

Beyond micromachining: the potential of diatoms

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Diatoms are microscopic, single-celled algae that possess rigid cell walls (frustules) composed of amorphous silica. Depending on the species of diatom and the growth conditions, these frustules can display a wide range of different morphologies. It is possible to design and produce specific frustule morphologies that have potential applications in nanotechnology.

There has recently been a great deal of interest centred around the design and manufacture of devices of nanometre proportions and this speculation has spawned a new industry, termed nanotechnology. Much has been written about the potential applications of nanometre-sized devices with electronic, optical and/or mechanical properties such as gears, motors and transistors¹⁻³. However, at present, the tools for creating such devices are still in the early stages of development.

The two main premises for creating nanotechnological devices is that they should be cheap to manufacture and they should also possess order at the atomic level. At present, it is possible to use micromachining processes to create tiny gears and motors that are measured in tens of micrometres. In addition, ion-beam etching can be used in microelectronics to etch lines less than 1 μm wide on wafers of silicon⁴. We propose that directed self-assembly by growing cultures of single-celled diatoms (Bacillariophyceae) may provide a valuable means of providing order at a scale between that currently obtainable by the latest micromachining processes and the atomic level, while also providing a cheap alternative to both of these technologies⁵.

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Introduction to diatoms

Diatoms are microscopic ($\sim 1\text{--}500 \mu\text{m}$ in length) single-celled algae with characteristic rigid cell walls (frustules) composed of amorphous silica. They are ubiquitous organisms found in a wide variety of habitats and are thought to be responsible for up to 25% of the world's net primary production of organic carbon⁶. There are currently estimated to be over 100 000 different species, classified by their unique frustule morphologies⁷. Diatoms are usually classified as one of two main groups depending upon the symmetry of their frustules (Fig. 1a,b).

Centric diatoms tend to be radially symmetrical, while pennate diatoms tend to be elongated and generally have parallel striae (furrows or rows of holes in the silica) arranged normal to the long axis. The spacing between adjacent striae is species specific and typically varies from ~ 0.3 to 2 μm . The lines of silica between the striae are called costae. Costae tend to be arranged in combs or other space-filling patterns such as honeycombs, which possess remarkably uniform pores. Aside from their symmetry, frustules display an unparalleled diversity in structure and morphology, and this may be exploitable in nanotechnological applications.

The diatom frustule

The diatom frustule consists of two almost equal halves that fit together like a petri dish, enclosing the bulk of the single cell within (Fig. 1c). Each half (theca) consists of a valve (which forms the larger outer

