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Nature shapes silicon

During the last half century silicon has shaped life. Now it's the other way about, says, S.Ananthanaryanan.

The last half century can easily be called that of electronics. And all electronics, from the early transistors to today's million transistor processor chips, are silicon based. Keneth H Sandhage and colleagues at Georgia Institute of Technology, USA have discovered a way of harnessing nature to shape silicon into intricate patterns.

Silicon

Silicon, like its cousin carbon, on which all life depends, has remarkable electrical properties because of its atomic structure. Carbon owes its great versatility in forming compounds to the four electrons structure of the carbon atom in its outer shell. Atoms, in combining with one another, try to reach a two or eight electron, outer shell economy. And carbon, which is half-way, finds it easy to combine with 1, 2 3 or 4 hydrogen, oxygen, nitrogen, sulphur, etc atoms, and is hence the base of the billions or compounds in world of living cells, DNA, man-made polymers, plastics.

The atom of silicon is similarly endowed, but its compounds stay stubbornly solid at usual temperatures and life is really not possible. But because of the four electron outer shell of silicon, other atoms with five or three outer shell electrons can plug into silicon crystals and create a floating, 'free' electron or electron 'hole'. It is this feature that makes for the electronics applications which have led to transistors, diodes and millions of these units built on the surface of postage stamp size silicon chips!

Shaping silicon

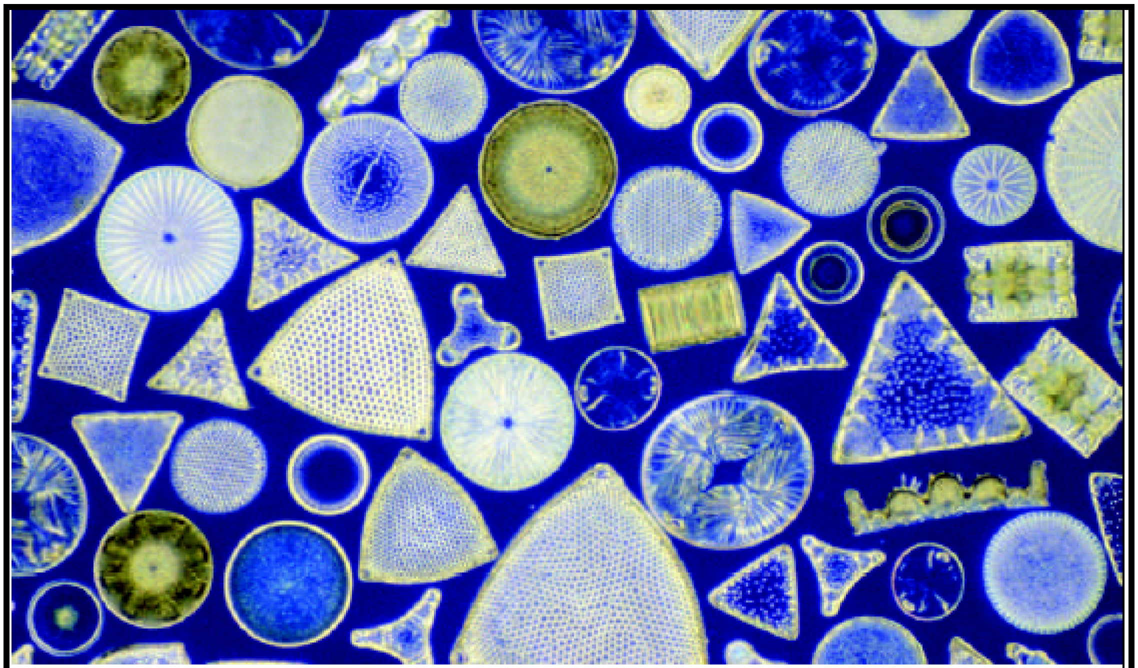
The current nanotechnology capability hungers for miniscule silicon forms that can be adapted for microscopic electronics or optical applications. Pure silicon is prepared by reduction of its ubiquitous oxide, silica or common sand, a form of everyday glass. But the temperature of 2000ºC for reduction of silica hardly allows any artistry in the shapes that silicon can take.

A promising avenue has been the fine shapes of silicon containing forms that living things create – like forms within bones, shells and spines. The shapes are often regular and potentially useful and at dimensions many times smaller than can be manually approached. The trouble is that these patterns are all in compounds like carbonates, phosphates and silicates. The carbonates and the phosphates can be got out of the way, but we are still left with silicates, like silica, and not silicon.

The discovery of the Georgia scientists is a method to reduce the silicates to silicon in mild conditions, so that the complex shapes are retained.

Mild reaction

A type of unicellular algae has cell walls that are silicon based and the creature's exoskeleton, or shell, takes myriad shapes. The scientists allowed the delicately wrought cell walls to react with magnesium gas at 600 ºC. This reduced the silica to silicon and resulted in a solid that contained both silicon and magnesia, the oxide of magnesium. At this relatively low temperature silicon is stable and keeps the shape of the original silica. The magnesia is washed off using acids and the silicon frame remains!



Algae come in different shapes and sizes picture credtt: Nature

The scientists have tried this out with the exoskeletons of different organisms and have been able to create silicon scaffolds in intricate, species-specific shapes. The method used results in a solid with a large number of pores and channels, which could be a disadvantage where solid silicon is desired. But it is an advantage in some applications, like sensors, where a large surface area is useful.

The nanoscale crystals of silicon also have special optical properties, which bulk silicon does not have. Nanoscale silicon also exhibits fluorescence. But the main importance of the work is that different silicon materials can be derived with the help of shapes wrought by nature. This opens the door to new fabrication techniques and applications for silicon in new roles in the nano-dimension.