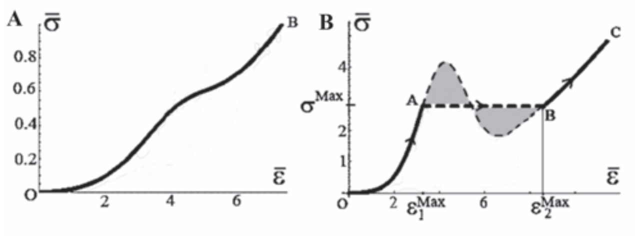

Figure 7. A) Homogeneous damage up to failure; B) localised deformation and damage (modified from Figure 3A-B by De Tommasi *et al.*, 2008).

Conclusions

Greenhouse structures must withstand the different climatic conditions ensuring energy efficiency features and technological characteristics depending on productions. Therefore new structure and cover technologies that are efficient and durable represent a fundamental task for applied research. This work has focused attention on the rigid plastic laminates used in the greenhouses such as PC, PMMA and PET-G. Radiometric characteristics, mechanical and thermomechanical properties were analysed. From the radiometric point of view the four different materials considered in this work showed different parameters suitable to crop production, depending on the needs of the plants. Focusing on the mechanical characteristics we conclude that the PMMA is the less ductile material. The PET-G, while reaching maximum stresses of the same order of magnitude of the other materials, exhibits a breaking elongation much higher than the other materials. This has important effects on both seismic resistance and definition of safety parameters.

Finally thermographic analysis showed the actual correlation between the location of the damage and the registration of a peak in the temperature of the specimen for all materials except the PMMA, which arrives at break with a homogeneous material damage. A theoretical interpretation has been delivered. Further study on this kind of polymers will be performed in the next future in order to validate the results here presented and to give a more detailed theoretical interpretation of the thermo-mechanical behaviour of these materials.

References

Al-Mahdouri A., Baneshi M., Gonome H., Okajima J., Maruyama S. 2013. Evaluation of optical properties and thermal performances of different greenhouse covering materials. Sol. Energy 96:21-32.

Briassoulis D., Schettini E. 2002. Measuring strains of LDPE films: the strain gauge problems. Polym. Test. 21:507-12.

Briassoulis D., Schettini E. 2003. Analysis and design of low-density polyethylene greenhouse films. Biosys. Eng. 84:303-14.

Briassoulis D., Waaijenberg D., Gratraud J., Von Eslner B. 1997. Mechanical properties of covering materials for greenhouses: Part 1, general overview. J. Agr. Eng. Res. 67:81-96.

De Tommasi D., Marzano S., Puglisi G., Saccomandi G. 2010. Localization and stability in damageable amorphous solids. Continuum Mech. Therm. 22:47-62.

De Tommasi D., Puglisi G., Saccomandi G. 2008. Localized versus diffuse damage in amorphous materials. Phys. Rev. Lett. 100:085502.

Giacomelli G.A., Sase S., Cramer R., Hoogeboom J., MacKenzie A., Parbst K., Scarascia-Mugnozza G., Selina P., Sharp D.A., Voogt J.O., Van Weel P.A., Mears D. 2012. Greenhouse production systems for people. Acta Hortic. 927:23-38.

ISO (International Standard Organisation). 2001. ISO 8257-2:2001. Plastics - Poly(methyl methacrylate) (PMMA) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties. Available from: http://www.iso.org/iso/home /store/catalogue_tc/catalogue_detail.htm?csnumber=26816

ISO (International Standard Organisation). 2006. ISO 7391-2:2006. Plastics - Polycarbonate (PC) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties. Available from: http://www.iso.org/iso/home/store/ catalogue_tc/catalogue_detail.htm?csnumber=36276

ISO (International Standard Organisation). 2014. ISO 3167:2014. Plastics - Multipurpose test specimens. Available from: http://www.iso.org/iso/catalogue_detail.htm?csnumber=65105

Kittas C., Baille A. 1998. Determination of the spectral properties of several greenhouse cover materials and evaluation of specific parameters related to plant response. J. Agr. Eng. Res. 71:193-202.

Papadopoulos A.P., Hao X. 1997. Effects of three greenhouse cover materials on tomato growth, productivity, and energy use. Sci. Hortic. 70:165-78.

Puglisi G. 2006. Hysteresis in multi-stable lattices with non-local interactions. J. Mech. Phys. Solids 54:2060-88.

Russo G., Verdiani G. 2013. Production and reuse of waste in rural area with high density of greenhouse. J. Agr. Eng. 44:240-6.

Samaca Martinez J.R., Le Cam J.B., Balandraud X., Toussaint E., Caillard J. 2013. Mechanisms of deformation in crystallizable natural rubber. Part 2: Quantitative calorimetric analysis. Polymer 54:2727-36.

Sartore L., Vox G., Schettini E. 2013. Preparation and performance of novel biodegradable polymeric materials based on hydrolyzed proteins for agricultural application. J. Polym. Environ. 21:718-25.

Scarascia-Mugnozza G. 2003. Strutture e tipologie nuove negli impianti serricoli. Colture Protette 6:89-104.

Schettini E., De Salvador F.R., Scarascia-Mugnozza G., Vox G. 2011. Radiometric properties of photoselective and photoluminescent greenhouse plastic films and their effects on peach and cherry tree growth. J. Hort. Sci. Biotech. 86:79-83.

Schettini E., Stefani L., Vox G. 2014. Interaction between agrochemical contaminants and UV stabilizers for greenhouse EVA plastic films. Appl. Eng. Agric. 30:229-39.

Sica C., Loisi R. V., Blanco I., Schettini E., Scarascia Mugnozza G., Vox G. 2015. Swot analysis and land management of plastic wastes in agriculture. pp 745-54 in Proc. 43rd International Symposium on Agricultural Engineering: Actual Tasks on Agricultural Engineering, 24th-27th February, Opatija, Croatia.

Stefani L., Zanon M., Modesti M., Ugel E., Vox G., Schettini E. 2008. Reduction of the environmental impact of plastic films for greenhouse covering by using fluoropolymeric materials. Acta Hortic. 801:131-7.

Vox G., Schettini E. 2013. Effects of agrochemicals, ultra violet stabilisers and solar radiation on the radiometric properties of greenhouse films. J. Agr. Eng. 44:e11.

Vox G., Schettini E., Scarascia-Mugnozza G. 2005. Radiometric properties of biodegradable films for horticultural protected cultivation. Acta Hortic. 691:575-82.