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Review

The chemomechanical properties of microbial polyhydroxyalkanoates

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ABSTRACT

Microbially produced polyhydroxyalkanoates (PHAs) are fully biodegradable biopolyesters that have attracted much attention recently as alternative polymeric materials that can be produced from biorenewable and biowaste resources. The properties of these biological polymers are affected by the same fundamental principles as those of fossil-fuel derived polyolefins, with a broad range of compositions available based on the incorporation of different monomers into the PHA polymer structure, and with this broad range tailoring subsequent properties. This review comprehensively covers current understanding with respect to PHA biosynthesis and crystallinity, and the effect of composition, microstructure and supramacromolecular structures on chemomechanical properties. While polymer composition and microstructure are shown to affect these properties, the review also finds that a key driver for determining polymer performance properties is compositional distribution. From this review it follows that PHA–PHA blend compositions are industrially important, and the performance properties of such blends are discussed. A particular need is identified for further research into the effect of chemical compositional distribution on macromolecular structure and end-use properties, advanced modeling of the PHA accumulation process and chain growth kinetics for better process control.

Contents

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2D	two-dimensional
3D	three-dimensional
^{13}C	carbon-13
3HB	3-hydroxybutyrate
3HD	3-hydroxydecanoate
3HDD	3-hydroxydodecanoate
3HHx	3-hydroxyhexanoate
3H2MB	3-hydroxy-2-methylbutyrate
3H2MV	3-hydroxy-2-methylvalerate
3H4MV	3-hydroxy-4-methylvalerate
3HO	3-hydroxyoctanoate
3HP	3-hydroxypropionate
3HPE	3-hydroxy-4-pentenoate
3HTD	3-hydroxytetradecanoate
3HV	3-hydroxyvalerate
4HB	4-hydroxybutyrate
ACP	acyl carrier protein
Ae	aerobic
ADF	aerodynamic feeding
AFM	atomic force microscopy
An	anaerobic
BOD	biochemical oxygen demand
CCD	chemical compositional distribution
CH_2	methylene group
CoA	coenzyme A
COD	chemical oxygen demand
Da	Dalton
DMTA	dynamic mechanical thermal analysis
DO	dissolved oxygen
DOC	dissolved organic carbon concentration
DSC	differential scanning calorimetry
DP	degree of polymerization
E_a	activation energy
EBPR	enhanced biological phosphorus removal
ESI-MS	electrospray ionization multistage mass spectrometry
F_{BB}	fraction of the BB diad sequence in a P(3HB-*co*-3HV) copolymer
F_{BV}	fraction of the BV diad sequence in a P(3HB-*co*-3HV) copolymer
F_{VB}	fraction of the VB diad sequence in a P(3HB-*co*-3HV) copolymer