The Shape of Things to Come

Stephen Dawson

***Nanotechnology** has the potential to shift the world economy from a manufacturing to an IT base*

Of all the exciting things that are happening in science, nanotechnology is perhaps the hardest to get a handle on, mostly because it has, as yet, yielded very little in the way of practical products.

Nanotechnology is concerned with the creation of very small devices and materials, or the use of very small devices to create regular-sized objects. The 'nano' part of the name comes from nanometre—one billionth of a metre. The very small devices are envisaged to be of the order of ten to a hundred nanometres in size.

What use would these be?

The term was coined, after a fashion, by K Eric Drexler, an American engineer, in 1986, who was influenced by a 1959 talk by Nobel Prize-winning physicist Richard Feynman in which some of the basic ideas of nanotechnology were outlined. (Incidentally, Norio Taniguchi's use of the word in 1974 is not relevant, since it was related to high precision manufacture of moderate sized objects.)

As developed by Drexler, the idea is that instead of making things by bending large objects to shape, or chiselling away the bits you don't want, you could build up an object, molecule by molecule, using tiny machines. Lots of tiny machines. The first stage of the process would be to build tiny machines that could make copies of themselves, then they would network with each other and co-operate in building whatever it is that you want built.

This would potentially be far more efficient than our present way of building objects, lend itself better to automation, permit levels of construction detail presently impossible, and open the way to universal manufacturing devices.

Consider: if the manufacturing process becomes merely a set of instructions, akin to a computer program, and all the necessary raw materials are piped in gas or liquid form to the nanotechnology assembler, then the same unit could make plastic dinner plates and glass vases and electronic components. All that would need to change would be the instructions.

The economy would shift even further from a manufacturing to an information technology base. The industrial engineers of manufacturing would be replaced by the software engineers of product design.

PRACTICAL NANOTECHNOLOGY

Although originally concerned with sub-microscopic machines—complete with tiny cogs and motors—the word nanotechnology has been adopted in a range of more practical applications. Thus new materials for clothing with special properties of stain rejection are labelled by their manufacturers as nanotechnology. The purist may object, but in light of the obstacles likely to be put in the way of nanotechnology, any positive associations with the word in the public mind are to be welcomed.

Another development in the field also concerns materials. There is a peculiarly important element in chemistry: carbon. Its ubiquity and its four valence bonds allow it to form many different structural patterns. Thus the hard diamond is pure carbon with the carbon atoms formed in the shape of a tetrahedron. But slippery graphite is also pure carbon, with the atoms forming planes which can slide easily over each other.

In recent decades, other forms have been discovered, including the oddly named buckminsterfullerene, named after the chap who promoted geodesic domes. Each of these molecules is made of 60 carbon atoms shaped in the form of a hollow soccer ball (count them, there are 60 vertices between the pentagonal and hexagonal panels sewn together to form its surface). They are more popularly known as buckyballs.

This led to attempts to engineer carbon molecules in more useful shapes (recent studies suggest that buckyballs might

Stephen Dawson is a freelance writer based in Canberra.

be incredibly harmful to health), of which the most promising is the carbon nanotube. As the name implies, the carbon atoms are arranged in the form of an open-ended cylinder.

Times are early for these—the longest nanotube made so far is just 40 mm in length, yet only one nanometre in width—but their promise is enormous. They can conduct electricity, and already animal experiments have been conducted in which the tubes have been run through even the finest capillaries without damage, suggesting possible future treatments to bypass nerve damage.

And they are strong, immensely so. A single nanotube is, after all, a single molecule, albeit a large-scale one (like a diamond). The molecular bonds provide huge strength. Some nanotubes have been developed with 50 times the tensile strength of high tensile steel (for a given weight), 20 times that of Kevlar, four times that of spider silk (the previous record holder).

In 2003, the price of nanotubes was upwards of $US20 per gram, but last year a Japanese firm started building a production facility which is expected to produce nanotubes for $US1 per gram.

As nanotubes get longer and cheaper, we can expect extraordinary new materials to be developed that incorporate them. Clothing materials that resist wear indefinitely, advanced non-metallic shells for making car and airplane bodies that are far lighter, yet stronger.

And there are potential applications in space travel, since materials are now approaching the strength required for the 'space elevator', a cable reaching from the surface of the earth to beyond geostationary orbit, along which an elevator can climb all the way into orbit. This would allow people and materials to be moved into space without the fire and fury of current practices, and allow much of the energy used on the 'up' trip to be recovered during the 'down' trip.

GREY GOO

Drexler's 1986 book, *The Engines of Creation*, also introduced the term 'grey goo' (of which he said in 2004, 'I wish I had never used the term'). The danger is straightforward: if you have tiny machines building copies of themselves, what's to stop them from going on indefinitely, eventually covering the surface of the earth with a writhing mass of themselves, and destroying all life in the process?

Lots of things, as it happens. Mechanisms that can be designed to self-replicate can equally be designed to self-destruct. They can also be designed to thrive only in specified environments (for example, in the presence of the 'nutrient' feed containing the materials required for their work). And recent work suggests that such machines would have difficulty spreading themselves, and would have to use a large proportion of their energy output merely to synthesize the construction materials for replication.

Unfortunately, how nanotechnology works, how it might go haywire and how such misbehaviour could be controlled are all highly technical subjects with which only a few thousand people across the world are competent to grapple. And that immediately puts it into the same league as nuclear engineering, genetic engineering and much environmental science.

In other words, the dangers are easy to state—and to exaggerate—and the protections less comprehensible. Some of its applications are inherently scary: little hunter-killer robots whooshing through your bloodstream zapping cancer cells. What if they make a mistake, or 'mutate' and start killing off healthy cells?

And surely molecular manufacturing will upset our current industrial/social arrangements in unpredictable and possibly harmful ways. That cable for the space elevator would be some 40,000 kilometres long. What if it fell and wrapped all the way around the earth, destroying all in its path?

Even nanotubes, if they became 'free', might float through the air like asbestos fibres and induce cancers.

If ever there were a technology that cries out for application of the 'Precautionary Principle', nanotechnology is surely it. At least that is the way it is certain to be presented by Green groups, by 'caring' individuals and by the media, for which the story of danger is often more compelling than the story of success.

For example, Prince Charles, upon whom one can usually rely to make conservative utterances of the most foolish kind, has of course expressed his concern about the dangers of nanotechnology which prompted a report from the UK Royal Society and UK Royal Academy of Engineers. This, naturally, recommends government regulation of nanotechnology and its products.

Expect to see nanotechnology, over the coming decade, offer great promise, yet be faced with great hurdles.

IPA