

Mechanical properties–morphology relationships in nano-/microstructured epoxy matrices modified with PEO–PPO–PEO block copolymers

Maider Larrañaga,¹ Elena Serrano,¹ Maria Dolores Martin,¹ Agnieszka Tercjak,¹ Galder Kortaberria,¹ Koro de la Caba,¹ Carmen Cristina Riccardi² and Iñaki Mondragon^{1*}

¹Materials + Technologies Group Dpto. Ing. Química y M Ambiente, Escuela Univ Politécnica, Universidad del País Vasco/Euskal Herriko Unibertsitatea, Pza Europa, 1, 20018 Donostia/San Sebastián, Spain

²Institute of Materials Science and Technology (INTEMA), University of Mar de Plata and National Research Council (CONICET), JB Justo 4320-(7600) Mar de Plata, Argentina

Abstract: Epoxy-based blends containing poly(ethylene oxide)-*co*-poly(propylene oxide)-*co*-poly(ethylene oxide) (PEO–PPO–PEO) block copolymers with different PEO/PPO molar ratios have been investigated in order to analyze the effect of the generated morphologies and interactions between components on the mechanical properties of the blends. Mechanical, morphological and dynamic mechanical analyses indicate that the observed increase of flexural modulus can be related to the decrease of free volume. In modified systems that remain miscible, an increase of flexural modulus, strength and fracture toughness can be observed. Also, macrophase- and microphase-separated systems show an increase of fracture toughness but not of flexural modulus and strength at low contents of block copolymers.

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INTRODUCTION

A large number of investigations have been carried out in the last decades to get a better understanding of the behaviour of thermosetting systems modified with block copolymers.^{1–23} Block copolymers are the focus of a great deal of research activity because of their intrinsic ability to form nanoscale ordered structures. The final morphology is governed by the volume fraction of each block and the block–block interactions. Recently, Ruzette and Leibler²³ published a review about block copolymers and their blends with other polymers. This shows the concept of physical and chemical compatibilization between epoxy systems and different types of block copolymers as shown previously by Hillmyer *et al.*² and Rebizant *et al.*^{11,12}

Although there have been many studies on the subject of toughening of thermosets by rubber and thermoplastics, only a few publications on the mechanical properties of thermoset systems modified with block copolymers are available.^{7–10,12–14} The fracture toughness of epoxies can be improved by introducing a dispersed rubbery phase.^{24,25} However, this modification reduces both stiffness and strength

and also the glass transition temperature (T_g) of the cured blends. Another modification often used is the addition of a high- T_g thermoplastic modifier.^{26,27} This route leads to good toughening enhancement, but, in most cases, less than that attained after modification with liquid rubbers. Modification with block copolymers can lead to the formation of ordered macrophase-/microphase-separated structures as well as improved toughness at low content of block copolymer.^{7–9,12,14}

Most investigations have been carried to create materials with new mechanical, optical or electronic properties as well as specific functions. In this way, self-organized block copolymers and their blends with epoxy systems could be widely used in several industrial sectors. The possible technological application considered are the preparation of nanoporous materials (for water-permeable membranes), photonic crystals, nanocapsules, nanoparticle patterning at surfaces, nanoreactors for nanoparticle production, nanolithography, etc.^{1,2,8,15,20,21}

The final morphology, and consequently the mechanical properties, is governed by several parameters such as the degree of polymerization of

* Correspondence to: Iñaki Mondragon, Materials + Technologies Group Dpto. Ing. Química y M Ambiente, Escuela Univ Politécnica, Universidad del País Vasco/Euskal Herriko Unibertsitatea, Pza Europa, 1, 20018 Donostia/San Sebastián, Spain

E-mail: inaki.mondragon@ehu.es

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