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Mapping of instrumented elastic modulus of EVA layer after DH aging

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INTRODUCTION

- Dynamic nanoindentation is used for obtaining the instrumented elastic modulus (*EIT*) of EVA in the laminate cross-section with a high spatial resolution.
- The investigation of mechanical changes is complemented by chemical and optical characterization.

EXPERIMENTAL PART

- The EVA is aged and characterized in a PV module-like laminate: Glass-EVA-Backsheet with a high permeability for water vapor.
- Accelerated aging: Damp-Heat (DH) (85 % rh / 85 °C).
- The cross-sections of laminates are embedded in epoxy resin and polished.
- Mechanical characterization: Indentation is done by using Nanoindentation Tester (Anton Paar) with a spherical and blunt indenter tip, maximum load of 50 mN, sinus frequency of 1 Hz and force amplitude of 5 mN. The distance between each indent is 200 µm (Fig. 1).
- Chemical characterization: FTIR-ATR spectroscopy is performed at glass/EVA interface. Raman spectroscopy is performed through the glass.
- Optical characterization: Color measurements are done through the glass.

RESULTS

- The qualitative *EIT* is calculated from the implementation of a model and analysis of oscillatory indentation [1,2].
- The DH exposure induces a slight increase in the *EIT* of the EVA (Fig. 2).
- The distribution of *EIT* throughout the thickness of the EVA is uniform for the fresh and the highly aged samples (3500 h DH).
- The interface BS/EVA shows high modulus (bottom part of Fig. 2) due to the adjacent backsheet layer which is stiffer than the EVA layer.
- The chemical composition of the EVA at the EVA/glass interface changes after 1500 h DH (Fig. 3, blue arrows).
- The yellowness index and fluorecence background of EVA increase with the DH aging (Fig. 4, 5).

