Fundamental Material Properties - Molecular Dynamic Characteristics -

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Scope of Research

The research activities in this subdivision cover structural studies and molecular motion analyses of polymers and related low molecular weight compounds in the crystalline, glassy, liquid crystalline, solution, and frozen solution states by high-resolution solid-state NMR, dynamic light scattering, electron microscopy, X-ray diffractometry, and so on, in order to obtain basic theories for the development of high-performance polymer materials. The processes of biosynthesis, crystallization, and higher-ordered structure formation are also studied for bacterial cellulose.

Research Activities (Year 2001)

Presentations

Molecular Dynamics Simulation of Conformation and Dynamics for Liquid Crystalline Polyether, Ishida H, Maekawa Y, Horii F, et al., Annual Meeting, Soc. Polym. Sci., Jpn., 24 May.

Structural Analysis of Polyether Crystallized from the Liquid Crystalline Glass, Murakami M, Ishida H, Horii F, Symposium on Macromolecules, Soc. Polym. Sci., Jpn., 14 September.

Structure and Optical Properties of σ–π Conjugated Polymers with Different Silylene Chain Lengths [I] Analysis of Conformation by Solid-State NMR Spectroscopy, Yamada S, Kaji H, Horii F, Annual Meeting, Soc. Polym. Sci., Jpn., 23 May.

Dynamic Properties of Cellulose Triacetate in Methyl Acetate in Dilute-Semidilute Solution Region, Tsunashima Y, Mizuno M, Horii F, Annual Meeting, Soc. Polym. Sci., Jpn., 24 May.

Dynamic Clustering of Cellulose Triacetate in Solution as Measured by Dynamic Light Scattering (Prague, Czech), Tsunashima Y, IUPAC Czech Chemical Society, 11 July.

Dynamics and Structure Formation of Cellulose Triacetate in Dilute Solution, Tsunashima Y, Onodera G, Horii F, Soc. Polym. Sci., Jpn., 13 September.

Dissipative Structures and Non-Ergodic Scattering in Solution of Cellulose Acetates in Couette Flow (New York, USA), Tsunashima Y, SUNY Chemical Society, 14 December.

TEM structure analysis of band-like cellulose assemblies produced by *Acetobacter xylinum* at low temperature, Hirai A, Tsuji M, Horii F, Annual Meeting, Soc. Polym. Sci., Jpn., 23 May.

Structure changes of band-like cellulose assemblies produced by *Acetobacter xylinum* during low temperature cultivation, Hirai A, Tsuji M, Horii F, Annual meeting, Cellulose Soc. Jpn, 13 July.

Aggregated state of cellulose molecules produced by *Acetobacter xylinum*, Hirai A, Tsuji M, Horii F, Symposium on Macromolecules, Soc. Polym. Sci., Jpn., 12 September.

Study on the new microbe isolated from reservoir rock. 2. Structures on different levels for cellulose produced, Horii F, Hirai A, Kuwabara K, et al., Annual meeting, Cellulose Soc. Jpn, 13 July.

Conformational Analyses of Poly(ethylene naphthalene-2,6-dicarboxylate) by Two-Dimensional Double-Quantum Solid-State NMR Spectroscopy, Inui N, Kaji H, Horii F, et al., Symposium on Macromolecules, Soc. Polym. Sci., Jpn., 12 September.

