Elastic response and secondary structure of single-stranded DNA

Xavier Viader-Godoy,[1] Joan Camunas-Soler,[1] Maria Marti-Prieto,[1] and Felix Ritort[1, 2]

[1] *Departament de Fisica Fonamental, Universitat de Barcelona, Diagonal 647, 08028 Barcelona, Spain*
[2] *CIBER de Bioingeniera, Biomateriales y Nanomedicina, Instituto de Salud Carlos III, Madrid, Spain*
email: fritort@gmail.com

Single-stranded DNA (ssDNA) plays a major role in several biological processes, such as replication or transcription. Therefore, it is of fundamental interest to understand how the elastic response and the formation of secondary structures are modulated by non specific base pairing and the electrostatic interactions. In general,these are non-specific interactions that make the elastic properties of ssDNA more complex than for double-stranded DNA (dsDNA). Furthermore, its properties have been less well studied than for dsDNA.
Single-stranded DNA is obtained by mechanically unzipping a DNA hairpin attached to two micron-sized beads using optical tweezers, and the thermal fluctuations play a major role since the energies involved in the formation of this secondary structure are of the order of k_BT. The mechanical response of ssDNA has been collected in four different-length DNA-hairpin molecules: 6770bp, 3665bp, 1758bp and 480bp, and it shows two different regimes.

I. ELASTIC RESPONSE OF SSDNA

Over 15pN (at room temperature) the elastic behaviour of the force-extension curves can be fitted using the Worm-Like Chain model:

$$f = \frac{k_BT}{L_p}\left[\frac{1}{4}\left(1-\frac{x}{L_0}\right)^{-2}+\frac{x}{L_0}-\frac{1}{4}\right]. \qquad (1)$$

Where L_p and L_0 are the persistence length and the contour length, the charasteristic elastic parameters of the studied molecules. The force only depends on the relative x/L_0 since the original hamiltonian is obtained by only considering local deformation terms, which agrees with previous data[1], within the uncertainty.

II. SECONDARY STRUCTURE OF SSDNA

Under stretching forces of 10pN, the ssDNA molecules show a plateau that indicates the formation of a non-specific secondary structure.
Nucleic acids, specially RNA, have been found[2,3] to be able to create long-range structures. In the force-relative extension curves shown in Fig. (1), they would appear in the form of differences between the force-plateau of different-length molecules: higher plateau-forces for longer molecules. Despite what has been previously

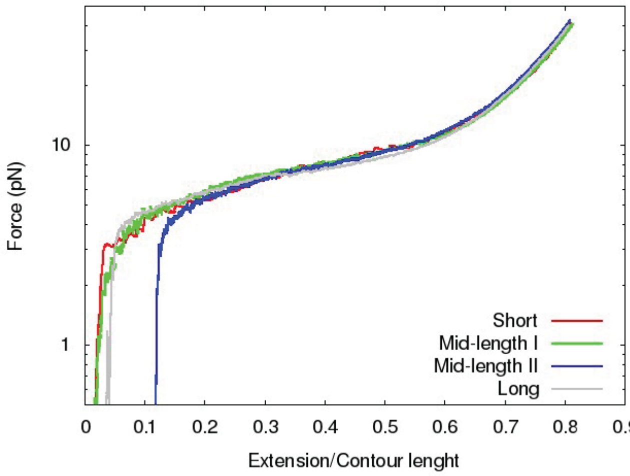

FIG. 1. Data of Short (480bp), Mid-length I (1758bp), Mid-Length II(3565bp) and Long (6770bp) are depicted in this semilogarithmic Force-Normalized Extension. It can be seen the elastic response over 15pN, and under 10pN the emergence of a secondary structure that does not depend on the length of the studied molecules. Data has been averaged in order to minimize the thermal fluctuations.

shown[1], this differences are not found in the random sequences we are working with. Furthermore, a cinematic model based on a previous one[4] of structural disorder is being develop in order to describe the results shown in Fig. (1).

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