Self-assembling in gelation processes of NIPAAM gel

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N-Isopropylacrylamide (NIPAAM) gel is a chemical gel and exhibits volume phase transition at 32°C. The dynamics of the volume phase transition is affected by the internal structure of the gel and the formation process of the internal structure is very important. The internal structures or inhomogeneity of NIPA gels strongly depends on the gelation temperature since the polymer/NIPAM/water system has lower critical solution temperature phase diagram with theta temperature being 30.5°C so that the macrophase separation is involved during the gelation process at higher temperature.

In this study, we investigated the gelation process of NIPA after the onset of temperature-jump by using time-resolved small-angle X-ray scattering (SAXS). We shall present how the temperature affects the internal structure formation.

EXPERIMENTAL

Materials and Method. NIPAAM (monomers, 1.47M), N,N,N,N-tetramethyl ethylenediamine (accelerator, 17.8mM) were dissolved into water purged with nitrogen. After addition of 17.8mM ammonium peroxydisulfate (AP) solution to the monomer solution, the AP solution =25/75 (v/v), the monomer solution was quickly transferred into a cell. Then the cell was put into the heater block for SAXS experiments. SAXS experiments were conducted at the BL45XU, Spring-8. We used the CCD camera with Image-Intensifier. After the onset of the pressure jump, we measured the time changes in the scattered intensity with the scan rate being 10s/scan. All scattered intensity profiles were corrected for background and then circularly averaged for further analyses.

RESULTS AND DISCUSSION

Figure 1 shows the time change in the scattered intensity I(q,t) as a function of the magnitude of scattering vector q=(4πλ)/λsin(θ/2), with θ being the scattering angle, after the onset of temperature jump to 35.0°C, where the turbid gel was formed. At time t=145s, I(q) show q⁴ dependence and obeys Porod law, indicating that the macroscopic phase separation has already occurred before the completion of the gelation. We found that the scattered intensity during the gelation process can well be described by the following equation:

\[ I(q) = Aq^4 \frac{I(0)}{1 + q^2s^2} \]  (1)

where A is proportional to interfacial area density and the square of the amplitude of the concentration between two phases, I(0) represents the osmotic compressibility of the gel network, and s is the correlation length of the network corresponding to the mesh size of the network. Fig 2 shows the time changes of A, I(0), and s. From the time changes in these parameters, the gelation process at 35.0°C can be divided into the following two regions.

(i)Region 1, t<295s : In this region, all parameters increase with time, indicating that the macrophase separation progresses and the macrophase separation is accelerated by the increase of molecular weight of NIPA gel.
(ii) Region II, 295s<t : In this region, A becomes constant whereas I(0) and s decreases with time. Invariance of A is due to the fact that the macrophase separation has been pinned down by gelation. The decrease in I(0) and s is caused by the fact that the networks becomes dense associating with the progress of the gelation.

The results of the gelation process at 19.7°C will be discussed in the meeting.

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REFERENCES