AKB 20 Nano-Biomaterials and Devices

Time: Thursday 09:45–12:45 Room: ZEU 255

Invited Talk AKB 20.1 Thu 09:45 ZEU 255

DNA self-assembly: nanostructures and molecular machines — •Andrew Turberfield — University of Oxford, Department of Physics, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, United Kingdom

DNA is a wonderful material for nanoscale construction. It is a structural material whose self-assembly can be programmed by making use of its information-carrying capability; its hybridization can also be used as an energy source for molecular devices. I shall describe our recent work on three-dimensional nanofabrication and molecular machinery, including progress towards the construction of a free-running synthetic molecular motor.

Invited Talk AKB 20.2 Thu 10:15 ZEU 255

Synthesis, properties and perspectives of complex nanocrystal structures — •Liberato Manna — National Nanotechnology Laboratory of CNR-INFM, Distretto Tecnologico - Isufi, Via Arnesano Km 5, 73100 Lecce, ITALY

Research on colloidal nanocrystals has moved from the synthesis of simple structures, such as spherical nanoparticles, to more elaborate shapes such as rods,[1-3] stars, discs, branched nanocrystals [1,4] and recently to nanoparticles based on inorganic sections interconnected without the need of organic linkers.[5-8] Nanocrystal heterostructures represent a convenient approach to the development of nanoscale building blocks, as they group inorganic sections with different functionalities in the same particle. The present talk will give an overview of the synthetic strategies to complex nanocrystals and will highlight their structural properties, as well as the perspectives in this field.

[1] Manna, L.; Scher, E. C.; Alivisatos, A. P., Synthesis of soluble and processable rod-, arrow-, teardrop-, and tetrapod-shaped CdSe nanocrystals. Journal of the American Chemical Society 2000, 122, (51), 12700-12706.

[2] Peng, X. G.; Manna, L.; Yang, W. D.; Wickham, J.; Scher, E.; Kadavanich, A.; Alivisatos, A. P., Shape control of CdSe nanocrystals. Nature 2000, 404, (6773), 59-61.

[3] Hu, J. T.; Li, L. S.; Yang, W. D.; Manna, L.; Wang, L. W.; Alivisatos, A. P., Linearly polarized emission from colloidal semiconductor quantum rods. Science 2001, 292, (5524), 2060-2063.

[4] Manna, L.; Milliron, D. J.; Meisel, A.; Scher, E. C.; Alivisatos, A. P., Controlled growth of tetrapod-branched inorganic nanocrystals. Nature Materials 2003, 2, (6), 382-385.

[5] Milliron, D. J.; Hughes, S. M.; Cui, Y.; Manna, L.; Li, J. B.; Wang, L. W.; Alivisatos, A. P., Colloidal nanocrystal heterostructures with linear and branched topology. Nature 2004, 430, (6996), 190-195.

[6] Kudera, S.; Carbone, L.; Casula, M. F.; Cingolani, R.; Falqui, A.; Snoeck, E.; Parak, W. J.; Manna, L., Selective growth of PbSe on one or on both tips of colloidal semiconductor nanorods. Nano Letters 2005, 5, (3), 445-449.

[7] Mokari, T.; Rothenberg, E.; Popov, I.; Costi, R.; Banin, U., Selective growth of metal tips onto semiconductor quantum rods and tetrapods. Science 2004, 304, (5678), 1787-1790.

[8] Gu, H. W.; Zheng, R. K.; Zhang, X. X.; Xu, B., Facile one-pot synthesis of bifunctional heterodimers of nanoparticles: A conjugate of quantum dot and magnetic nanoparticles. Journal of the American Chemical Society 2004, 126, (18), 5664-5665.

AKB 20.3 Thu 10:45 ZEU 255

DNA-switchable hybrid structures — •Andreas Reuter, Michael Olapinski, Tim Liedl, and Friedrich Simmel — Department für Physik, Ludwig-Maximilians-Universität München, Geschwister-Scholl-Platz 1, 80539 München

Programmable self-assembly with DNA molecules has been previously used for the construction of a variety of nanoscale structures as well as for the realization of simple machine-like molecular devices. These devices were capable of performing nanoscale movements such as stretching, rotation and even translocation. In combination with functional nucleic acids such as aptamers or ribozymes, functional DNA devices could be realized which can bind or release molecules, compute and respond autonomously to environmental inputs. We here demonstrate that also hybrid devices can be realized which are composed of an inorganic part such as a nanoparticle or a microstrucured electrode on a surface and a DNA actuating component. The DNA actuator part can be used to reversibly and selectively change the distance between organic components of the hybrid devices (such as fluorescent dyes) and the inorganic components. The conformational changes can be characterized by monitoring energy transfer between fluorophores and metallic device components. Such structures may find use in sensors and actuators where the transduction of a biomolecular recognition event to an electronic or optical signal is desired. On a more fundamental level, the ability to tailor and reversibly change the distance between nanoscale components can be used to study distance-dependent interaction phenomena between these components.