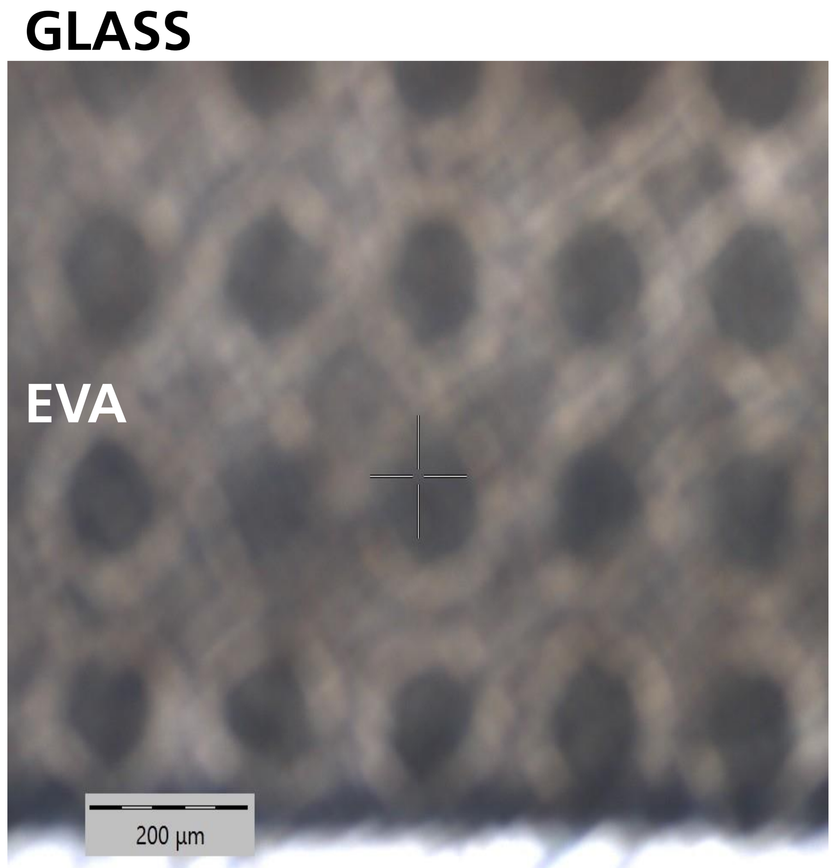

Fig. 1. Microscopic image of the cross-section of the laminate

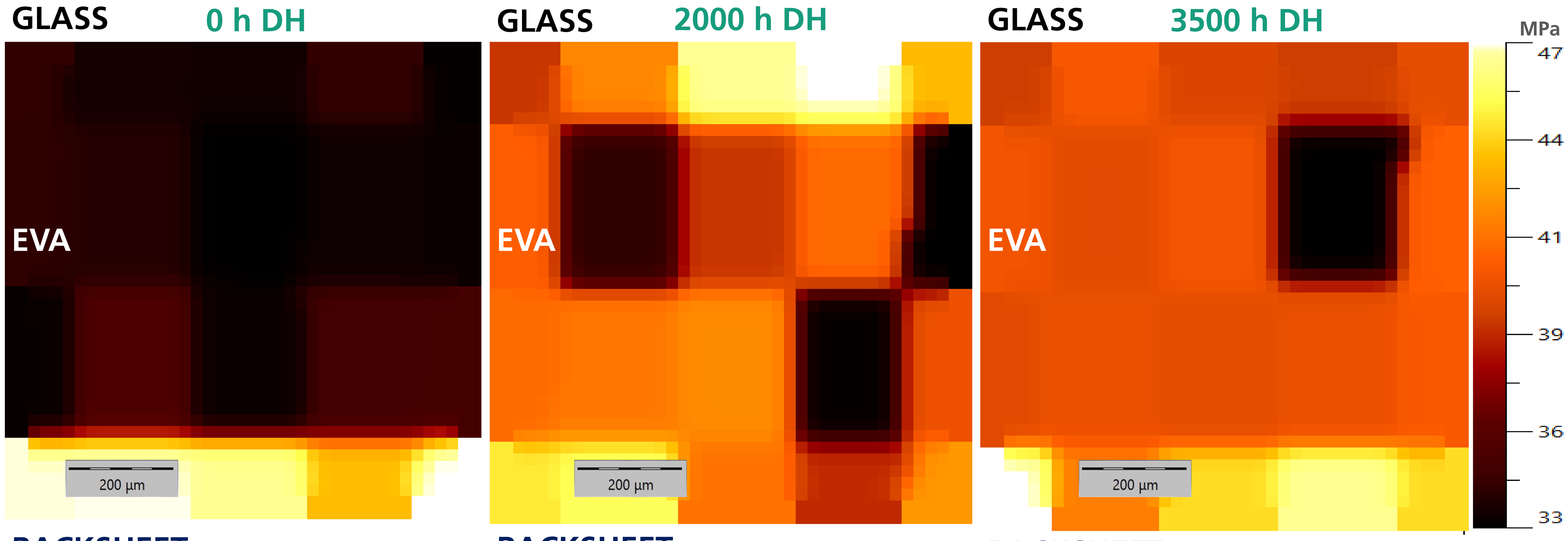

Fig. 2. Qualitative instrumented elastic modulus distribution along the cross-section of the EVA before and after DH aging

