Symposium Physics of Self-Organization in DNA Nanostructures (SYDN)

jointly organized by
the Chemical and Polymer Physics Division (CPP),
the Biological Physics Division (BP),
the Dynamics and Statistical Physics Division (DY), and
the Metal and Material Physics Division (MM)

Artur Erbe
Helmholtz-Zentrum Dresden-Rossendorf
Bautzner Landstraße 400
01328 Dresden
a.erbe@hzdr.de

Friedrich Simmel
Technische Universität München
Am Coulombwall 4a
85748 Garching
simmel@tum.de

Tim Liedl
Ludwig-Maximilians-Universität München
Geschwister-Scholl-Platz 1
80539 München
tim.liedl@physik.lmu.de

Ulrich F. Keyser
Cavendish Lab
University of Cambridge
JJ Thomson Ave
Cambridge CB3 0HE
ufk20@cam.ac.uk

DNA nanotechnology provides a wide range of tools for the fabrication of nanostructures by self-assembly, thus bridging the gap between fabrication strategies, which rely on top-down miniaturization of materials, and those, which create materials from the smallest entities by more traditional synthetic strategies. In addition, the ability of DNA nanostructures to reconfigure in response to external triggers makes these systems ideal candidates for studies of self-organization at the nanoscale. The field has witnessed tremendous progress during the past years, especially due to the development of the DNA origami technique and other synthetic techniques leading to well-ordered structures with dimensions up to several hundred nanometers. This symposium will give an overview of the methods for building nanostructures by self-assembly and of the principles of their interaction with the environment. It will thus provide insight in the possibilities for the construction of controlled nanosystems which new developments in DNA nanotechnology offer.

Overview of Invited Talks and Sessions

(Lecture hall H1)

Invited Talks

SYDN 1.1	Thu	9:30–10:00	H1	**Functional DNA Nanostructures and Their Applications** — •Itamar Willner
SYDN 1.2	Thu	10:00–10:30	H1	**Gaining control of DNA-based nanodevices** — •Francesco Ricci
SYDN 1.3	Thu	10:30–11:00	H1	**Self-assembly and optical properties of single molecule polymers on DNA origami** — •Kurt Gothelf
SYDN 1.4	Thu	11:15–11:45	H1	**DNA origami route to dynamic plasmonics** — •Laura Liu
SYDN 1.5	Thu	11:45–12:15	H1	**DNA templated metal nanostructures** — •Ralf Seidel, Jingjing Ye, Türkan Bayrak, Artur Erbe

Sessions

SYDN 1.1–1.5	Thu	9:30–12:15	H1	**Physics of Self-Organization in DNA Nanostructures**

SYDN 1: Physics of Self-Organization in DNA Nanostructures

Time: Thursday 9:30–12:15 Location: H1

Invited Talk SYDN 1.1 Thu 9:30 H1

Functional DNA Nanostructures and Their Applications — •Itamar Willner — Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

The base sequence of DNA encodes substantial structural and functional information into the polymer. The triggered reconfiguration of nucleic acids provides means to control the functions of DNA nanostructures and materials. This will be exemplified with four examples: 1. DNA machines triggered by auxiliary stimuli, such as a bipedal walker or interlocked circular DNA nanostructures (catenanes), will be introduced. The application of the machines to organize switchable and programmed Au nanoparticle assemblies will be presented. 2. DNA origami tiles provide versatile building blocks for the guided assembly of functional structures. This will be exemplified with the reconfiguration of origami dimer tiles and the use of the system for programmed catalysis. In addition, the triggered unlocking of holes in origami tile, and the use of the nano-holes as confined environments for programmed catalysis will be introduced. 3. DNA-based constitutional dynamic networks (CDNs) provide organized assemblies mimicking complex biological networks. The adaptive and emergent, signal-triggered, functions of CDNs will be introduced, and their application for the programmed transcription/translation of proteins will be addressed. 4. Reversible, signal-triggered DNA-based hydrogels, revealing switchable stiffness properties, are constructed. The stimuli-responsive hydrogels are applied as shape-memory matrices, self-healing materials, signal-controlled drug carriers and mechanical devices.

