DNA-induced Turbulent Drag Reduction and Their Molecular Characteristics

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Polymer induced turbulent drag reduction achieved by adding minute amounts of high molecular weight DNAs (λ- and calf-thymus DNAs: CT-DNA has a molecular size of about 75.7 kbp with polydispersity while the monodisperse λ-DNA possesses 48.5 kbp) was investigated using a rotating disk apparatus (RDA). The RDA consists of a stainless steel disk enclosed in a cylindrical thermostatically controlled container [1]. The percent DR was obtained as a function of time by injecting drag reducer into the turbulent flow generated by the RDA. Its result on molecular degradation under turbulent flow was verified via an eletrophoresis analysis such that the DNA chains having much higher molecular size are more susceptible to mechanical degradation in a turbulent flow [2, 3]. The DR efficiency of CT-DNA having molecular weight distribution was much lower than that of monodisperse λ-DNA. But the values of DR were nearly constant for an hour, contrary to λ-DNA. The number CT-DNA molecules having effective chain length for DR is considered to be small at a same concentration. In addition, DNA chains having much higher molecular size are much susceptible to mechanical degradation in turbulent flow
Fig. 1 shows the comparison with linear flexible high molecular weight polyacrylamide at the same condition with λ-DNA [2, 4]. The mechanical degradation behavior was totally different from that of DNA. Although it showed much higher DR efficiency, the DR effect eventually diminished to zero effect within five min.

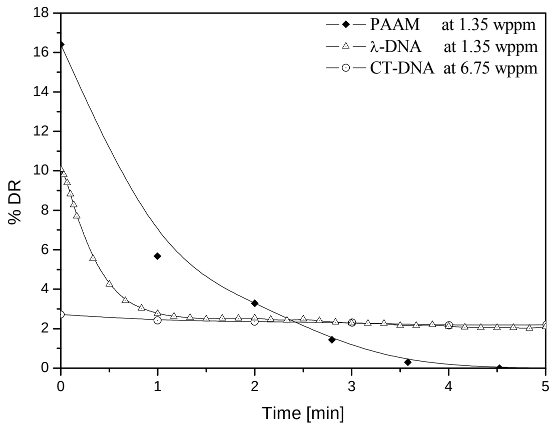

Fig. 1 DR characteristics of PAAM ,CT- and λ-DNA.

Fig. 2 shows the %DR for 1.35 wppm of λ-DNA as a function of time at 1157rpm ($N_{Re}=5.9\times10^5$) with and without SPD. To identify the role of SPD in turbulent drag reduction induced by DNA, we compared the results with that of simple λ-DNA drag reducing phenomena.

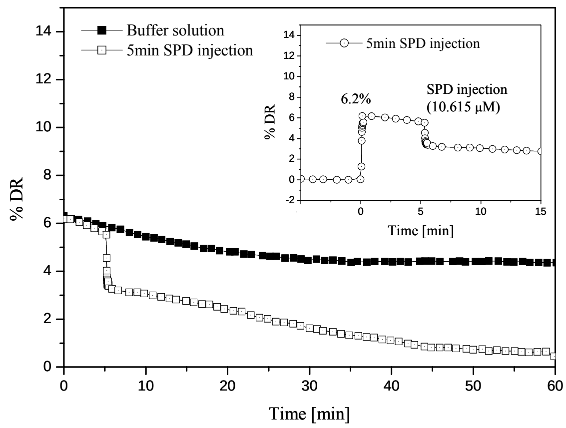

Fig. 2 %DR versus time for λ-DNA in buffer solution at 25℃ (with (□) and without (■) SPD).

We report on DNA compaction by condensing agent in a turbulent flow, based on DR efficiency [5]. By adopting the coil-globule transition concept of DNA to turbulent drag reduction phenomena, we can evidently and dramatically examine the structural effect on the DR. The addition of spermidine (SPD) into turbulent flow as a condensing agent of the λ-DNA showed the sudden decrease of DR efficiency. The resistant and residual DR efficiency is originated from the residual half cut DNA in turbulent flow. This single step mechanical molecular degradation can be explained via the critical strain rate concept (ε_f), which is related to the contour length (L) and then to the molecular weight (M_w) of a polymer chain in an inverse square mode [6]; $\varepsilon_f \propto 1/L=1/M_w^2$, indicating that the single step half-cut degradation process may be possible, if the critical strain rate for half-cut polymer is much higher than the flow field. This work thus shows that model DNA can be efficiently used to investigate the length scale involved in the DR.

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