CO_2 absorption into EVA in photovoltaic modules, stage of a delamination treatment for their recycling

Axel BRIAND[1,2], Guy LUMIA[1], Claire AUDOIN[2], Olivier DOUCET[2], Jean Christophe RUIZ[1], Antoine LEYBROS[1], Fabrice LAMADIE[1], Agnès GRANDJEAN[1]

[1] CEA, DES, Univ. Montpellier, DMRC, STDC, F-30207 Bagnols sur Cèze, France
[2] Univ. Grenoble Alpes, CEA, LITEN, DTS, INES, F-38000 Grenoble, France

The volume of End-of-Life (EOL) Photovoltaic (PV) panels to be treated, will substantially increase during the next decade [1]. In order to be able to ensure the growth in energy demand using solar energy and with a view to a circular economy that respects environment, it becomes more than necessary to develop efficient recycling processes. Their strong rigidity and cohesive strength make them difficult to disassemble by conventional means. Moreover, the diversity of module sizes (up to 2 m²) demands a process that can address any type of module. Coupling of treatment routes as chemical, mechanical or thermal processes can be used, but they are not respectful of the environment by producing gaseous or liquid effluents to be managed [2]. In this context, a delamination process using supercritical CO_2 was studied for the recycling of EOL PV modules (Figure 1).

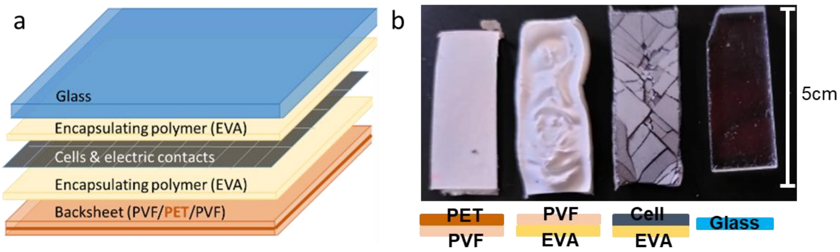

Figure 1 : (a) PV module exploded-view – A PV module is a multilayer assembly composed of glass, an encapsulating polymer (polyethylene-co-vinyl-acetate (EVA)), a backsheet (polyvinyl-fluoride (PVF) and polyethylene-terephthalate (PET)) and solar cells based on Silicon electrically connected by Silver and Copper contacts. (b) PV module delaminated by CO_2 treatment

The delamination in supercritical CO_2 medium of a multilayer structure composed of at least one polymer component, consists on separating each layer to each other. The process consists on a phase of CO_2 absorption within the polymer at a pressure above the critical pressure followed by a rapid depressurization (from 1 bar.s^{-1} to 300 bar.s^{-1}) leading to the foaming of the encapsulant polymer (EVA). This foaming phenomenon leads to a loss of adhesion at the interfaces of the foamed polymer [3], or even delamination [4]. This work focuses on the first phase of the treatment described above: the CO_2 absorption into the EVA in photovoltaic modules. The CO_2 absorption into polymers is widely described in the literature ([5], [6], [7] and [8]). However, the CO_2 absorption into a polymer in a multilayer structure has not yet been described. For a gas absorption into a polymer two aspects are basically considered: the phase equilibrium of CO_2/polymer (solubility) and the kinetic sorption of CO_2 into the EVA (diffusion coefficient). In this study, another aspect is considered; the influences of the PV module interfaces on CO_2 absorption.
The oral presentation will contained results obtained by swelling experiments in temperature and pressure ranging from 60°C to 90°C and 60 bar to 200 bar thanks to a homemade optical set-up with a high-pressure cell composed of transparent sapphire windows (Figure 2).

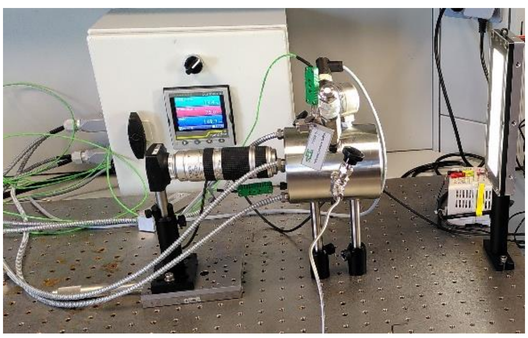

Figure 2 : Optical set-up for swelling experiments

References:

[1] I. IRENA, « End-Of-Life Management: Solar Photovoltaic Panels », *International Renewable Energy Agency and the International Energy Agency Photovoltaic Power Systems*, 2016.
[2] J. Tao et S. Yu, « Review on feasible recycling pathways and technologies of solar photovoltaic modules », *Solar Energy Materials and Solar Cells*, vol. 141, p. 108-124, oct. 2015, doi: 10.1016/j.solmat.2015.05.005.
[3] J. L. Sumey, J. A. Sarver, et E. Kiran, « Foaming of polystyrene and poly(methyl methacrylate) multilayered thin films with supercritical carbon dioxide », *Journal of Supercritical Fluids*, vol. 145, p. 243-252, 2019, doi: 10.1016/j.supflu.2018.12.001.
[4] S. Sanyal *et al.*, « Understanding and optimizing delamination/recycling of printed circuit boards using a supercritical carbon dioxide process », *Journal of Cleaner Production*, vol. 41, p. 174-178, 2013, doi: 10.1016/j.jclepro.2012.10.011.
[5] D. L. Tomasko *et al.*, « A Review of CO2 Applications in the Processing of Polymers », *Ind. Eng. Chem. Res.*, vol. 42, nº 25, p. 6431-6456, déc. 2003, doi: 10.1021/ie030199z.
[6] Z. Chen, K. Cao, Z. Yao, et Z. Huang, « Modeling solubilities of subcritical and supercritical fluids in polymers with cubic and non-cubic equations of state », *The Journal of Supercritical Fluids*, vol. 49, nº 2, p. 143-153, juin 2009, doi: 10.1016/j.supflu.2008.12.013.
[7] J. K. Lee, S. X. Yao, G. Li, M. B. G. Jun, et P. C. Lee, *Measurement Methods for Solubility and Diffusivity of Gases and Supercritical Fluids in Polymers and Its Applications*, vol. 57. 2017.
[8] G. Mensitieri, G. Scherillo, C. Panayiotou, et P. Musto, « Towards a predictive thermodynamic description of sorption processes in polymers: The synergy between theoretical EoS models and vibrational spectroscopy », *Materials Science and Engineering R: Reports*, vol. 140, 2020, doi: 10.1016/j.mser.2019.100525.