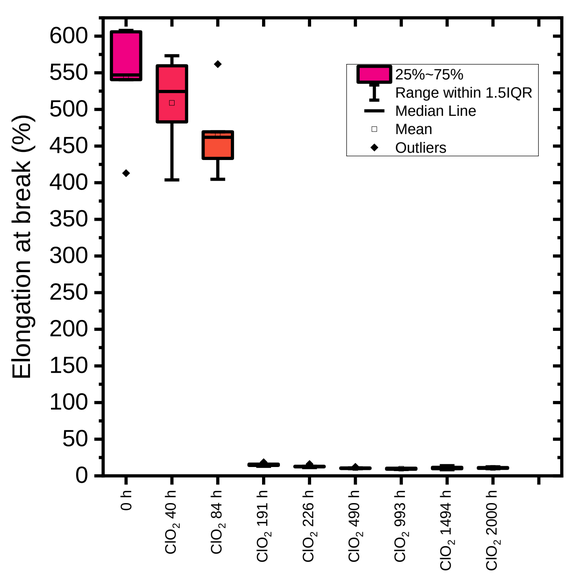


Fig. 1: FTIR ATR spectra of specimens exposed to ClO_2 up to 2000 hours (above) and to UV up to 4670 hours (below)



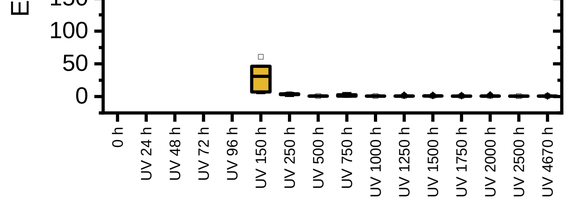


Fig. 2: Elongation at break (%) for specimens exposed to ClO_2 up to 2000 hours (above) and to UV up to 4670 hours (below)

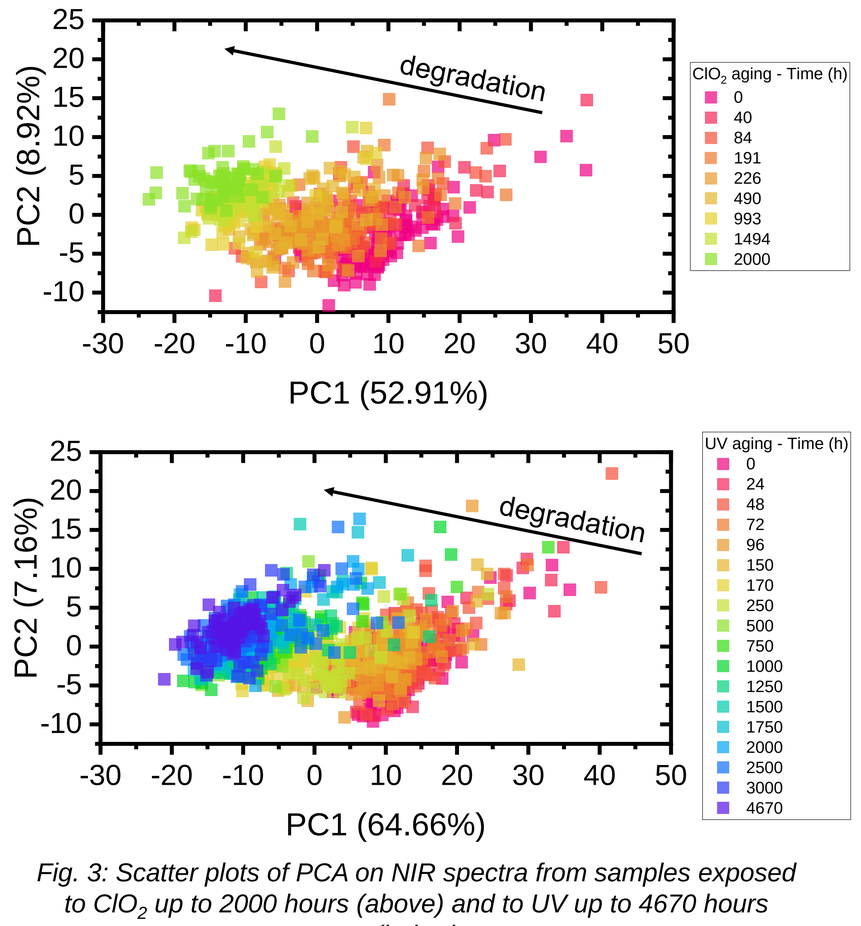


Fig. 3: Scatter plots of PCA on NIR spectra from samples exposed to ClO_2 up to 2000 hours (above) and to UV up to 4670 hours (below)

- Machine learning algorithms were developed to separate degraded from less degraded samples according to their mechanical properties
- Samples with low mechanical stability could be identified with an accuracy of 92% and 96% for ClO_2 and UV aged materials, respectively
- **Aged PE can be identified with NIR hyperspectral imaging and advanced data analysis**

CONCLUSIONS AND OUTLOOK

Samples were produced using **HDPE** blow moulding grade

Specimens underwent artificial **aging tests** with different protocols

Samples exposed to ClO_2 and UV showed **strong chemical** and **mechanical degradation**

Degraded samples could be **identified** using **NIR hyperspectral imaging,** PCA and machine learning algorithms **Classification** of **PE samples** based on mechanical properties can be achieved with **high accuracy**

Next: Effect of degraded polymers on properties of recyclates?

ORCID ID

The research work presented here was performed at the Polymer Competence Center Leoben GmbH (PCCL, Austria) within the framework of the **COMET-program** of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology and the Federal Ministry for Labor and Economy. The PCCL is funded by the Austrian Government and the State Governments of Styria, Lower Austria and Upper Austria.