Conformation changes of man-made DNA nanostructures

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Nucleic acids form dynamical structures in living organism that have a given function. They are also nanosized materials that can be used in the lab for the construction of self-assembled two-dimensional and three-dimensional nanostructures. Thus, complex man-made structures, such as tiles, rods, cages and more can now be realized using nucleic acids programmed molecular recognition through complementary base pairing. Through the structures' design, it is also possible to introduce the possibility of movement and/or change of conformation, so that the structure is dynamical and can perform a given function. Here, we focus on two of those structures: a box made of DNA [1] and a DNA actuator [2].

The opening of the self assembled DNA box and the rolling motion of the DNA actuator are investigated by fluorescence resonance energy transfer (FRET) spectroscopy and microscopy. FRET spectroscopy is a very sensitive technique that is able to measure small changes in the distance between two fluorophores that are between ~3-7 nm apart. Thus, by labeling the DNA structures with a donor and an acceptor fluorophore, their conformational changes can be followed. Single molecule fluorescence microscopy allows for additional insight into complex and heterogeneous biomolecules [3]. Indeed, single molecule measurements permit to follow the conformational changes dynamics of each molecule independently. This gives information on the conformational heterogeneity and movement dynamics of the studied nanostructures and allows studying specific sub-populations within heterogeneous samples.

The self-assembled DNA box, Figure 1, is made by folding a long single-stranded viral DNA genome in the desired shape with the help of hundreds of short DNA staple strands using the origami technique. It is a closed container 43x36x36 nm^3 in size, whose lid can be opened with DNA keys [1]. A tight control of the box opening is important for potential applications such as the controlled release of a nanocargo. The DNA box is labeled with Cy3 and Cy5 fluorophores, which are placed so that closed and fully opened boxes have high and low FRET efficiency, respectively. We find that the closed boxes indeed show a FRET effect and that the measured value holds information about the local structure of the lid. Upon addition of all keys, no energy transfer between the two fluorophores is observed, indicating that the box opens fully. The lid opening with the help of several DNA keys can thus successfully be controlled.

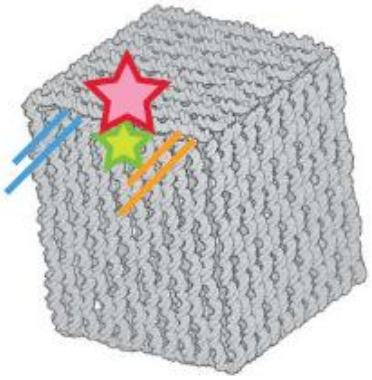
The DNA actuator, Figure 2, is a man made DNA structure that could act as an extendable arm in a nanoscale assembly line. The actuator is composed of two pistons that can slide with respect to each other and the device can be locked in place in 11 different states [2]. By attaching a donor and acceptor fluorophore on each of the two pistons respectively, we can follow the movement of the actuator at the nanometer scale. We find that the actuator can be switched from state to state with the help of DNA locking strands and that movement can be controlled with nanometer precision. Single molecule measurements allow for additional insight into how the DNA actuator is moving.

Our studies allow gaining insight into and control of the movement of complex man-made DNA structures.

References

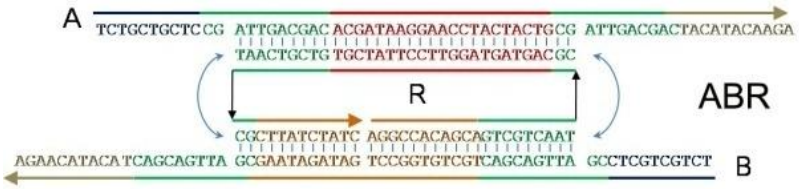
[1] E. S. Andersen *et al.*, Nature 459 (2009) 73-75.
[2] Z. Zhang *et al.*, Angew. Chem. Int. Ed. 50 (2011) 3983-3987.
[3] V. Birkedal *et al.* Microscopy Research and Technique 74**,** (2011) pp.688-98.

Figure 1



Schematic drawing of a DNA box structure with two DNA locks, fluorophore positions are shown with red and green stars [1].

Figure 2



Schematic drawing of a DNA actuator, made of two piston DNA strands A and B and a roller, R, the direction of movement is shown by the arrows on strand A and B (right panel) [2].