DNA-Based Nanodevices

Danny Porath

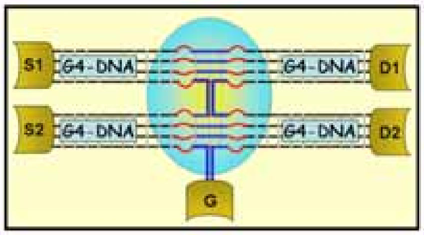
Physical Chemistry Department, The Hebrew University. Physical Chemistry Department, The Hebrew University, Jerusalem. 91904, Israel

porath@chem.ch.huji.ac.il

Objectives.

We propose the design, realization, and testing of DNA-based devices that can serve as building blocks for self-organized molecular nano-electronics.

Specific goals:



- Attainment and improvement of control over the production process of DNA-based nanowires, specific modifications at desired locations along the wires, and the electrical properties of the DNA-based nanowires (G4-DNA, M-DNA, DNA-polymer-hybrids);
- Realization of DNA-based molecular nanodevices with a non-linear electric response;
- Morphological, spectroscopic and electrical characterization of the above nanowires and nanodevices;
- Prediction and interpretation of the structural and electrical properties through complementary theoretical methods.

These objectives bear a huge promise in the context of device miniaturization: in fact, the limits towards scaling down electronic architectures and increasing circuit integration are strongly related to the ability to fabricate individual device components at the nanoscale (≤10 nm). In particular, biological strategies may unravel new ways to assemble wires into devices and devices into functional networks, based on the spontaneous self-organization of intrinsically tiny components.

Technical approach.

The ambitious goals of the project and the novelty of the suggested approach necessitate a concerted, inter-disciplinary research effort feeding on state-of-the-art expertise in bio-synthetic engineering of nanosystems, surface-chemistry, SPM and electrical transport measurements, various kinds of theory. The expertise of the partners thus encompasses several disciplines, as described in the initial Table.

Expected achievements/impact.

The envisaged devices constitute a significant step forward in view of future self-assembled nanoelectronic circuits.
Major problems are foreseen with the further miniaturization of the conventional Si devices beyond 20 nm features, both because of problems of technical nature as well as cost management. Alternative approaches are therefore explored. DNA-based self-organized electronics is a prime example of an entirely alternative approach. It will take advantage of the unprecedented recognition and assembling properties of DNA. DNA-based nanoelectronic

devices will enable to reduce the size of the current devices by ~1000 times. The production process will be shifted from complicated and defect-rich lithographic steps to protocols that are based on self-assembly and self-organization and maintain an extreme structural accuracy. We expect to be able to produce prototype embedded devices that allow us to estimate the feasibility of electronics based on DNA derivatives.

A specific innovative focus of this project is to investigate novel *DNA-derivatives* and modifications that hold potential for improved properties with respect to *native-DNA*: this expectation is indeed emboldened by preliminary results of the proposing consortium (FP5 contract IST-2001-38951). The derivatives that we suggest, G4-DNA, M-DNA and polymer-DNA-hybrids, pioneer as modified biomolecules that are proposed as electrical molecular wires. Our novel approach is to chemically alter the native structure of the nucleic acids in order to realize *DNA-derivatives* that are possibly more conductive than *native-DNA*, but that at the same time maintain the addressability and structured arrangement of *native-DNA*. Moreover, a strong emphasis is put on inserting foreign components along the wires that constitute the basis of devices embedded in the wires themselves. The first characteristic that we require to the envisaged simplest devices is non-linearity. This will then open the way to a next generation of more complex devices that are able to recognize each other and assemble into computing networks. The use of the proposed structured wires may give alternating electrical properties of partial elements along the wires, such that they will act as devices that are extremely small (few nm) and exceptionally close to each other, and have a very controlled structure and performance. The miniaturization that can be obtained by realizing such devices may even well exceed the size reduction of the wires themselves.

This project provides a unique combination of state of the art capabilities for the production and manipulation of DNA-based molecules, unique surface chemistry, low temperatures scanning probe microscopy (SPM) and scanning tunneling spectroscopy (STS) measurements, sophisticated nanofabrication, and leading theoretical skills, all combined to provide new solutions and information about the core problems at the forefront of the research on conduction through DNA derivatives. Success in this project may provide a key step towards the development of DNA-based nanoelectronic devices. It addresses a high-risk long-term research and could ultimately contribute to the development of innovative devices. A strong impact that the project may have on the research community is to enrich it with a team of complementary scientists from various fields able and trained to work with each other and to adapt their knowledge and skills to what is needed for the particular investigation targets of their colleagues. Students and young scientists particularly benefit from this lively/challenging environment.

Contract Number. FP6-029192
Project Acronym. DNA-NANODEVICES
Project Name. DNA-based Nanoelectronic Devices
Priority/Priority Component. IST FET-Open

Project Logo.
http://dna-nanowires.s3.infm.it