The vocabulary may be new, you may have to draw on all your powers of imagination to understand and appreciate the concept - but Mark Held suggests you persevere in his layman's guide to grand thinking on a scale measured in thousandths of a micron.

Moving into an era of nanotechnology



We make many assumptions about the make up of things around us. At the simplest of levels we draw a distinction between 'natural' and 'man made' objects. We accept, almost without question, that 'natural' or living objects are there by virtue of an immensely complex system of molecular interaction. For those not actively involved in the science of such things, knowing that molecules interact with energy forces, such as sunlight for example, is usually enough and we cease to question. Man-made objects on the other hand are often of more interest to us and their finite methods of production fit comfortably with our understanding of order and humankind's ability to take raw materials and process them. This is, however, a matter of complexity, for as we go into areas such as micro electronics, or chemical polymers, we start to feel less easy and look once more for a comfortable 'box' into which we can put sophisticated processes.

Biotechnology

Biotechnology takes us one step further down this road and begins to allow us to modify living objects in a way we would synthetic ones. The make up of living objects has been sequenced into component genes and, by modifying gene structure, we can effectively alter 'living' machines. The implications of biotechnology make many people uncomfortable and cause us to question the technological limits of man's ability to master the environment. Yet biotechnology does not allow us to manufacture living objects, it merely lets us modify in a selective manner.

Nanotechnology

There are two main definitions of nanotechnology. The first uses the term to describe any science or research where some crucial size is less than one micron (=1,000 nanometers). The second main area is often referred to as 'molecular nanotechnology' and this area occupies the gap between molecules and atoms in terms of scale. The best way to think about it is to imagine a fusing of mechanical engineering and molecular science. Throw out notions of crude construction methods and mix and match chemistry, and replace them with the concept of self-regulating molecular machines that build from the bottom up, molecule by molecule.

Origins

As a concept, nanotechnology is not new: over forty years ago, Richard Fenyman, a Nobel Prize winning physicist, was presenting the perspective that physicists could not see any theoretical reasons why engineering atom by atom could not take place.

"*….put the atoms where the chemist says, and so you make the substance.*"

Richard Fenyman, 1959

But how would we go about the task of positioning atoms in their precise order? Current manufacturing techniques in the micro- electronics industry utilise macroscopic positioning devices that ensure components are positioned correctly. Similarly, nanotechnology will use nano sized machines that will effectively be able to position atoms in the exact order required to synthesise a material or object.

Two materials that are likely to be crucial to the future development of this area are diamond and graphite. Both materials exhibit remarkable properties in terms of adhesion between individual atoms, though the number of bonds and the exact structure are different. Synthesised diamond structures could form a crucial building block for the required positioning machines via the creation of nano bearing surfaces that require no lubrication, yet allow the movement needed for accurate positioning.

Self Replication

Talk of synthesised diamond and graphite is one thing, managing this process in a cost effective and controllable way is not quite so simple. Currently diamond can be made artificially via a process known as Chemical Vapour Deposition, but this technique does not provide the control necessary

and as such work is ongoing to find ways of controlling this process accurately. This moves us on to the idea of a process being self-replicable and once again this is not a new concept, having been originally theorised by Von Nuemann in the 1940s. The idea of self-replication provides a crucial platform for nanotechnology to become commonplace and, importantly, cost effective. One of the foremost exponents of nanotechnology, Eric Drexler, has devised an architecture for a self-replicating nano assembler that is based on the principle of a molecular constructor tip, which is in turn controlled by a molecular computer. Research has shown that the complexity required of such a system is feasible and the number of 'bytes' required has been compared with other known self-replicating systems in existence, such as the E. Coli virus, or various computer based systems.

Summary So Far

Working on a scale that is measured in 1,000th of a micron, we understand in principle how molecular manufacturing technology will operate. Machines will reproduce clone machines at low cost and then, utilising such materials as diamondoids, they can be reprogrammed to build new items. The possibilities of such technology has wide ranging implications for all of us and the next part of this article will look at some of the possible areas of use.

Materials

Diamond fibre based materials could theoretically replace aluminium as a basic material in the aerospace industry. It would have a strength to weight ratio of more than forty times that of aluminium, which would bring enormous benefits in terms of fuel efficiency. Similarly, energy consumption in producing the material would be much lower than that of aluminium and this would have both cost and environmental benefits.

In the textiles industry there are a number of companies actively looking at the possibilities of nanotechnology. Burlington Industries, Inc., announced in November 1999 that they had acquired a 51% stake in AvantGarb, now Nano-Tex, LLC of Emeryville, California. According to George Henderson, chairman and CEO of Burlington Industries, research to date has produced good results. "Nano-Tex scientists are applying nanotechnology to textiles by developing unique polymer chemistry…the goal is to impart highly desirable features to fibres and fabrics, without losing softness, durability or breathability."

