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ORIGINAL RESEARCH

# The effect of graphene nanoplatelets on dynamic properties, crystallization, and morphology of a biodegradable blend of poly(lactic acid)/thermoplastic starch

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**Abstract**
Based on the capabilities of nanographenes in improving the properties of polymeric blends, the effects of graphene nanoplatelets on compatibility, morphology, and crystallinity of the biodegradable thermoplastic starch/poly(lactic acid) (TPS/PLA) blends have been investigated. The localization of graphene nanoplatelets has also been predicted by wetting coefficients. TPS was first prepared and added in various concentrations to the PLA melted in an internal mixer instrument. After that, various amounts of graphene nanoplatelets as 0, 1, 2, and 3 wt% were added to the PLA/TPS blends at two different 90/10 and 70/30 weight compositions. The blends were examined by DMTA, SEM, and DSC tests. The wetting coefficient was evaluated by contact angle measurements to predict the dispersion and localization of graphene nanoplatelets, and also to confirm the predicted results with those obtained by other tests. DMTA results demonstrated that the addition of 1 wt% graphene nanoplatelets into the PLA/TPS blend has increased the compatibility of the two phases. SEM images revealed the dependence of the TPS-dispersed phase particles on the blend composition and amount of graphene nanoplatelets. DSC thermograms showed a reduction in cold crystallization temperature to zero due to the addition of graphene nanoparticles to PLA/TPS blends. Based on the wetting coefficient values, the localization of graphene nanoplatelets was found to be at the interface of PLA and TPS phases.

**Keywords** Compatibility · Nanocomposite · Graphene nanoplatelets · Morphology · Poly(lactic acid) · Thermoplastic starch

## Introduction

The environmental issues caused by non-biodegradable petrochemical-based plastics as well as their limited sources have led to the research development in natural biodegradable materials. The three main application categories of biodegradable polymers are in the fields of medicine, agriculture, and packaging of goods. PLA is a biodegradable polymer which can be synthesized from renewable agricultural sources and can be readily degraded through hydrolysis. The ability of this polymer to be absorbed as a biodegradable polymer by environment has resulted in its wide range of applications in medicine, pharmacy, packaging, and agriculture. However, the properties and applications of PLA are somehow restricted due to its drawbacks compared to petroleum-derived general purpose plastics, including low thermal resistance, low barrier, low impact strength, limited processability, high price, and also low crystallization rate which results in the reduction of physical properties such as stability, modulus, and strength. The properties of PLA can be modified by either addition of various additives such as softeners, lubricants, and fillers, or through blending with other polymers [1, 2]. PLA belongs to the category of aliphatic polyesters and is considered as a thermoplastic polymer with high strength and modulus [3]. This polymer is mainly derived from renewable sources such as corn and cane [4]. PLA possesses a limited impermeability against water, oxygen, and carbon dioxide [5]. Although PLA is derived

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