AKB 20.4 Thu 11:00 ZEU 255

Driving a DNA conformational switch with a pH oscillator — •Tim Liedl and Friedrich Simmel — Department für Physik, Ludwig-Maximilians-Universität München, Geschwister-Scholl-Platz 1, 80539 München

DNA conformational changes occuring in artificially generated DNA structures can be used to produce motion on the nanometer scale. Such DNA-based nanodevices are either driven by hybridization events between complementary strands of DNA or by buffer-induced conformational changes. One prominent example of such a conformational change is the formation of the so-called i-motif, which is a folded four-stranded DNA structure characterized by noncanonical hemiprotonated cytosine-cytosine base-pairs. The transition of DNA strands prone to fold into the i-motif occurs in the pH range between 5 and 7. Usually, DNA devices are driven by the manual addition of fuel molecules or by the periodic variation of buffer conditions. In an attempt to produce self-running nanodevices which do not require intervention by an external operator, we here show that a DNA switch based on the i-motif can also be driven autonomously within a continuously stirred flow reactor in which periodic pH oscillations are generated by a nonequilibrium chemical process. The conformational changes are monitored simultaneously with the pH value in fluorescence resonance energy transfer experiments.

AKB 20.5 Thu 11:15 ZEU 255

Fundamental Hemostasis Investigations in Microdevices — •Heather Evans, Stephan Herminghaus, and Thomas Pfohl — Max Planck Institut für Dynamik und Selbstorganisation, Göttingen, Germany 37073

Fibrin is a prominent protein in the complex process of hemostasis, or blood clotting. This protein aggregates at a site of injury when monomers of fibrinogen assemble into fibers of fibrin via enzyme catalysis. The biodegradable nature and good tissue tolerance of fibrin networks have already been demonstrated in terms of commercially available wound covering agents, and this protein has been implicated in medical conditions such as artherosclerosis, cancer, and multiple sclerosis. Our studies aim to elucidate mechanisms of fibrin assembly while utilizing the spatiotemporal resolution and confinement induced by microchannel structures. Microchannel devices require less reagent, resulting in a more efficient and cheaper experimental design, and enable investigations of the evolution of biomolecular interactions in ambient conditions. Small angle X-ray microdiffraction and microscopy studies have been conducted on fibrin formed within microchannels. In our experimental system, the addition of enzyme and subsequent formation of fibrin can be carefully controlled by adjusting parameters such as concentration, flow rate, and channel geometry. To this end, network densities and fibrin bundle sizes of structures formed within microchannels will be discussed.

AKB 20.6 Thu 11:30 ZEU 255

Light-induced Manipulation of DNA on Amorphous Silicon Surfaces — •M. Höb, S. Gatz, M. Stutzmann, and M. Brandt — Walter Schottky Institut, Technische Universität München, D-85748 Garching, Germany

Lab-on-a-chip devices depend on methods, which ideally are non-mechanical, to move, dispense, sort or mix (bio)chemical substances such as DNA. Electrokinetics is ideally suited to perform such functions, as the movement is induced and controlled by electric fields. We report a novel technique to manipulate DNA based on light-induced dielectrophoresis on hydrogenated amorphous silicon surfaces (a-Si:H), in which the coupling of an inhomogeneous ac electric field to the induced dipole moment

of DNA allows the manipulation of the macromolecules. An otherwise unstructured a-Si:H/ZnO-layer sequence, which is locally illuminated, serves as a light-controlled 'virtual electrode' to create the non-uniform electric field necessary in the electrolyte. Light-induced positive dielectrophoresis of the DNA molecules to the virtual electrode is observed by fluorescence microscopy. The attraction to the illuminated spot is studied as a function of frequency and amplitude of the applied ac voltage as well as the power density of the illumination.

AKB 20.7 Thu 11:45 ZEU 255

Rapid Chiral Synthesis of Rigid DNA Building Blocks for Molecular Nanofabrication — •Catherine F. Tardin[1], Russell P. Goodman[2], Iwan A.T. Schaap[1], C. M. Erben[2], Richard M. Berry[2], Andrew J. Turberfield[2], and Christoph F. Schmidt[1] — [1]Dept. Physics, Vrije Universiteit, Amsterdam, NL — [2]Clarendon Laboratory, Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK

The programmability of base-pairing interactions makes DNA an ideal molecule for construction by self-assembly. Practical components for 3D molecular nanofabrication must be simple to produce, stereopure, rigid and adaptable. We report a family of DNA tetrahedra, less than 10nm in size, that can be made in seconds with near-quantitative yield. Their triangulated architecture allows them to support a compressive load: by compressing a DNA tetrahedron by little more than 1 nm with an AFM we have measured the axial compressibility of DNA and have observed the buckling of the double helix under high loads.

