〈技術資料〉

紙包装の高機能化に向けたナノコンポジットコーティング設計：データに基づく分散と性能の最適化

Data-Driven Design of Nanocomposite Coatings for High-Performance Paper Packaging: Linking Nanoclay Dispersion to Barrier Properties

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Abstract

Paper-based packaging is increasingly demanded as a renewable and recyclable alternative to plastics, yet its intrinsic porosity and hydrophilicity limit barrier performance and wet durability. Nanocomposite coatings, where layered silicate nanoclays are dispersed in biodegradable polymers, can enhance oxygen and water-vapor barriers via a tortuous diffusion path, but practical implementation is often constrained by difficult dispersion control. This article introduces a data-driven framework to evaluate and design nanoclay dispersion by combining Hansen solubility parameters (HSP) and low-field time-domain NMR relaxation. HSP provides a predictive measure of solvent–particle affinity, while an NMR-based relaxation number, derived from T_2 relaxation behavior, quantifies interfacial interactions even in rapidly settling, unstable dispersions through *in situ*, short-time measurements. Using this approach, a synthetic hectorite nanoclay was selected and incorporated into poly (butylene adipate terephthalate) (PBAT) coatings on paper using tetrahydrofran. XRD and TEM confirmed intercalation and partial exfoliation with relatively uniform dispersion at moderate clay loadings, leading to clear improvements in gas and water-vapor barrier properties, as well as water/oil resistance and mechanical performance. The proposed framework shifts formulation from empirical trial-and-error to rational dispersion design applicable across coatings, inks, and adhesives.

キーワード：紙包装、ナノコンポジットコーティング、ナノクレイ分散、ハンセン溶解度パラメータ（HSP）、低磁場時間領域（パルス）NMR（TD-NMR）

Keywords: Paper packaging, Nanocomposite coatings, Nanoclay dispersion, Hansen solubility parameters (HSP), Low-field time-domain pulsed NMR (TD-NMR)

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