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Synthesis and Characterization of Novel PPC-Silica Hybrid with Improved Thermal, Mechanical, and Water Sorption Properties

Sher Bahadar Khan[1,2], Jongchul Seo[3], Eui Soung Jang[4], Kalsoom Akhtar[5], Kwang In Kim[4], and Haksoo Han*[,4]

[1]*Chemistry Department, Faculty of Science, King Abdul Aziz University, P. O. Box 80203 , Jeddah 21589, Saudi Arabia*
[2]*The Center of Excellence for Advanced Materials Research, King Abdul Aziz University, P.O. Box 80203, Jeddah 21589, Saudi Arabia*
[3]*Department of Packaging, Yonsei University, Gangwon 220-710, Korea*
[4]*Department of Chemical and Biomolecular Engineering, Yonsei University, Seoul 120-749, Korea*
[5]*Division of Nano Sciences and Department of Chemistry, Ewha Womans University, Seoul 120-750, Korea*

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Abstract: Organic-inorganic hybrids (H1-H5) based on environmentally friendly and biodegradable polymer, poly (propylene carbonate) (PPC) and tetraethoxysilane (TEOS) were synthesized using the sol-gel technique. The synthesized hybrids were characterized structurally and morphologically by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). H1-H5 were examined in term of detailed thermal, mechanical, and anti-water sorption properties using thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), dynamic mechanical analysis (DMA) nanoindentation, and thin film diffusion analysis, which revealed that H4 has the highest thermal, mechanical, and anti-water sorption properties. H4 greatly increased the thermal decomposition temperature ($T_{d10\%}$) and glass transition temperature, which are 45 and 11 °C higher than that of pure PPC. Accordingly, H4 showed a high storage modulus (2.54×10^9 Pa), elastic modulus (2.601 ± 0.110 GPa), hardness (0.175 ± 0.013 GPa), and lowest water absorption. This improvement in the thermal, mechanical, and anti-water absorption properties of PPC shows that PPC can be used as a packaging and bio-material.

Keywords: hybrid, poly(propylene carbonate), tetraethoxysilane, thermal property, mechanical property, water absorption property.

Introduction

In the general context of sustainable development, the formulation of biodegradable plastics has gained increasing interest. Throughout the world today, the development of biodegradable materials with controlled properties has been a subject of great research challenge to the community of scientists.[1] These materials tend to substitute synthetic plastics in all the applications which cause huge amount of waste, for example, packaging. However, biodegradable polymers alone have limited physical and mechanical properties which, at present, do not allow them to replace fully the mainstream plastics. Poly(propylene carbonate) (PPC), a copolymer of propylene oxide and carbon dioxide and a main component of greenhouse gases that contributes to global warming, is one of the new biodegradable aliphatic polycarbonate which could allow degradation under the natural environment and have gained considerable interests due to the urgent need for the development of green materials.[2] Owing to biodegradability and thermoplasticity, PPC has been processed into biomedical, packing materials and binder resins.[3] However, the flexible carbonate groups in backbone chains have created many blemishes, including non-crystallizability, weaker processing stability, poorer mechanical properties and poor thermal stability. This has prevented more extensive PPC use and limited its applications.[4] As it has interesting physical and chemical properties, being an attractive green environmental material for many applications,[5] it is needed to improve its thermal and mechanical properties. The preparation of bionanocomposites defined as a combination between a biopolymer and inorganic nanofiller is a route to enhance some of the biodegradable polymers properties.[6] Nanoclays or silica are classically used to improve biodegradable polymers' stress and stiffness, reduce their gas/water vapor barrier properties, increase their thermal stability, and modify their biodegradation rate.

Polymer-inorganic hybrids especially silica based are an emerging class of innovative nano-structured materials with tailored properties - seldom seen in other types of materials

*Corresponding Author. E-mail: hshan@yonsei.ac.kr