MECHANICAL PROPERTIES OF A SINGLE PARA-HEXAPHENYLENE NANOFIBER

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Using a nanoscale structure as an electronic component, a light-emitting device or a sensor has several advantages compared to their conventional counterparts. However, it often requires being able to position the nanoscale structure and perhaps to shape it into a particular configuration to obtain the desired characteristics. Therefore, when attempting the integration of nanoscale structures into microsystems to construct functional devices, it is important to understand the interplay between the external forces exerted during construction and operation on the nanoscale structure, and its intrinsic mechanical properties.

In this work we investigate individual para-hexaphenylene (p6P) nanofibers. These nanofibers can act as nanoscale optical waveguides [1] and the electroluminescence spectrum of p6P show strong emission in the blue regime [2], which suggests their potential use as future nanophotonic components. This requires a detailed study of their intrinsic and contact properties and of how external stimuli affect the nanofibers. Through a combination of atomic force microscopy, nanomanipulation, and fluorescent microscopy, we study the mechanical properties of nanofibers that are supported on different substrates with dissimilar hydrophobic properties as well as suspended nanofibers.

The single-crystalline organic nanofibers consist of stacked layers of p6P molecules. The nanofibers are made by evaporating phenylene oligomers onto a heated mica (0001) surface under high vacuum conditions, where the oligomers self-assemble into fiber-like aggregates through interaction with the surface dipoles [3]. The nanofibers typically have a width between 100 and 400 nm, a height between 20 and 50 nm, and often have lengths of several tens of µm.

Releasing the nanofibers from the mica surface in a droplet of water allows them to be transferred on to the desired substrate. Subsequent fluorescent microscope imaging is used to verify the transfer of the nanofibers. The manipulation and mechanical measurements are performed using the 'nanoManipulator', which consists of an atomic force microscope equipped with a haptic interface that allows the user to perform complex manipulation while "feeling" the structure under investigation [4]. Some experiments are made with a transparent substrate in a setup that allows imaging of the fibers with an inverted optical microscope during the manipulation with the atomic force microscope as shown in fig. 1.

The supported nanofibers allow us to investigate the interaction between a nanofiber and the supporting surface as well as the force required to rupture the nanofibers. This is essential for determining whether mechanical manipulation is a possible route or if other methods of positioning must be sought. Fig. 2 shows atomic force microscope images of a nanofiber being manipulated. Suspending a fiber across a trench removes the interaction with the surface, which enable us to determine its elastic properties.

References:

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Figures:

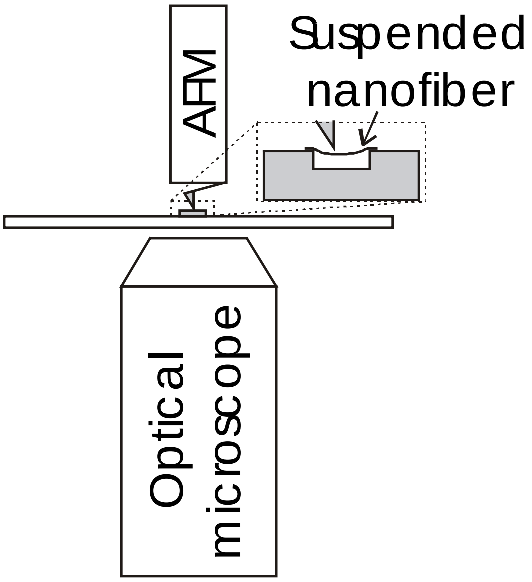

Fig. 1: Schematic showing the set-up. The inverted optical microscope is used to observe the nanofiber being manipulated with the atomic force microscope.

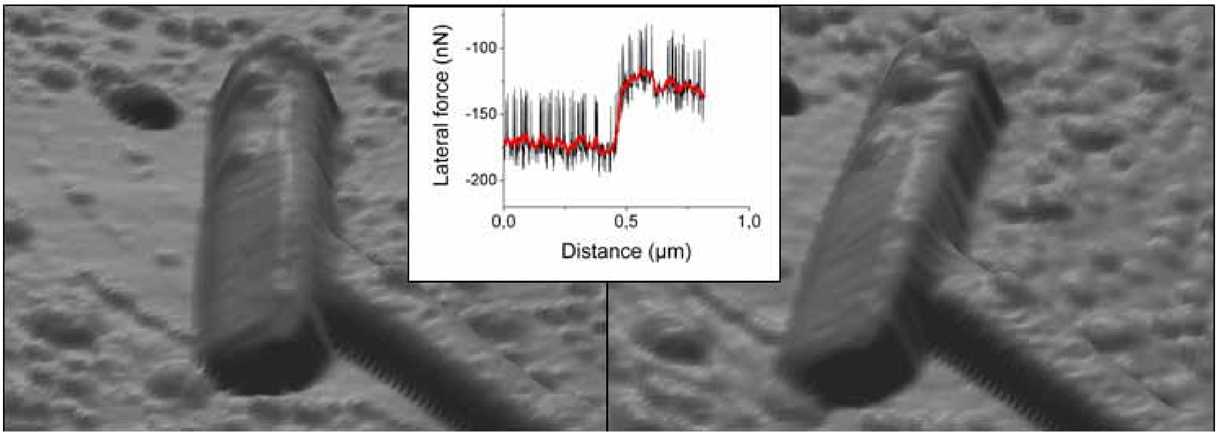

Fig. 2: Atomic force microscopy images showing a ~ 400 nm diameter p6P fiber lying on a fluorinated siloxane silicon substrate: (Courtesy of Niels B. Larsen, Risoe National Laboratory). The nanofiber is rotated by pushing laterally from left to right with the microscope tip. Inset shows lateral force during manipulation