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Recycling of Polymethyl Methacrylate Waste Using A Nature-Derived Biodegradable Polymer

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ABSTRACT

This work investigated the recycling of polymethyl methacrylate (PMMA) waste using a nature-derived biodegradable polymer, aiming to improve the biodegradabilité of the recycled PMMA. In this context, the biopolymer chitosan (Cs) was used. The recycled PMMA was generated by an extrusion process for the manufacturing of sheets. Fourier transform infrared spectroscopy in attenuated total reflectance mode (FTIR-ATR) spectra did not reveal changes in the chemical structure of recycled PMMA/Cs blends compared to virgin PMMA/Cs samples, indicating that chain scission reactions, is the dominant degradation mechanism of PMMA during processing. The dynamic mechanical analysis (DMA) results reveal a single value of glass transition temperature (Tg) for the blends, implying miscibility of the components. Recycled PMMA/Cs samples exhibit slightly lower values of T_g compared to virgin PMMA/Cs blends. The recycled PMMA slightly reduces the thermal stability of the blends. In contrast, it improves the water uptake of the bio-blends comparing to virgin PMMA.

Keywords: Recycling, PMMA waste, biodegradable polymer, Blend.

1. Introduction

Generation of large quantities of plastic waste are recognized as major hazards that can threaten environmental sustainability and climate-smart health care. Polymer blends based on plastics waste and natural biodegradable polymers is an interesting strategy in view of environmental and technical concerns. Blending nature-derived biopolymers with synthetic polymers has been recognized as an excellent approach to develop new polymeric materials with a high degree of biocompatibility, biodegradability and optimum mechanical properties [1]. Among biopolymers, polysaccharides are the most important choices mainly due to their renewable and recyclable nature, biodegradability and abundance in the biomass. Chitosan (Cs), the polymer obtained from the deacetylation of chitin is one of the most extensively used polysaccharides in a variety of applications considering its interesting material properties. Chitosan is biodegradable, biocompatible, and non-toxic. On the other hand, polymethyl methacrylate (PMMA) is one of the most widely explored non-biodegradable synthetic polymers. It presents many advantages including transparency, lightness, biocompatibility and non-toxicity. However, it is estimated that only 10% of the production of PMMA is recycled, and landfilling and incineration are still the prevalent methods for PMMA waste disposal [2]. This may induce serious issues for the global ecosystem, since petroleum-based plastics take hundreds of years to decompose in landfill because of their non-degradable nature. Hence, blending PMMA waste with biodegradable materials such as chitosan could be an appealing approach to solve this problem by increasing the degradation rate of the material after use. Therefore, the present work aimed to study the use of post-processed PMMA waste by blending the recycled polymer with chitosan using the solution casting method, aiming to improve the biodegradabilité of the recycled PMMA. The structure and properties of virgin and recycled PMMA / Chitosan blends were investigated.

2. Experimental

The virgin and recycled polymethyl methacrylate (PMMA)/chitosan (Cs) blend samples (v-PMMA/Cs and p-PMMA/Cs) at 5 and 10 wt% of Cs were prepared by solution casting technique. Virgin and recycled

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PMMA waste were separately dissolved in dimethylformamide and stirred at 90 °C for 15 min. Cs was dissolved in 1% aqueous acetic acid solutions and stirred at 50 °C for 20 min. Blend solutions were prepared by mixing the solutions followed by stirring for about 10 minutes at room temperature. The resulting homogenous solutions were cast on Petri dishes and allowed to dry in a vacuum oven at 40 °C to form films of about 150 μm in thickness. Changes in the chemical structure were analyzed by Fourier transform infrared spectroscopy in attenuated total reflectance mode (FTIR-ATR), respectively. The miscibility of the blends was probed using dynamic mechanical analysis (DMA). The thermal stability and water uptake of the blends was investigated by thermal gravimetric analysis (TGA) and water absorption test, respectively.