Other developments in fibre technology allow fibres to be combined with Piezoelectrics, materials which convert mechanical movement to high voltage electricity and vice versa. Conventional piezoelectric materials are mostly sintered ceramics, but scientists have developed a means of forming nano sized fibres onto the ends of the piezoelectric crystals which increases tenfold the electrical output. This technology could be used to produce ultra compact transformers, no more than a few centimetres long and a few millimetres wide and able to turn a 150v input into a 20kv output. (Ultra compact car ignition systems for example?)

Medical

It is likely that huge advances will be made by linking bio and nano technology. Healing effectively takes place via cell structures that can be stimulated to respond to modern drugs. Imagine a situation where we are able to directly heal injuries at a cellular level and administer drugs via intelligent delivery machines that can test and regulate according to results. Similarly, tools for surgery could be made to operate at a much more sophisticated level than that of the current scalpel for example, which really is very crude at the cellular level.

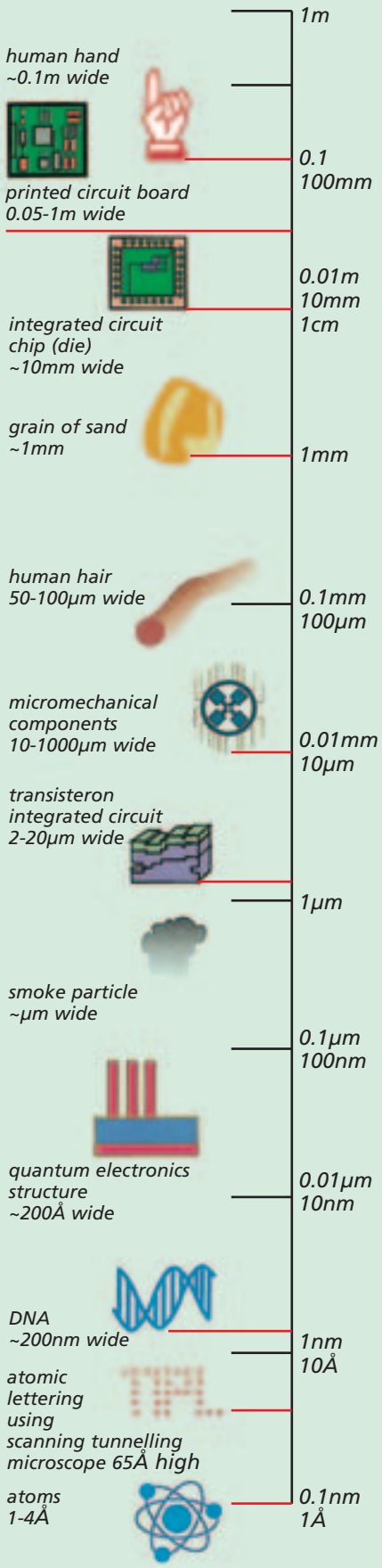
Coatings

The use of nano particles in the field of coatings has clear potential. On solar cells the ability to place a single layer coating on a semi-conductor could enhance the output of electrons when the cell is directed to sunlight. Other areas of coating technology that can be enhanced by nano science are corrosion resistant materials and bearing surfaces.

Automotive

We have already mentioned the possibilities in terms of ignition systems and lightweight panels, but the automotive industry is a clear contender in terms of benefiting from this technology. From items in current use, such as air bag sensors, to a whole host of other electronic and sensing products, the automotive industry is investing heavily in research.

Some size scales from human to atomic



source: 'Chemistry in Britain' by permission of Royal Society of Chemistry

Electronics

The impact of nanotechnology will be dominant in the field of electronics. Current computer chip manufacture relies on high-resolution lithography, which is incredible in itself, but probably unable to advance much further than its current status. (It involves a complex process of depositing fine patterns of chemicals onto a silicone surface.) The technology of chemical sprays and washes that are used in this process can in no way be compared with the ability to lay down a far more intricate pattern via the positioning of individual atoms. The increase in power that can be expected from such technology is vast, as is the impact in terms of miniaturisation. Combinations of 'mega' chips and devices could be used to make minute sensors and processors that could replace enormous amounts of current electronic machinery.

Sporting Goods

All very well and interesting, but what relevance does this have to textiles and sporting goods? The answer in the short term is "not a lot"! But think beyond our conventional paradigms and start to consider the impact of integrating cost effective electronics into garments. Nano sensors that can activate fibre reactions that could for example increase, or decrease, surface area according to either temperature or UV exposure? Controllable ventilation via micro fan technology; or camouflage sensors that modify pigmentation according to the environment? The list goes on and on and the implications for both good and bad in our industry, and outside it, make it well worth our while to keep it in mind.