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Nano Technology: A Microscopic Solution

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ABSTRACT
The essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. Nanotechnology is concerned with materials and systems whose structures and components exhibit novel and significantly improved properties. These physical, chemical, and biological properties, processes and phenomena are novel due to their nanoscale size in the range of about 10-9 to 10-7 m (1,000 times smaller than the diameter of human hair). The aim is to exploit these properties by gaining control of structures and devices at atomic, molecular, and supra-molecular levels and to learn to efficiently manufacture and use these devices. New behavior at the nanoscale is not necessarily as predictable as observed at large size scales. The most important changes in behavior are caused not by the order of magnitude size reduction, but by newly observed phenomena intrinsic to the nanoscale, such as size confinement, predominance of interfacial phenomena and quantum mechanics.

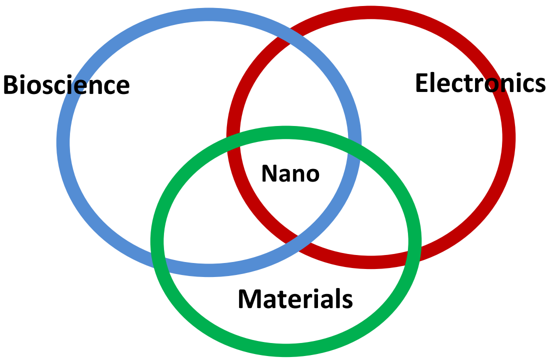
The objectives of this paper in Nano Technology are the design, modeling, and fabrication of molecular machines, molecular devices and software issues to design kind of devices and machine in Medical field those can help the mankind in proper understanding of diseases pathology and its treatment. The design and modeling of molecular machines is, however, quite feasible with present technology. More to the point, such modeling is a cheap and easy way to explore the truly wide range of molecular machines that are possible, allowing the rapid evaluation and elimination of obvious dead ends and the retention and more intensive analysis of more promising designs. It is clear that the right computational support will substantially reduce the development time. With appropriate molecular computer aided design software, molecular modeling software and related tools, we can plan the development of molecular manufacturing systems on a computer. The current Nano Design software architecture is a set of C++ classes with a tcl front end for interactive molecular gear design. We envision a future architecture centered on an object oriented database of molecular machine components and systems with distributed access via CORBA from a user interface based on a WWW universal client to eventually enable a widely disbursed group to develop complex simulated molecular machines.

Keywords
Molecular Modeling, TCL, CORBA, Cross - Bar Latch, Object Oriented Database of Nano Technology, Molecular Computer Aided Design Software.

1. INTRODUCTION
The concept of nanotechnology was founded by Richard Feynman in 1959 through his famous lecture, “There is Plenty of Room at the Bottom”. He envisioned that if one could fabricate materials and devices at the molecular scale, a new class of miniaturized instrumentation would be needed to manipulate and measure the properties of these small nanostructures. It was not until the 1980s that instruments were invented with the capabilities Feynman envisioned. These instruments, including scanning tunneling microscopes, atomic force microscopes, and near-field microscopes, provide the capabilities for nanostructure measurement and manipulation. Modern computational capabilities enable sophisticated simulations of material behavior at the nanoscale. Nanotechnology may be defined as “Research and technology development at the atomic, molecular and macromolecular levels in the length scale of 1–100 nanometer range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small size.” Nanometer is one billionth of a meter – a scale at which Hydrogen and carbon atoms appear as large as baseballs. Now imagine picking up those atoms and building a machine. In other words, nanotechnology is about building things atom-by-atom, molecule-by-molecule.

It is becoming increasingly accepted that we will, eventually, develop the ability to economically fabricate a truly wide range of structures with atomic precision. This will be of major economic value. Most obviously a molecular manufacturing capability will be a prerequisite to the construction of molecular logic devices. The continuation of present trends in computer hardware depends on the ability to fabricate ever smaller and ever more precise logic devices at ever decreasing costs. The limit of this trend is the ability to fabricate molecular logic devices and to connect them in complex patterns at the molecular level. The manufacturing technology needed will, almost of necessity, be able to economically manufacture large structures (computers) with atomic precision (molecular logic elements). This capability will also permit the economical manufacture of materials with properties that border on the limits imposed by natural law. The strength of materials, in particular, will approach or even exceed that of diamond. Given the broad range of manufactured products that devote substantial mass to load-bearing members, such a development by itself will have a significant impact. A broad range of other manufactured products will also benefit from a manufacturing process that offers atomic precision at low cost. Given the promise of such remarkably high payoffs it is natural to ask exactly what such systems will look like, exactly how they will work, and exactly how we will go about building them. One might also enquire as to the reasons for confidence that such an enterprise is feasible, and why one should further expect that our current understanding of chemistry and physics (embodied in a number of computational chemistry packages) should be sufficient to explain the operating principles of such systems.

