DNA-Based Construction For Nanoelectronics

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The application of biomolecules in nanostructure generation is an interesting alternative to techniques in physical nanotechnology. Nucleic acids, and especially DNA, provides suitable chemical and physical properties to become an interesting object for molecular construction. The core principle of such DNA-based complexes is the self-organization of the DNA molecules. Synthetic short single-stranded DNA can be coupled to substrate surfaces, and the resulting thin films represent functional monolayers. Long DNA molecules provide the framework for nanoconstructions. The connections between these molecules and biologically functionalized planar or nanoparticular substrates is realized by self organization guided by the predefined complementarity and affinity of the utilized DNA. This coupling reaction can be controlled by simple parameters, such as temperature and pH.

Based on this straightforward algorithm, a versatile bottom-up toolkit has been developed. Intermediate complexes are created by coupling of individual elements. Intermediate structures connected in solution can be immobilized onto biologically functionalized substrate surfaces. A key element is the integration of these molecular structures into microsystem environments, such as microelectrode arrays defined by photo or e-beam lithography. Therefore, molecular constructs are connected to macroscopic technical equipment in a defined way, and a parallelization is (as requirement for future industrial use) in principle possible.

Metal nanoparticles represent active parts of the toolkit. They can be bio-functionalized, and thereby assembled with complementary modified surfaces or molecules. Their interesting electrical and optical properties is the base for possible application as single-electron tunneling confinement, as template for metal nanowires or as nanoconverter of light into thermal energy.

I will present results from a project aimed at a single-electron tunneling transistor based on an DNA positioning. Therefore, methods have been developed to position individual DNA molecules in an extended and defined state in microelectrode gaps. Methods for DNA metallization based on direct metal deposition, the sequence-unspecific binding of nanoparticles and the sequence-specific hybridization of metal nanoparticles are presented. The nanoparticles were subjected to silver enhancement steps, so that their size could be controlled. First electrical measurements on metal nanostructures generated along individual

DNA-molecules in microelectrode gaps show a relation between the nanogap size and the resistance.

The interaction of the electrons in nanoparticles with photons is utilized in another project that aims at manipulating the particles by pulsed laser light. Using different materials and sizes of particles as well as various laser parameters (such as wave length and power), an optimal protocol for laser manipulation has been developed and demonstrated by ultramicroscopic characterization of the interaction process.

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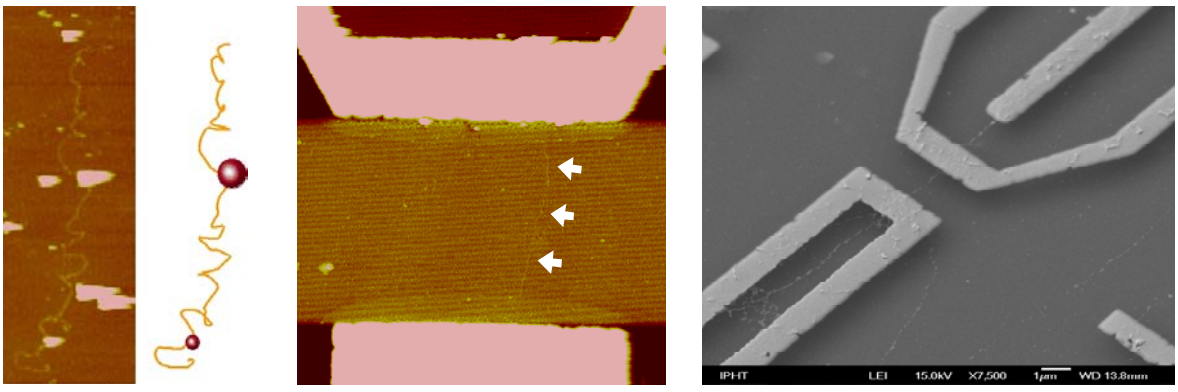

Gold nanoparticles funtionalized with defined short DNA sequences coupled to the complementary region along a long DNA molecule (left). An individual DNA molecule positioned by self-organization using a flow chamber into a prestructured electrode gap of 3 micron (center). SEM of an individual DNA structure imobilized in an extended state on a microelectrode arrangement by a modified droplet method prior to metal nanoparticle labeling (right).