Research Center for Photovoltaics

Research Institute for Sustainable Chemistry

Characterization of ethylene vinyl acetate copolymers and their degradation products at a molecular level: current situation, pitfalls and future orientation

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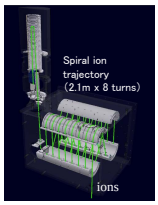
Motivations / purposes

Ethylene / vinyl acetate copolymers (EVA) are used as a sealing material for protecting the power generating cell in photovoltaic (PV) modules. Evaluating its deterioration is important as it partly dictates the lifespan of the PV module. Among other pathways, the degradation of EVA is considered to consist of the deacetylation of VA unit (hydrolysis or thermal ageing), the formation of ketone (oxidation) and so on. So far, the exploration of these degradation pathways has been limited to the bulk level (infrared spectroscopy, thermal analysis). Combined with allied tools and relying on the ionization of intact individual polymeric chains, matrix-assisted laser desorption ionization high resolution mass spectrometry (MALDI-HRMS) is proposed as a new reference technique for the molecular analysis of pristine, processed and degraded EVA by hydrolysis and thermo-oxidation. They constitute model samples prior to characterize actual EVA samples.

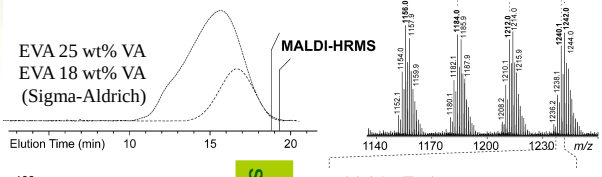
Spiral TOF high resolution mass analyzer



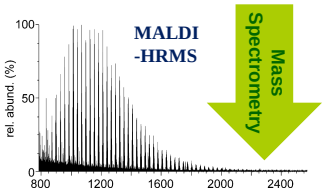
Current situation – preliminary results

Pristine EVA [1]

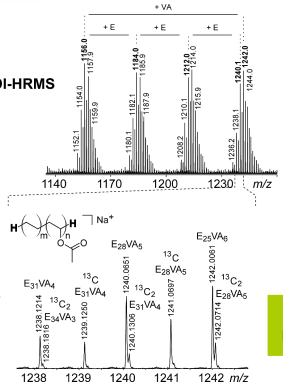
Size exclusion chromatography



MALDI-HRMS

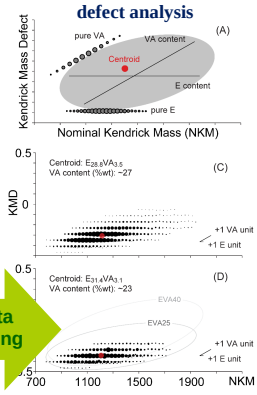


Mass Spectrometry



Data mining

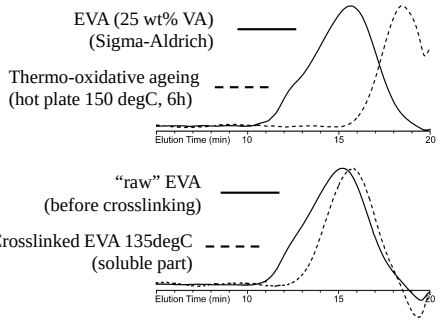
Kendrick mass defect analysis



- VA content readily evaluated from MALDI data / Visual comparison of data using KMD plots

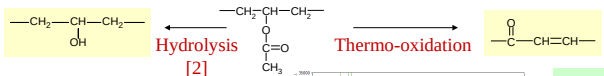
Processing vs. ageing

Size exclusion chromatography

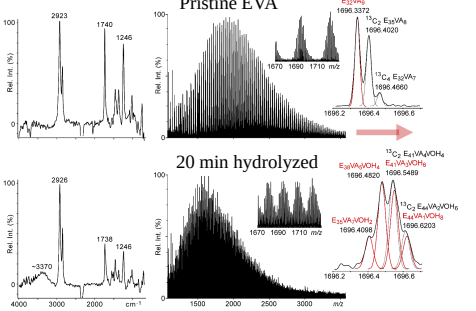


- No chain scission during the cross-linking step

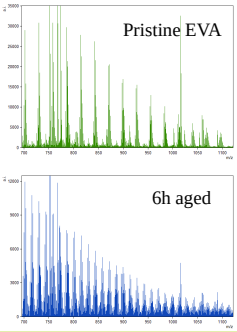
Models of ageing routes



FTIR-RAS

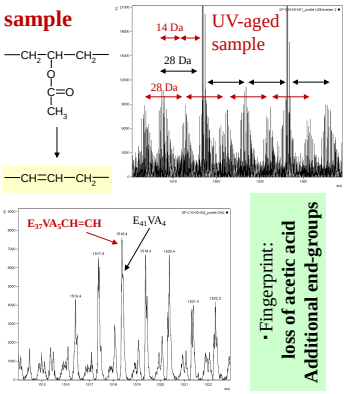


- Typical fingerprint: **isobaric species towards higher masses**



- Typical fingerprint: **isobaric species towards lower masses**

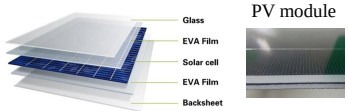
Actual sample



- Fingerprint: **loss of acetic acid Additional end-groups**

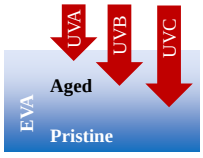
Pitfalls

Sample recovery



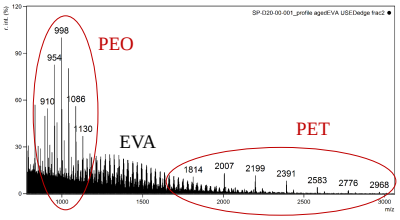
- EVA sheets hardly recoverable

Bulk vs. surface

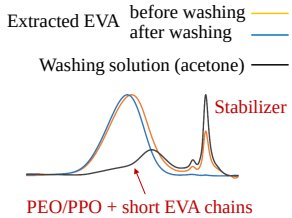


- Depth of penetration of UV < 1 mm

Formulation / processing



- Undesirable intense polymer series putting a damper on the detection of informative EVA



- Non selective washing

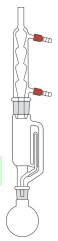
Future orientation

← Microtome

Sample collection

- Recovery of the aged part of the sample only
- Evaluation of the depth of penetration

Soxhlet extraction →

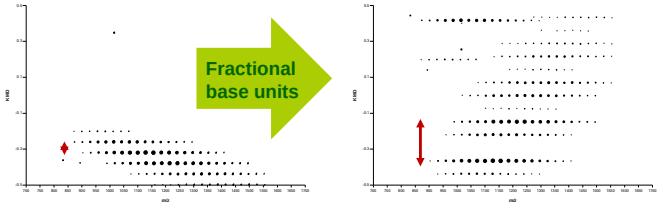


- Soluble part amenable to MALDI-MS and liquid NMR

Data mining

High resolution KMD (HRKMD) [3]

- Improved resolution of the KMD plots => Enhanced visualization and easy assignment



References:

[1] T. Fouquet, S. Nakamura, H. Sato, Rapid Commun. Mass Spectrom. 2016, 30, 973-981.

[2] T. Fouquet, H. Aizawa, H. Sato, Rapid Commun. Mass Spectrom. 2016, 30, 1818-1822.

[3] T. Fouquet, H. Sato, Anal. Chem. 2017, 89, 2682-2686.

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