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Biodegradable polymers and their layered silicate nanocomposites: In greening the 21st century materials world

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Abbreviations: AIBN, *N*,*N*′-azobis(isobutyronitrile); ASP, aliphatic synthetic polyester; ATRP, atom transfer radical polymerization; BAP, biodegradable aliphatic polyester; C, cloisite®; CL, caprolactone; CA, cellulose acetate; CAB, cellulose acetate butyrate; CAP, cellulose acetate propionate; CEC, cation exchange capacity; C18MMT, octadecyl ammonium modified montmorillonite; CTEM, conventional transmission electron microscope; DD, deacetylation degree; DGEBF, diglycidyl ether of bisphenol F; DMA, *N*,*N*′-dimethylacetamide; DMA, dynamic mechanical analysis; ELO, epoxidized linseed oil; ESO, epoxidized soybean oil; FH, fluorohectorite; FVO, functionalized vegetable oil; HDT, heat distortion temperature; HRTEM, high resolution transmission electron microscope; MMT, montmorillonite; OEL, octyl epoxide linseedate; OMLS, organically modified layered silicate; OMSFM, organically modified synthetic fluorine mica; o-PCL, oligo poly(caprolactone); PBS, poly(butylene succinate); PHA, poly-(hydroxy alkanoates); PHB, poly(3-hydroxy butyrate); PHBV, poly(3-hydroxybutyrate-co-3- hydroxyvalurate); PCL, poly(caprolactone); PDI, polydispersity index; PEO, poly(ethylene oxide); PLA, polylactide; PLS, polymer layered silicate; POM, polar optical microscopy; PS, polystyrene; PVA, poly(vinyl alcohol); PVC, polyvinyl chloride; XRD, X-ray diffraction; TEM, transmission electron microscopy; THF, tetrahydrofuran; SAP, saponite; SEM, scanning electron microscopy; SAXS, small angle X-ray scattering; T_D^i, initial degradation temperature; TEC, triethyl acetate; TEMPO, 2,2,6,6-tetramethylpiperidine; TGA, thermogravimetric analysis; TPS, thermoplastic starch; XRD, X-ray diffraction.

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Abstract

This review aims at highlighting on recent developments in preparation, characterization, properties, crystallization behaviors, melt rheology, processing, and future applications possibilities of biodegradable polymers and their layered silicate nanocomposites. These materials are attracting considerable interest in materials science research. Montmorillonite and hectorite are among the most commonly used smectite-type layered silicates for the preparation of nanocomposites. In their pristine form they are hydrophilic in nature, and this property makes them very difficult to disperse into biodegradable polymer matrices. The most common strategy to overcome this difficulty is to replace the interlayer clay cations with quarternized ammonium or phosphonium cations, preferably with long alkyl chains.

A wide range of biodegradable polymer matrices is described in this review with a special emphasis on polylactide because of more eco-friendliness from its origin as contrast to the fully petroleum-based biodegradable polymers and control of carbon dioxide balance after their composting.

Preparative techniques include (i) intercalation of polymers or prepolymers from solution, (ii) in situ intercalative polymerization method, and (iii) melt intercalation method.

This new family of composite materials frequently exhibits remarkable improvements of mechanical and material properties when compared with virgin polymers or conventional micro- and macro-composites. Improvements can include a high storage modulus both in solid and molten states, increased tensile and flexural properties, a decrease in gas permeability and flammability, increased heat distortion temperature and thermal stability, increase in the biodegradation rate, and so forth.

Contents