Nucleic-acid based molecular structures, devices and circuits

Friedrich Simmel, Physics Department, TU München

The highly predictable base-pairing interactions between sequence-complementary DNA (or RNA) molecules have already been utilized for the construction of a large variety of molecular structures and devices. Most spectacularly, the recently developed DNA origami technique facilitates the molecular assembly of two- and even three-dimensional nanoscale objects with almost arbitrary shape - and with nanometric precision. In this talk, some of our recent work on DNA nanoconstruction will be presented, in particular the utilization of super-resolution microscopy methods for the characterization of DNA nanoassemblies [1,2], and the arrangement of nanoparticles along such DNA scaffolds.

In addition to the realization of static molecular nanostructures one of the goals of molecular nanotechnology is the creation of dynamic molecular assemblies that resemble naturally occurring molecular machines. DNA and RNA molecules have already been utilized for the construction of a variety of molecular devices that can be switched between several distinct mechanical states, that generate nano-scale motion or that bind and release molecules on demand [3].

Even more, DNA recognition reactions have also been employed for the realization of artificial regulatory circuits, which can be used to control the timing of molecular assembly processes, and to direct the operation of nucleic acid-based nanodevices. As an example for this, an artificial RNA-based reaction “circuit” will be demonstrated that generates oscillating RNA concentrations in vitro. The oscillations can be utilized to control the motion of the well-known DNA “tweezers” system, or to clock the production of functional RNA molecules [4]. An important aspect of the generation of larger and more complex molecular circuit is the “back-action” that is exerted by increasing molecular load on the overall systems behavior. This issue will be also discussed in the context of the oscillator/tweezers system.

[1] C. Steinhauer, R. Jungmann, T. L. Sobey, F. C. Simmel, P. Tinnefeld, DNA Origami as a Nanoscopic Ruler for Super-Resolution Microscopy, *Angew. Chem. Int. Ed.* 48, 8870 (2009).
[2] R. Jungmann, C. Steinhauer, M. Scheible, A. Kuzyk, P. Tinnefeld, F. C. Simmel, Single Molecule Kinetics and Super-Resolution Microscopy by Fluorescence Imaging of Transient Binding on DNA Origami, *Nano Lett* 10, 4756 (2010).
[3] Y. Krishnan, F. C. Simmel, Nucleic Acid Based Molecular Devices, *Angew. Chem. Int. Ed.* 50, 3124 (2011).
[4] E. Franco, E. Friedrichs, J. Kim, R. Murray, E. Winfree, F. C. Simmel, Timing molecular motion and production with a synthetic transcriptional clock, *Proc Natl Acad Sci U S A* 108, E784 (2011).