1. **Viscosity measurements.** To measure viscosity, a latex bead ensemble with a known size (~200 nm in radius) in the two PEG solutions were measured by dynamic light scattering method (Malvern Zetasizer Nano-ZS90) in order to infer the viscosity of the PEG solutions using Stokes-Einstein relation. The viscosity was set as the parameter of water \( (\eta_{\text{water}}) \) in the size measurements, which resulted in a larger measured value compared with its real size \( (r_{\text{real}}) \). Then, the measured size \( (r_{\text{measured}}) \) has a relationship with the viscosity of the PEG solution according to Stokes-Einstein relation: 

\[
\frac{\eta_{\text{water}}}{\eta_{\text{PEG}}} = \frac{r_{\text{real}}}{r_{\text{measured}}}
\]

Figure S1 gives the results of the size measurements. Using the results and the relationship, it was inferred that the viscosity of PEG 600 is \(~3.9\) times of the viscosity of water, and the ratio is \(~4.5\) for PEG 6000.
Fig. S1 Size measurements of a latex ensemble (~200 nm in radius) in different solutions by dynamic light scattering.
2. Relaxation dynamics by varying the external force.

Fig. S2 The relaxation curve of DNA conformation by varying the external force ($F$) from 4.0 pN to 2.3 pN. The circled region indicated that the relaxation took less than 2 sec.