Electronic Supplementary Material (ESI) for Soft Matter.
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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 (η_{water}) in the size measurements, which resulted in a larger measured value compared with its real size (r_{real}). Then, the measured size ($r_{measured}$) has a relationship with the viscosity of the PEG solution according to Stokes-Einstein relation: $\frac{\eta_{water}}{\eta_{PEG}} = \frac{r_{real}}{r_{measured}}$. 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.

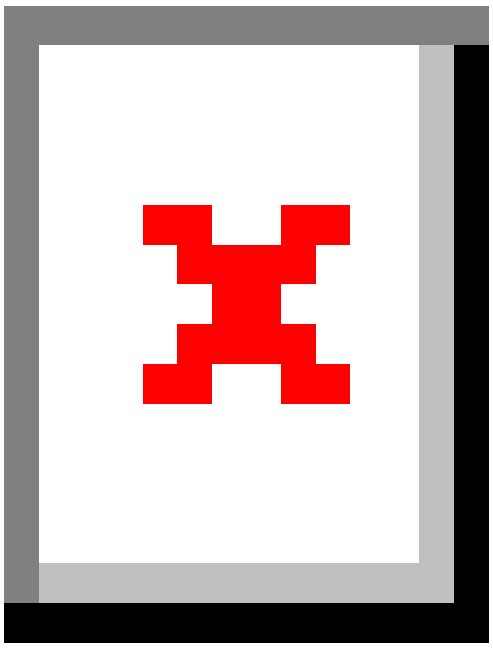

Fig. S1 Size measurements of a latex ensemble (~200 nm in radius) in different solutions by dynamic light scattering.

2. **Relaxation dynamics by varying the external force.**

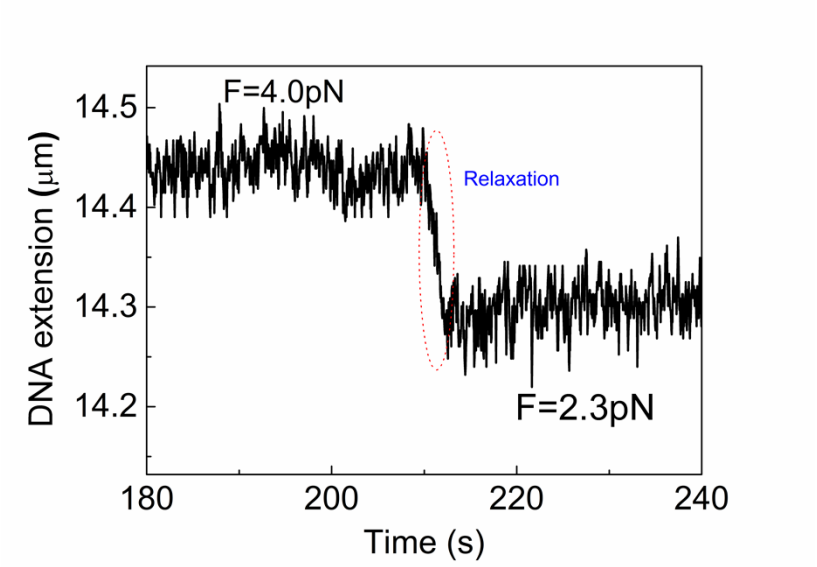

Fig. S2 The relaxation curve of DNA conformation by varying the external force (F) from 4.0 pN to 2.3 pN. The circled region indicated that the relaxation took less than 2 sec.