

Internal Structure of Novel Nanoparticles Composed of Chitosan/DNA/ Poly- γ -Glutamic Acid

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In this study, biodegradable nanoparticles (NPs), composed of chitosan (CS) and poly- γ -glutamic acid (γ -PGA), were prepared by an ionic-gelation method for transdermal DNA delivery (CS/ γ -PGA/DNA NPs). The conventional CS/DNA NPs without the incorporation of γ -PGA was used as a control. Small-angle X-ray scattering (SAXS) was used to examine the internal structures of test NPs. The SAXS profiles of the CS/ γ -PGA, CS/DNA and CS/ γ -PGA/DNA complexes and γ -PGA/DNA mixture were compared. The mixture of γ -PGA and DNA in aqueous solution displayed no ordered scattering peaks, showing that these two anionic polyelectrolytes were well dispersed in the aqueous medium without complexation. The scattering intensity of CS/ γ -PGA complex exhibited a power-law-like scattering, signaling a fractal-like internal structure in the complex.

The SAXS profile of CS/DNA NPs was seen to display a well-defined peak at 2.3 nm^{-1} . In this case, the complex NPs consisted of CS, DNA and water. Since the electron density of DNA was much larger than the other two species, it was reasonable to assume that the observed SAXS pattern was dominated by DNA, namely, the pattern related primarily to the spatial correlation of the DNA chains in the complex. The characteristic interhelical distance calculated from the peak position (q_{DNA}) via $d_{\text{DNA}} = 2 / q_{\text{DNA}}$ was 2.7 nm, which was slightly larger than the diameter of DNA (2.0 nm). Consequently, the DNA condensation induced by its complexation with CS generated a mesophase in which the DNA chains were closely packed.

The SAXS profile of the system containing CS, γ -PGA and DNA appeared to be the superposition of the two scattering curves of CS/DNA and CS/ γ -PGA

complexes. In this case, the DNA-DNA correlation peak from the CS/DNA complex was partly masked by the monotonically decayed profile associated with the CS/ γ -PGA complex. However, the position of this peak was essentially identical with that found for the binary CS/DNA NPs. The observed scattering feature hence attested that DNA and γ -PGA complexed rather independently with CS in the solution and the internal structures of the respective complexes closely resembled those formed in the corresponding binary systems. We thus proposed that the individual NPs formed through the complexation in the ternary system actually consisted of two types of domains, namely, the CS/ γ -PGA complex domain and the CS/DNA complex domain in which the DNA chains were closely packed, as schematically illustrated in Figure 1.

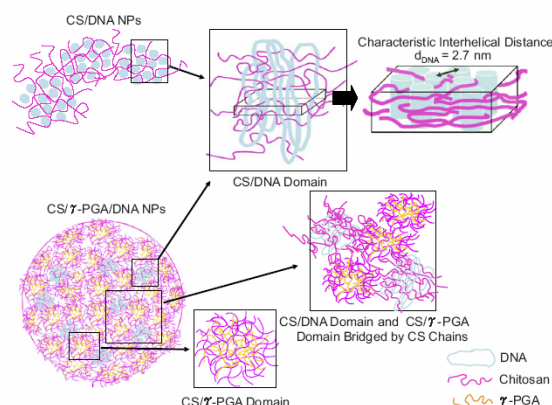


Figure 1. Schematic illustrations of the internal structures of CS/DNA and CS/g-PGA/DNA. CS: chitosan; g-PGA: poly-g-glutamic acid.