What Determines Hierarchical Structure of Microbial Cellulose?  
–Interplay among Physics, Chemistry and Biology–

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Abstract

In this paper, we investigate the hierarchical structure in "pellicle" (microbial cellulose gel), produced by bacteria genera Acetobactor Xylinum. A pellicle is a supramolecular system, surprisingly containing up to 99% water by weight. The formation of hierarchical structures in the pellicle involves a nearly simultaneous and subsequent process of polymerization, crystallization and assembly. These processes are controlled by combined factors of (i) highly symmetric and stiff molecular structure of -1,4-linked glucans, (ii) biogenesis by prokaryotic and aerobic genera and (iii) physicochemical factors, imposed under a cultivation process (temperature, agitation and etc.). This is a new topic of soft matter science as a non-equilibrium open system, therein physics, chemistry and biology interplay. We employed ultra-small-angle neutron scattering, in order to cover over a wide length scales from nm to 10 m. The microbial cellulose swollen by water shows small-angle scattering obeys a power law q-behavior according q as a function of a magnitude of scattering vector q. The power law, determined by scattering, is attributed to mass fractal due to distribution of the center of mass for crystallite (microfibril) in amorphous cellulose swollen by water. As q increases, varies as 2.5, 1 and 2.35, corresponding to a gel-network composed of bundles, a bundle composed of cellulose ribbons, and concentration fluctuations in a bundle, respectively. From mass fractal q-behavior and its length scale limits, we evaluated a volume fraction of crystallite in a microbial cellulose. It was found that the crystallite occupies only about 10% of a bundle. For in-situ observations on the hierarchy, we used a focusing & polarized neutron small-angle scattering spectrometer (SANS-J-II) at research reactor JRR3, Tokai, Japan.

Keywords: hierarchical structure, microbial cellulose, ultra-small-angle neutron scattering

References