6th semester project

Combing of Triplex and Quadruplex DNA molecular wires

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Background:

Besides "classical" Watson-Crick double helix DNA can form a large variety of other structures. Two interesting examples here are G-C-G triplexes and 4G quadruplexes formed via Hoogsteen pairing of two G-bases. As was recently found, those molecules can be of particular interest for future molecular electronics.
Generally, molecules to be used for electronic applications need to express three main features:

- **Structuring** – the possibility to tailor their structural properties (composition, length, etc.) "on demand";
- **Recognition** – the ability to attach them to specific sites or to other target molecules;
- **Electrical functionality** – suitable conductivity and control of their electrical characteristics.

In this respect usual DNA possess all this features except electrical functionality. Early work in this field has yielded seemingly controversial results for *native-DNA* showing electrical behaviors from insulating through semiconducting to conducting. One point of view is that though theoretically DNA can be conducting, any eventual bending misaligns orbital stacking in the molecules rendering it semiconducting. DNA triplexes and quadruplexes are significantly more rigid and as tentative measurements on those new DNA structures show that they possess number of unusual physical properties e.g. enhanced polarizability and enhanced fluorescence even without any doping. We are part of an EU project centered around research on those DNA derivatives with a final goal to create functional nanodevices (sensors, transistors etc.). This project will be a part of those efforts.

Project objective:

- developing techniques for controlled deposition of DNA nanowires (triplex DNA and G4-DNA) on planar and patterned surfaces;
- comparative AFM study of DNA-nanowires and ds-DNA.

Project methodology

The project will concentrate on the use of so-called DNA combing technique. If we move a substrate where DNA can stick to through a liquid-air interface the DNA molecules will be aligned and stretched on the surface. The extent of the alignment and stretching depends on the surface properties as well as on the deposition buffer.
We will use two varieties of this technique:

- Direct combing of DNA nanowires and ds-DNA on the functionalized silicon surface, either planar or containing nanoelectrodes, with various types of functionalizations (silanes with various head groups) and using various buffers.
- Combing on PDMS rubber stamps with subsequent DNA stamping on functionalized silicon surface.

You will study the resulting DNA structure (height, persistent length, degree of stretching, etc.) using AFM.

Suggested methods and research highlights: Within the project you will:

- Functionalize silicon wafers with silanes in vapor phase;
- stretch native DNA, triplex and G4 using combing technique as well as moving droplet techniques on silicon and PDMS surfaces;
- verify the results using fluorescent microscopy and AFM. Use this data to optimize stretching procedure (buffer, slide coating and flow parameters) for each DNA derivative
- Perform EFM (electrostatic force microscopy, e.g. [2]) on stretched and "as deposited" DNA-derivatives
- Stretch across the electrodes [see e.g. [3]) and characterize electrical properties of DNA-nanowire.

References:

1. A. Kotlyar et.al Advanced Materials 17, 1901 (2005)
2. M. Bockrath et al Nano Letters 2, 187 (2002)
3. Porath, D., et al. *Nature* **403**, 635 (2000)

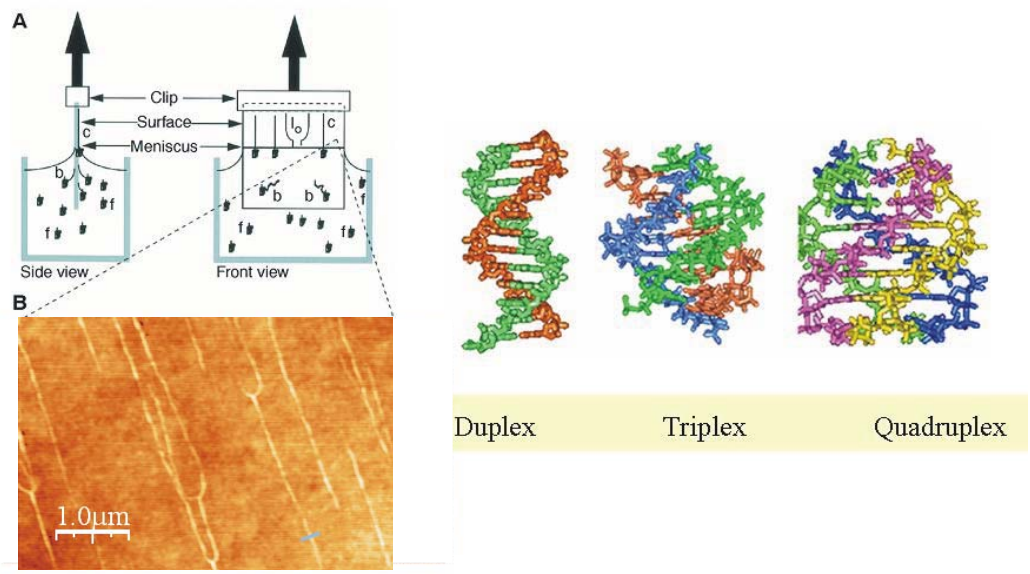

Figure 1. **A**: DNA stretching in shear flow. **B**: Strands of stretched vector DNA observed with AFM. **C**: Native and novel DNA structures