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Research papers

Phytic acid as a biomass flame retardant for polyrotaxane based phase change materials

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ABSTRACT

Petrochemical resources are facing depletion and human long-term survival needs sustainable development. In this era, it is very important to develop new sustainable phase change materials (PCMs), because it has shown great application value in the effective utilization of industrial waste heat, solar energy harvesting, and electronic heat treatment. In this work, we reported a biomass phytic acid (PA) modified polyrotaxane (PLR) as PCMs for thermal management. The tensile performances, fire safety, phase transition performances of the PCMs were investigated. It is found that all the tensile properties, char residual, and fire-safety of PLR can be enhanced remarkably by introduce of PA. Typically, the Young's modulus, yielding strength and tensile strength of the PLR were 826.7 MPa, 14.2 MPa and 14.2 MPa, respectively, and significantly increased to 1527.4 MPa, 22.1 MPa, and 24.0 MPa respectively, with the addition of 10 wt% of PA. Elongation (>783 %) for all modified PCMs was gradually increased with the increase of PA contents. Thermal analysis shows that the fire safety of PLR is significantly improved. Specifically, for the best sample PLR-PA30, the pHRR could decrease by 54.2 %, THR decreased by 34.0 %; and the LOI increased from 20.8 % to 28.2 %. The PCMs showed the perfect form stability and leakage-proof performance, enhanced thermal conductivity and outstanding cycle properties. Notably, its biomass source, and high flexibility, enhanced fire safety and completely green pathway may provide a practical way for the highly flexible and sustainable packaging of electronic devices for heat treatment.

1. Introduction

Bill Gates recently pointed out that climate warming will be a global disaster that may be more extensive, serious and far-reaching than the COVID-19. In order to avoid disaster, reverence and awe of nature is a life attitude everyone should have; low carbon emission and sustainable development need to be the primary concern of material scientists and chemists; and clean energy, green chemistry and environmental protection manufacturing should be our preferred scientific proposition and main direction. Phase change materials (PCMs) have attracted more and more attention recently in the corresponding field of thermal regulation [1,2] energy saving, harvesting and storage [3–5]. Nowadays, PCMs involving high melting enthalpy have been applied for heat regulation of electronic devices [6,7]. However, it is still a big challenge to apply PCMs conveniently because of their solid rigidity nature and leakage problem. Considerable strategies have been dedicated to prepare flexible PCMs by blending PCMs substances with some other flexible polymers [8–10]. The design and preparation of intrinsically flexible PCM films are also well explored [11]. With the further development of 5G technology, the amount of PCMs requests for both smart heat regulation and the safety concerns increases. However, the organic PCMs are easily flammable, e.g., PEG and paraffin. The fire safety is still the main limitation for the practical applications of organic PCMs. Thus, it is imperative to improve the fire safety for advanced PCMs.

Nowadays, introducing flame retardants into PCMs is a most widely used pathway to enhance the flame retardancy of PCMs [12–17]. On the other aspect, some renewable resources like DNA [18,19], chitosan [20], soy protein [21], starch [22], and phytic acid (PA) [23–25] have been widely applied as sustainable flame retardants in the past decades. PA, an eco-friendly molecule, is biocompatible, biodegradable, nontoxic, and phosphorus-rich (28 wt%) [26]. Thus it has been widely used as a bio-based flame retardant for polymers [27,28]. For examples, the

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