3. Results and Discussion

FTIR-ATR analysis do not show changes in the chemical structure of recycled PMMA/Cs blends compared to virgin PMMA/Cs samples. This suggests that the occurrence of chain scission reactions, and not oxidation, is the prevalent degradation mechanism of PMMA during processing. One of the criteria adopted for assessing the miscibility of polymer blends systems is the determination of glass transition temperature T_g. Miscible blends should exhibit a single T_g, which is located between the T_g values of the pure components. In this respect, the temperature dependence of loss factor tan δ of the homopolymers (Cs, v-PMMA and p-PMMA) and the bio-blends (v-PMMA/10Cs and p-PMMA/10Cs) determined by DMA analysis method is shown in figure 1. The values of T_g are identified as the maximum of the tan δ peak.

A slight decrease into the T_g of the recycled PMMA sample is noticed compared to virgin one. Indeed, the T_g value of PMMA is reduced by 3.1 °C after extrusion processing passing from 102.5 °C for v-PMMA to 99.4 °C for p-PMMA. This slight decrease of Tg may be explained by the slight reduction in the number average molecular weight of the recycled sample, due to polymer chain scissions during extrusion processing. Further, it can be noticed from figure 3 that virgin-PMMA/10Cs blend shows a single T_g value at 109.2 °C, indicating the miscibility between the two components. In the case of the blend with recycled PMMA sample (p-PMMA/10Cs), the corresponding DMA curve exhibits also a unique T_g value at 106 °C implying the miscibility of the blend system. The shift of the relaxation peak to slightly lower value, i.e., from 109.2 to 106 °C could be attributed to the reduction in the number average molecular weight the recycled PMMA sample.

The recycled PMMA slightly reduces the thermal stability of the blends. The water absorption test shows that the addition of chitosan to PMMA lead to a considerable increase of the water uptake of the bio-blends due to the hydrophilic character of Cs. The use of recycled PMMA further improves this property in the bio-blends compared to virgin PMMA.

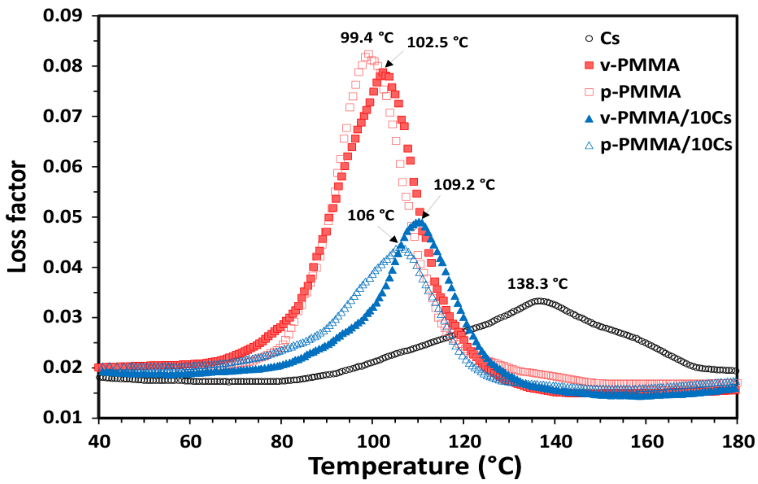

Figure 1: Temperature dependence of loss factor tan δ of the homopolymers Cs, v-PMMA and p-PMMA and the blends v-PMMA/10Cs and p-PMMA/10Cs.

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4. Conclusions

On the basis of the whole results obtained, it can be concluded that the thermal and physical properties of recycled PMMA/Cs blends using post-processed PMMA waste are not much affected compared to virgin PMMA/Cs samples, indicating the possibility of the use of PMMA waste in such blends up to 10 % of Cs content. In addition, an improvement of the biodegradation of post-processed PMMA wastes by the incorporation of chitosan would be expected, due to the effect of water absorption associated with the excellent biodegradability of chitosan.

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