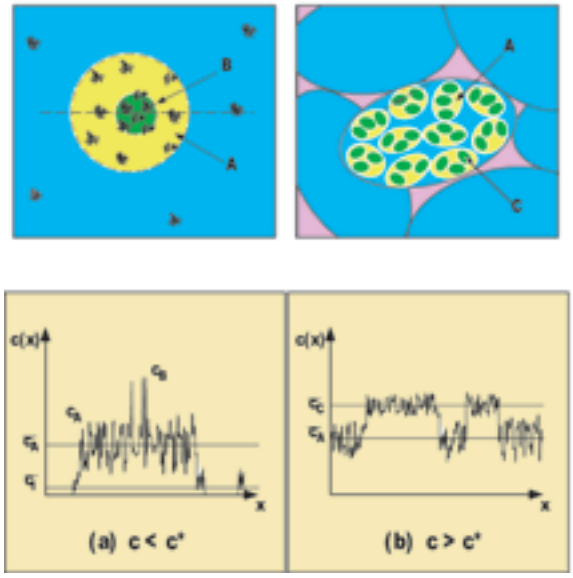
Topics

Dynamic Self-Assemblies of Cellulose Acetates in Polar Solvents

Abstract. Dynamics of cellulose diacetates (CDA, the degree of substitution DS=2.44, Mw = 1.70×10^5, Mw/Mn = 1.23) in polar solvents, dimethylacetamide (DMAc), was investigated at 2–60°C through dynamic light scattering (DLS) in quiescent state. CDA formed a few types of structures in polar solvents; a single CDA chain and the dynamical self-assemblies due to concentration fluctuations, which were created temporarily and locally by a solvent-mediated hydrogen bonding between the inter-molecular C-6 position hydroxyl groups. In addition, CDA showed low-temperature solubility; CDA was expected to dissolve molecularly below –20°C, but to take a phase separation above 65°C, and exhibited a chain reorganization in dynamic structures around a middle temperature T* = 34°C. Both the correlation length and the dynamical second virial coefficients of the dynamic structures gave a discontinuity, maximum, or minimum at T*. These dynamic features could correspond to the critical fluctuations and the LCST behavior provided that T* were regarded as the critical temperature.

Discussion. CDA took three translational modes in DMAc, i.e., the single chain diffusion (Mode I) and two dynamical fluctuations (Modes II and III). The former gave the hydrodynamic radius R_H and the latter the correlation lengths ξ_{II} and ξ_{III}. The temperature dependence of these sizes in the temperature range of 2–62°C shows a unique feature. In contrast to the monotonic increase of R_H with decreasing temperature (Mode I), ξ_{II} and ξ_{III} seem to show a singularity around T* = 33.8 °C in the way that they rise sharply toward a maximum or an infinity from both sides of T*. In addition, ξ_{II} and ξ_{III} disappear below –12 °C, and come to join into a small value above 65°C. These two features indicate that the molecular dispersion of the single chain can be achieved below –12°C and two phase separation occurs above 65°C. Thus, CDA is in the low temperature solubility system, i.e., stable at lower temperature. The extreme increase of ξ_{II} and ξ_{III} at T* means that Modes II and III would amplify their concentration fluctuations excessively and critically as T approaches to T*.

In accordance with the change in ξ, the dynamical second virial coefficients $k_{D,I}$ for the single chain changes its sign from positive (repulsive) to negative (attractive) at T*, while $k_{D,II}$ and $k_{D,III}$ for the assemblies are always negative but take zero or discontinuity at T*. The state that $k_{D,I} = k_{D,II} = 0$ would mean that the chains are unstable and that a variety of cluster formation would be amplified at T* because the intermolecular interactions are apparently cancelled out under a delicate balance between multi-order interactions acting on the chains. We could thus have an image that T* is a critical temperature in the LCST system. The peculiarity in ξ_{II} and ξ_{III} around T* could be recognized as the dynamic critical fluctuation. This image can be verified by double-logarithmically plotting ξ and R_H against $|T - T^*|$, as is the case for the usual critical phenomena. The critical exponent ν in the expression that $\xi \propto |T - T^*|^{-\nu}$ was given as 0.15, 0.68, and 1.5 for ξ_{III}, ξ_{II}, and R_H at $T > T^*$, respectively. The value $\nu = 0.68$ is close to the theoretical one, 0.625. The self-assemblies discussed above are formed in a nest of structures as illustrated by Figure below, where the temporarily created excess-concentration-fluctuations c(x) at a given time spot are plotted against the local space x.



Precise Conformational Analyses of Poly(acrylonitrile) by Two-Dimensional Multiple-Quantum Solid-State NMR Methods, Kaji H, Schmidt-Rohr K (Iowa State Univ.), Symposium on Macromolecules, Soc. Polym. Sci., Jpn., 12 September.

The analysis of O^2H-π interaction in phenoxy resins by a MAS NMR method without irradiating ^2H nuclei, Kaji H, Horii F, Schmidt-Rohr K (Iowa State Univ.), NMR Conf. Jpn., 14 November.

The analysis of dynamics in polymers by a two-dimensional solid-state ^{13}C MAT technique, Fuke K, Kaji H, Isomura T, et al., NMR Conf. Jpn., 16 November.

Grants

Horii F, Studies on effects of dynamics factors and hydrogen bonding on structure formation for main-chain thermotropic liquid crystalline polymers, Grant-in Aid for Scientific Research (B)(2), 1 April 2000 -31 March 2002.

Hirai A, Molecularly aggregated state of bacteria-produced cellulose made through nano-spinning, Grant-in Aid for Scientific Research (C)(2), 1 April 2001 -31 March 2003.

Kaji H, Precise analyses of polyamorphous structure and dynamics by advanced solid-state NMR, Grant-in Aid for Young Scientists (A), 1 April 2001 -31 March 2003.