



Uncovered

From single molecule to suspended DNA nanowires

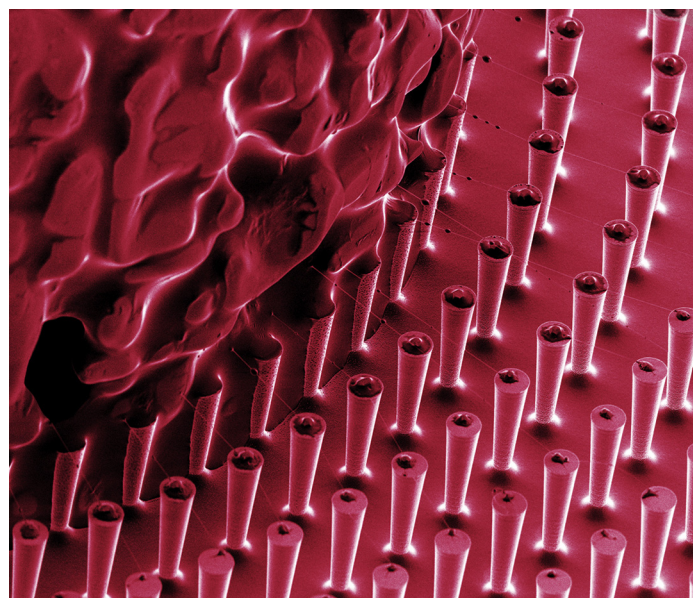
How DNA can be suspended in ordered nanometric bundles

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Determining the structure of DNA represented one of the most important scientific discoveries of the 20th century. As in that very famous case, the most frequently used way to determine the structure of macromolecules is based on X-ray diffraction. However, this method requires a sample in fiber or crystalline form. As a consequence, this limits the number of macro-molecules whose the structure can be investigated by X-ray diffraction. Conversely, direct imaging of macromolecules would allow us to overcome the limitations above, and open novel and unexplored roads for understanding both molecular and functional properties.

As reported in our previous works [1–4], we have developed a process, based on bio-inspired superhydrophobic substrates, which allows us to deposit suspended DNA of nanometric diameter and micrometric length. Nature shows copious examples of naturally occurring superhydrophobic surfaces, such as butterfly wings, duck feathers and lotus leaves [5]. They are non-wettable surfaces, showing high water drop contact angles and low-friction coefficient. As shown in one of our first works about similar superhydrophobic substrates, they can be used for the detection of few/single molecules even when dispersed in a highly diluted solution (*i.e.*, with attomolar concentration) [1].

Long suspended DNA wires are obtained starting from a low concentration (about 60 pM) of double strand nucleic acids, such as Lambda DNA, and diluted in saline buffer solution. A droplet with a diameter of about 1 mm is deposited in the middle of the patterned superhydrophobic surface at room temperature. During evaporation and the receding of the drop, at the three phase interface, DNA is pulled from the external to the inner closest pillar, then stretched and suspended.

When the superhydrophobic substrate is integrated with a regular array of holes among the micropillars, it can be used to study the internal structure of the wires by transmission electron microscopy. We showed that inside the bundles a fixed number of DNA helices are aligned, along the nanowire axis, in such a way to confer to the bundles an ordered and periodic structure [2]. Furthermore, we have recently exploited the DNA wire network as a template to grow zinc oxide microcrystals whose electrical properties have been also studied [6].

The cover image shows what is observed at the end of the droplet evaporation, when the DNA wire formation process is

completed. Here, the DNA wires are linked to the pillars closest to the dry droplet and disposed in an ordered network that apparently follows the circular micropillars pattern constituting the superhydrophobic surface. The residual part of the droplet is now embedding the micropillars on which the water evaporation was complete. This image was taken at the KAUST Imaging and Characterization Laboratory, using a field emission scanning electron microscope (FE-SEM) (FEI, Quanta 200) working at an acceleration voltage of 2 kV, with magnification of 2170 \times , and the sample tilted at 45°. Only the secondary electron signal was used to form the FE-SEM image.

The micro-fabrication of the super hydrophobic substrate shown here followed a four steps process. The first was the definition, by a standard optical lithography technique, of several patterns of disks in negative tone AZ5214 photoresist, on the top of a Si(1 0 0), *p*-type, wafer. These patterned layers act like a mask for a deep reactive ions etching step, whereby the final pillars are obtained with a height of about 20 μm . We used the well-known Bosch process for Si etching, which induced a typical roughness along the structures. The third step consisted in oxygen

plasma etching in order to remove the photoresist, without the use of any solvent that can introduce impurities on the surface. Finally the substrates were covered with a thin film (few nm) of teflon to get the desired surface superhydrophobicity.

Further reading

- [1] F. De Angelis, et al. *Nat. Photon.* 5 (2011) 682–687.
- [2] F. Gentile, et al. *Nano Lett.* 12 (2012) 6453–6458.
- [3] A.A. Yu, et al. *J. Am. Chem. Soc.* 127 (48) (2005) 16774–16775.
- [4] F. De Angelis, et al. *Nanoscale* 3 (7) (2011) 2689–2696.
- [5] Z. Guo, W. Liu, B.-L. Su, *J. Colloid Interface Sci.* 353 (2) (2011) 335–355.
- [6] E. Miele, et al. *Small* 11 (1) (2015) 134–140.



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