Invited Talk SYDN 1.2 Thu 10:00 H1

Gaining control of DNA-based nanodevices — •Francesco Ricci — Chemistry Department, University of Rome, Tor Vergata, Rome, Italy

Nature has invented a number of tricks and strategies by which the behaviour of proteins and other biomolecular machines can be finely controlled. These highly optimized and evolved mechanisms allow to control biological pathways with different chemical and environmental stimuli and are at the basis of the high specificity and selectivity of biomolecular machines.

Motivated by the above arguments we have characterized and recreated in-vitro several mechanisms to control the response of DNA-based nanodevices for diagnostic and drug-delivery applications. Using these mechanisms we can finely control the activity of DNA-based nanodevices with different chemical and environmental stimuli including pH, antibodies, enzymes, small molecules and electronic inputs.

I will present an overview of the most representative and recent examples developed in our lab in the above research directions and I will give a brief presentation of the new routes and possibilities that these results offer.

Invited Talk SYDN 1.3 Thu 10:30 H1

Self-assembly and optical properties of single molecule polymers on DNA origami — •Kurt Gothelf — iNANO, Aarhus University

We are using DNA as a programmable tool for directing the self-assembly of molecules and materials. The unique specificity of DNA interactions and our ability to synthesize artificial functionalized DNA sequences makes it the ideal material for controlling self-assembly and chemical reactions of components attached to DNA sequences. In particular we are using DNA origami, large self-assembled DNA structures as a template for positioning of materials such as organic molecules, polymers and biomolecules. In recent years we have developed methods for functionalizing conjugated polymers with multiple DNA strands in a graft type fashion. We have prepared long phenylene-vinylene and fluorene polymers and synthesized DNA strands extending from most of the repeat units of the polymers. The polymers self-assemble on tracks of complementary DNA strands extending from DNA origami structures and in this way the routing of the individual polymers can be controlled. By immobilizing fluorescent dyes along the polymer we have investigated the properties of the polymers as single molecule optical wires.

15 min. break

Invited Talk SYDN 1.4 Thu 11:15 H1

DNA origami route to dynamic plasmonics — •Laura Liu — Heidelberg University

A prerequisite to build advanced plasmonic architectures is the ability to precisely control the organization of metal nanoparticles in space. To this end, DNA origami represents an ideal construction platform owing to its unique sequence specificity and structural versatility. I will present sequentially a diverse set of DNA-assembled plasmonic nanostructures according to their characteristic optical properties. I will also discuss about the inevitable evolution from static to dynamic plasmonic systems along with the fast development of this interdisciplinary field. Finally, possible future directions and perspectives on the challenges are elucidated.

Invited Talk SYDN 1.5 Thu 11:45 H1

DNA templated metal nanostructures — •Ralf Seidel[1], Jingjing Ye[1], Türkan Bayrak[2], and Artur Erbe[2] — [1]Peter Debye Institute for Soft Matter Physics, Universität Leipzig, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Biological systems have developed a number of mechanisms how to assemble inorganic matter with complex shapes, e.g. by using correspondingly formed biomolecular structures as templates. DNA nanotechnology has recently provided a wealth of techniques to fold DNA into well-defined two- and three-dimensional structures. Here we explore, how we can use such complex DNA objects to synthesize inorganic materials with programmable shapes. To this end we employ a concept in which rigid three-dimensional DNA origami nanostructures are used as molds to dictate the final shape of metal particles that form by a seeded-growth procedure. We use individual molds as bricks to build extended and more complex mold structures. These support the formation of extended metal structures, such as μm-long gold nanowires with much higher uniformity than obtained in previous DNA metallization procedures. Furthermore, different specific interfaces between individual mold bricks as well as mold bricks of different shapes allow to tightly control the size as well as the morphology and geometry of the resulting metal structures in a programmable and highly modular fashion. Transport measurements confirm the electric conductivity of these structures. By integrating other materials into the mold-based assembly scheme, inorganic heterostructures can be assembled as a first step towards electronic device fabrication.