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Assessment of the Properties of Microcapsules with Different Polymeric Shells Containing a Reactive Agent for their Suitability in Thermoplastic Self-healing Materials

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Abstract : Self-healing polymers are one of the most investigated groups of smart materials. As materials engineering has recently focused on the design, production and research of modern materials and future technologies, researchers are looking for innovations in structural, construction and coating materials. Based on available scientific articles, it can be concluded that most of the research focuses on the self-healing of cement, concrete, asphalt and anticorrosion resin coatings. In our study, a method of obtaining and testing the properties of several types of microcapsules for use in self-healing polymer materials was developed. A method to obtain microcapsules exhibiting various mechanical properties, especially compressive strength was developed. The effect was achieved by using various polymer materials to build the shell: urea-formaldehyde resin (UFR), melamine-formaldehyde resin (MFR), melamine-urea-formaldehyde resin (MUFR). Dicyclopentadiene (DCPD) was used as the core material due to the possibility of its polymerization according to the ring-opening olefin metathesis (ROMP) mechanism in the presence of a solid Grubbs catalyst showing relatively high chemical and thermal stability. The ROMP of dicyclopentadiene leads to a polymer with high impact strength, high thermal resistance, good adhesion to other materials and good chemical and environmental resistance, so it is potentially a very promising candidate for the self-healing of materials. The capsules were obtained by condensation polymerization of formaldehyde with urea, melamine or copolymerization with urea and melamine in situ in water dispersion, with different molar ratios of formaldehyde, urea and melamine. The fineness of the organic phase dispersed in water, and consequently the size of the microcapsules, was regulated by the stirring speed. In all cases, to establish such synthesis conditions as to obtain capsules with appropriate mechanical strength. The microcapsules were characterized by determining the diameters and their distribution and measuring the shell thickness using digital optical microscopy and scanning electron microscopy, as well as confirming the presence of the active substance in the core by FTIR and SEM. Compression tests were performed to determine mechanical strength of the microcapsules. The highest repeatability of microcapsule properties was obtained for UFR resin, while the MFR resin had the best mechanical properties. The encapsulation efficiency of MFR was much lower compared to UFR, though. Therefore, capsules with a MUFR shell may be the optimal solution. The chemical reaction between the active substance present in the capsule core and the catalyst placed outside the capsules was confirmed by FTIR spectroscopy. The obtained autonomous repair systems (microcapsules + catalyst) were introduced into polyethylene in the extrusion process and tested for the self-repair of the material.

Keywords : autonomic self-healing system, dicyclopentadiene, melamine-urea-formaldehyde resin, microcapsules, thermoplastic materials
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