



Diatoms:

AFM Imaging of Natural Synthesis at the Nanoscale

Application Note

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Nanotechnology focuses on low-cost, high-throughput, directed synthesis of structures and devices at the nanoscale in order to address the requirements of a variety of applications. Microelectronics, for instance, offer more components per chip with faster response and lower power consumption. Nanometer-sized sensors for medical diagnostics, as well as magnetic storage systems of decreased size, also provide numerous advantages enabled by fabrication at the nanoscale.

Although various synthetic strategies, including lithography, self-assembly, size reduction, and template deposition, have been developed to create devices at the nanoscale, these techniques do not exceed the accomplishments of natural systems. The study of natural systems, therefore, may offer valuable insight into how biology, through energy-efficient, low-temperature, mild reaction conditions, has developed mechanisms for reproducible nanoscale structure.

Diatoms are an example of a natural system that utilizes such a mechanism. These unicellular photosynthetic algae, which are found in fresh water, salt water, and even in moist soil, extract silicon from orthosilicic acid in an aquatic environment to create an inorganic silica skeleton with nanoscale features. By removing the organic material from a diatom via acid cleaning with sulfuric acid, the silica cell wall is exposed and nanoscale features in the skeleton can be examined using high-resolution atomic force microscopy (AFM).

From an environmental standpoint, diatoms are of particular interest to researchers. Because they are photosynthetic organisms, diatoms play an important role in global climate control by removing

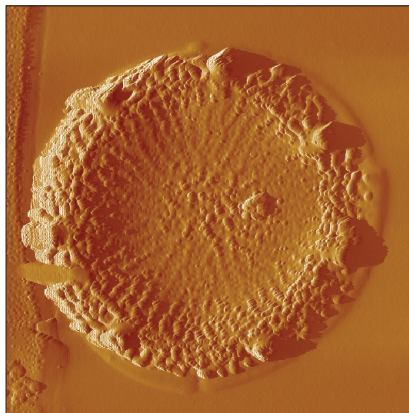


Figure 1. The centric diatom *Thalossiosira pseudonana* exhibits radial symmetry. Contact mode AFM image acquired using an Agilent atomic force microscope.

carbon dioxide from the atmosphere, thereby helping to keep greenhouse gases in check. As a major constituent of phytoplankton in the marine food chain, diatoms produce at least 40% of the earth's organic carbon each year. They are also responsible for producing roughly 20% of the oxygen we breathe, an amount equal to that produced by all of the earth's terrestrial rain forests combined. Diatoms have existed since the Jurassic Period and deposits of fossilized diatoms, as diatomaceous earth (diatomite), are mined for commercial use in paints, abrasives, filters, and many brands of toothpaste.

This application note presents AFM images of diatoms on a gelatin-coated mica surface. The gelatin-coated mica surface was made by dissolving 0.5gm of porcine gelatin (Sigma 2625) in distilled water at 100°C. When cooled to 60–70°C, freshly cleaved mica surfaces were dipped into the gelatin solution and allowed to dry overnight leaning against a vertical support

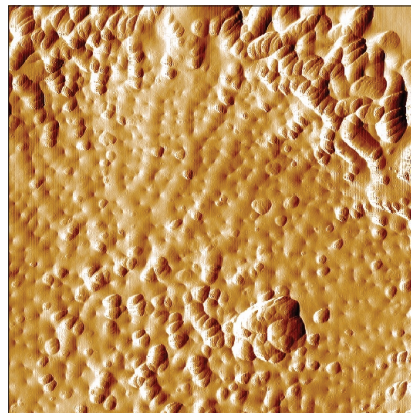


Figure 2. The silica spokes in *Thalossiosira pseudonana* are composed of nodules of 20–30 nm silicon spheres. Contact mode AFM image acquired using an Agilent atomic force microscope.

(plastic test tube rack) at approximately a 70° angle with the lower edge on a paper towel. The gelatin solution can be used for at least two months when stored in a refrigerator between experiments. A 10–20 µl droplet of diatom silica skeleton suspended in distilled water was applied to the gelatin-coated mica surface and spread with a micropipette tip. After drying, the sample can be imaged by either contact or AC mode AFM.

Diatoms are generally divided into two orders, based on symmetry. Centric diatoms have radial symmetry, where a central point in the diatom serves as the origin of symmetry. The diatom *Thalossiosira pseudonana* demonstrates this type of symmetry, in which a spokes-in-a-wheel arrangement of structures radiates from the center (Figure 1). In the high-resolution image of this diatom, one can easily see that the silica spokes are composed of nodules of 20–30 nm silicon spheres (Figure 2).



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Figure 3. The pennate diatom *Navicula pelliculosa* exhibits bilateral symmetry. Contact mode AFM image acquired using an Agilent atomic force microscope.

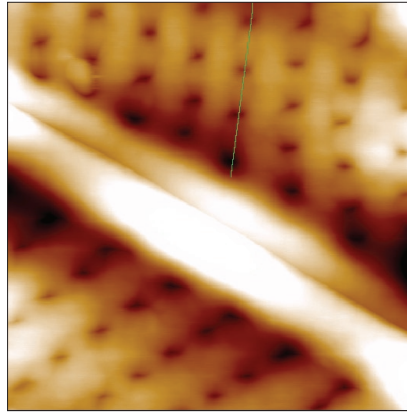


Figure 4. In *Navicula pelliculosa*, the smooth silica ribs radiating from both sides of the center are separated by highly ordered nanometer-scale pits, or holes. Contact mode AFM image acquired using an Agilent atomic force microscope.

Pennate diatoms, such as *Navicula pelliculosa*, exhibit bilateral symmetry, where symmetry originates at right angles from the center of the diatom along the entire length of the diatom (Figure 3). In this diatom, the smooth silica ribs radiating from both sides of the center are separated by highly ordered nanometer-scale pits, or holes (Figure 4).

More than 60,000 species of diatoms have been classified, yet experts in the field predict that this number represents less than 10% of these organisms. Diatoms are plentiful in both fresh and salt water, are easily collected and prepared for imaging, and are remarkable in the variety of structure they exhibit. They also may teach us how nature reproducibly and economically fabricates structure in great numbers at the nanoscale.

References

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