AKB 20.8 Thu 12:00 ZEU 255

Raman Sensors using Photonic Crystal Fibers for Chemical and Biological Applications — •John Erland Østergaard[1], Stig Christensen[2], Kasper Jørgensen[2], Søren Hassing[2], Thomas Søndergaard[3], Stefan Banke Ovesen[1], and Karsten Rottwitt[4] — [1]University of Southern Denmark, Fysisk Institut, Campusvej 55, DK-5230 Odense M — [2]Engineering College of Odense, Niels Bohrs Alle 1, DK-5230 Odense M — [3]Aalborg University, Institute of Physics and Nanotechnology, DK-9220 Aalborg Øst — [4]Technical University of Denmark, COM, DK-2800 Kgs. Lyngby

The recent development in photonic-crystal-fibers (PCF) is currently explored for new types of optical sensors taking advantage of introducing a liquid in the PCF for enhanced sensitivity for Raman signals generated from the liquid. For a Raman sensor, a large air-core PCF with air-holes running along the fiber is considered. It is possible to guide light strongly localized to the large central air-hole via the Bragg effect[1,2]. In our calculations for holes filled with water (n=1.33 compared to silica n=1.45), it is also possible to guide light confined to the core region of the fiber due to the band gap properties of the cladding material. Three frequency ranges for Raman sensing are identified where light is guided well in the core region. In the case where the liquid has a larger refractive index than glass, the PCF supports a mode localized to the liquid-filled core region of the fiber above a cut-off frequency, as for standard fibers. Experimental examples of Raman generation in the PCF for different light propagation regimes is discussed. [1] R.F. Cregan et al, Science, 285, 1537 (1999). [2] Broeng et al., Opt. Lett. 25, 96 (2000).

AKB 20.9 Thu 12:15 ZEU 255

A Novel Method to Fabricate Continuous Surface Tethered Membranes — •Christian Daniel[1], Luisa Andruzzi[2], Kirstin Seidel[2], Joachim Rädler[2], Erich Sackmann[1], and Bert Nickel[2] — [1]Techn. Univ. Munich, Physics Dep. E22, James-Franck-Str. 1, 85748 Garching — [2]L. M. Universität, Dep. f. Physik LS J. Rädler, Geschw.-Scholl-Pl. 1, 80539 München

Functionalization of solid surfaces (semiconductors, metal coated supports, electrooptical devices) with polymer supported lipid membranes provides a promising strategy to generate bio-analogue interfaces between inorganic and biological materials for scientific and practical applications. This work reports a new method for the generation of lipid bilayers separated from the surface by an ultra-thin soft polymer cushion mimicking the role of e.g. actin cortices of cell envelopes. The stratified films are fabricated by covalent anchorage of lipids on the solid surface and passivation of the uncovered surface with hydrophilic polymer films of different thickness. Spreading of vesicles on these activated surfaces results in the formation of supported membranes which are continuous over large areas and are characterized by very high long range mobility of constituents. Structural studies of the supported membranes by synchrotron x-ray reflectivity allow the determination of the thicknesses of the different interfacial films with sub-nanometer resolution. The major advantage of the tethered membranes is the reproducibility of the bilayer deposition procedure, which is expected to greatly facilitate the investigation of specific lipid-protein interaction mechanisms and their role for the self assembly and function of biological membranes.

AKB 20.10 Thu 12:30 ZEU 255

Silicon-on-insulator based nanogap structures for bio-molecular electronics — •Sebastian Strobel[1], Allan Hansen[1], Kenji Arinaga[1,2], and Marc Tornow[1] — [1]Walter Schottky Institut, TU München, 85748 Garching, Germany — [2]Fujitsu Laboratories Ltd., 10-1 Morinosato-Wakamiya, Atsugi 243-0197, Japan

The starting point for electrical transport measurements on bio-molecular "wires" such as DNA oligonucleotides is the preparation of suitable nanogap - electrodes that serve as contact to the molecules. Here, one necessary requirement are biocompatible substrates with sufficient stability in aqueous solutions, such as silicon and silicon oxide.

We pursue a new strategy to prepare nanogap structures of predetermined electrode distance based on silicon-on-insulator substrates. The combination of reactive ion etching and selective wet oxide etching allows for the fabrication of 10-20 nm wide trenches, which act as template for a subsequent metal thin film evaporation step.

We successfully verified the electrical functionality of 20 nm devices by bridging the electrodes with electrically trapped gold nanoparticles. First transport measurements after functionalisation with DNA oligonucleotides will be presented.