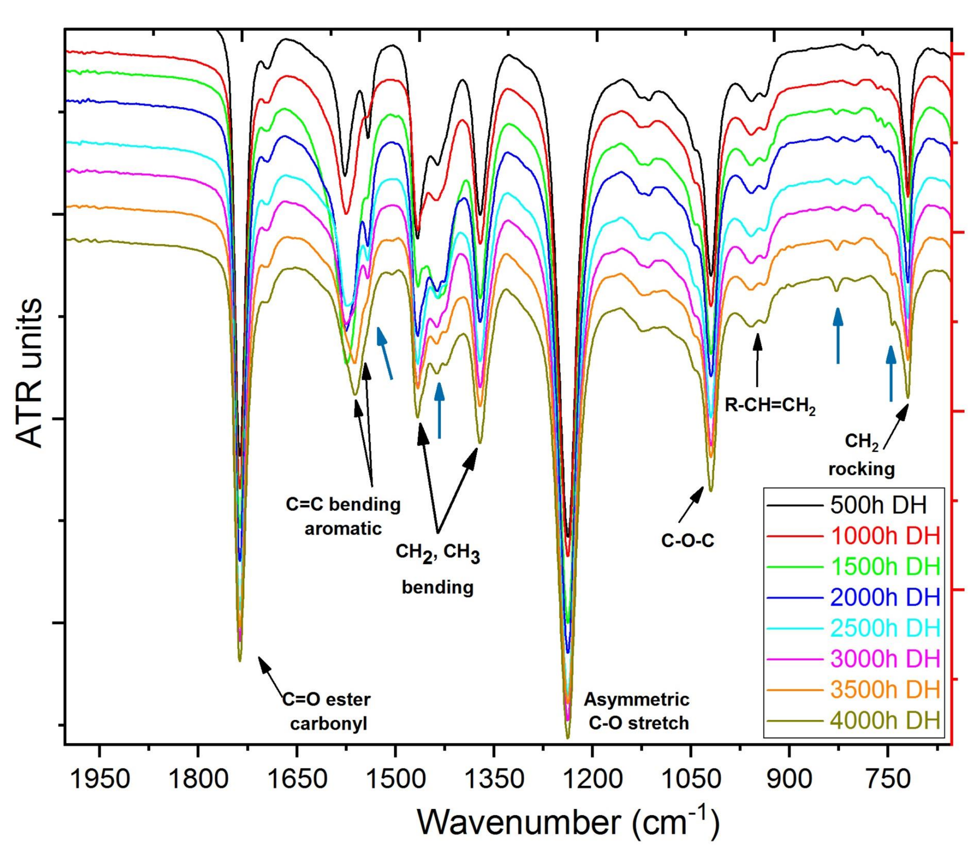

Fig. 3. ATR-FTIR spectra of EVA-glass interface after DH

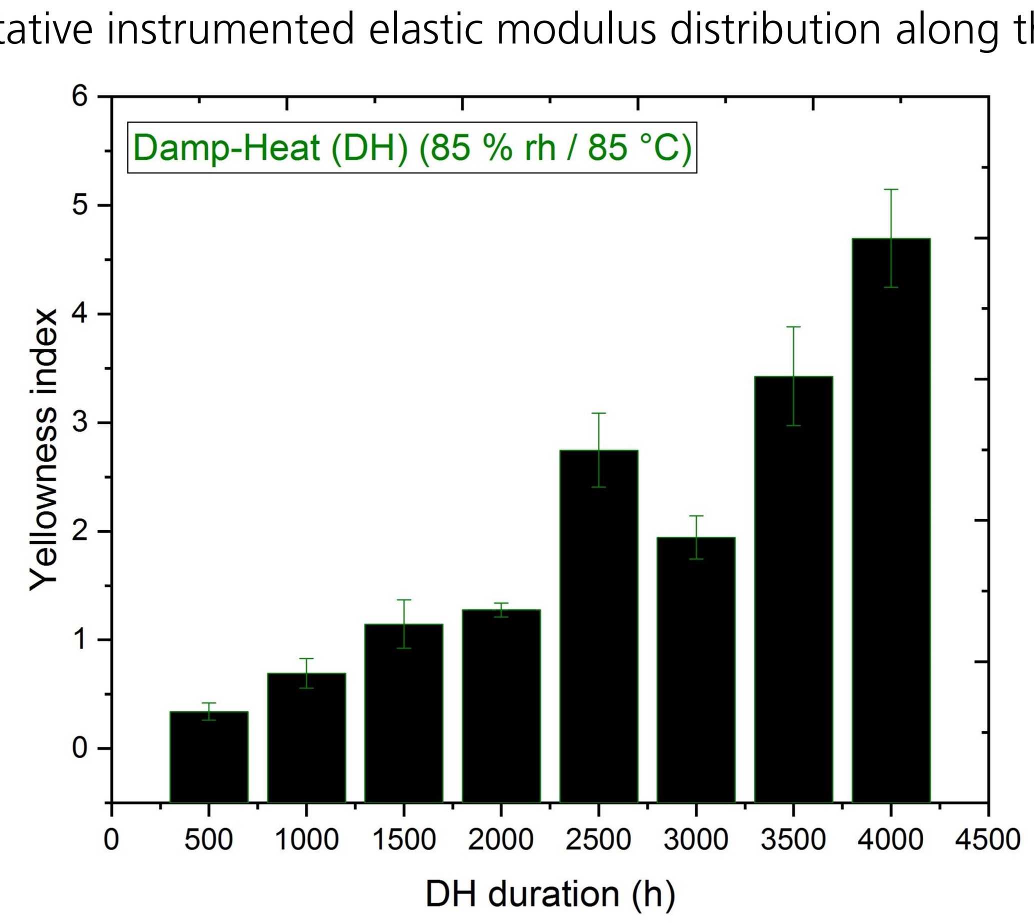

Fig. 4. Yellowness index of glass-EVA-BS after DH

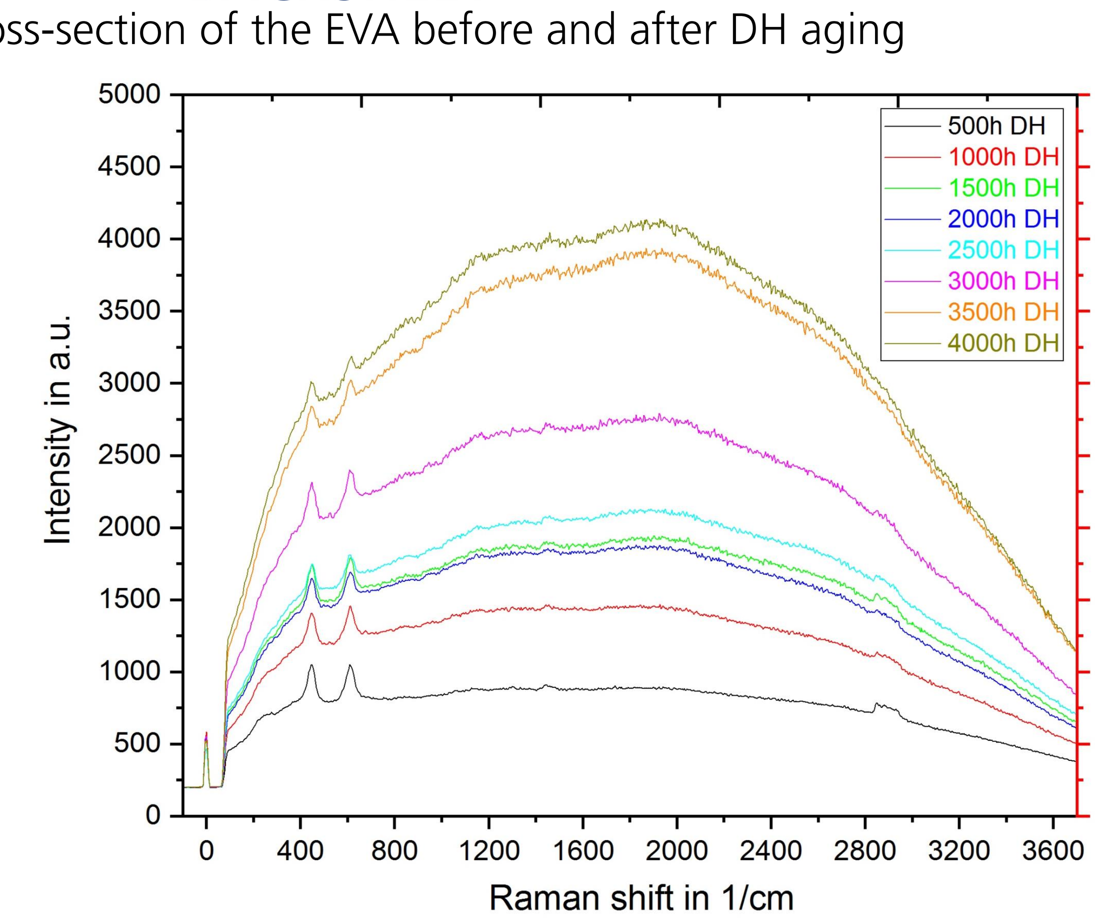

Fig. 5. Raman spectra of glass-EVA-BS after DH

CONCLUSIONS AND DISCUSSIONS

- The dynamic nanoindentation is used for qualitative measurements of the instrumented elastic modulus of the EVA layers inside PV module.
- The instrumented elastic modulus of the EVA increases with DH aging, i.e. the EVA gets stiffer.
- Chemical changes, increase in yellowing and fluorescence of the EVA are observed with DH aging. The chemical changes found in FTIR-ATR are not related to the EVA, but to the additives used in its formulation.
- The aging of the EVA is probably caused by the degradation of additives in presence of humidity and heat during the accelerated aging.

[1] Cheng Y-T, Ni W, Cheng C-M; Nonlinear Analysis of Oscillatory Indentation in Elastic and Viscoelastic Solids; Phys Rev Lett 2006. [2] Hay J, Crawford B; Measuring substrate independent modulus of thin films; J Mater Res 2011.

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