It is here that the value of computational nanotechnology can be most clearly seen. Molecular machine proposals, provided that they are specified in atomic detail, can be modeled using the tools of computational chemistry. The pursuit of nanotechnology comprises a wide variety of disciplines: chemistry, physics, mechanical engineering, materials science, molecular biology, and computer science.



In order to the miniaturization of integrated circuits well into the present century, it is likely that present day, nanoscale or nanoelectronic device designs will be replaced with new designs for devices that take advantage of the quantum mechanical effects that dominate on the much smaller, nanometer scale. A completely new way of designing an electronic interconnects for nano-scale circuits using coding theory, by using cross-bar architecture.

2. CROSS BAR ARCHITECTURE

Believe future chips will have to rely, at least in part on the '*cross-bar architecture*' as shown in the figure 1, in which a set of parallel '*nanoscale wires*' are laid atop another set of parallel wires at approximately a 90 degree angle, sandwiching a layer of electrically switchable material in between. Where the material becomes trapped between the crossing wires, they can form a switch that represents a "1" or "0," the basic building blocks of computer code[1].

The design consists of a pair of parallel wires crossed by a second set of wires. Together they create a switch that can deliver the functions currently assigned to transistors on silicon processors. Each latch is incredibly tiny, only a few microns wide. The crossbar latch design is "well-suited to tolerate the inevitable defects that are bound to occur in the fabrication process at such tiny dimensions" because it doesn't require the same level of precision as silicon circuits.

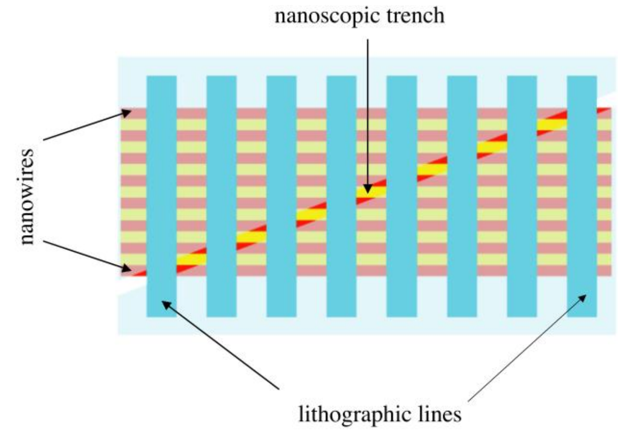


Figure 1: Cross-bar architecture

3. HOW IT WORKS?

Using electronic devices created by trapping an electrically switchable layer only a few atoms thick between crossed wires, a bit of memory can be stored or a logic function can be performed at each intersection of wires. Standard semiconductor circuits require three-terminal transistors to perform the 'NOT operation' and restore signals. However, it is generally believed transistors will not function at sizes of a few nanometers and that is why there is a practical limit to their miniaturization.

A microscopic device consisting of a single wire acting as a signal line, crossed by two control lines with an electrically switchable molecular-scale junction where they intersect. By applying a sequence of voltage impulses to the control lines and using switches of opposite polarities, the latch can perform the NOT function essential for general computing operations.

In addition, it can restore a logic level in a circuit to its ideal voltage value, allowing a designer to chain many simple gates together to perform an arbitrary computation, a working memory with molecular-scale junctions and logic devices that could perform simple logic operations such as AND and OR.

4. NANO TECHONOLOGY IN CHIP MAKING

Nanotech method for making microchip components which it says should enable electronic devices to continue to get smaller and faster. Current techniques use light to help etch tiny circuitry on a chip, but IBM is now using molecules that assemble themselves into even smaller patterns. Because the technology is compatible with existing manufacturing tools, it should be inexpensive to introduce. IBM says it hopes to pilot the nanotech process in about three to five years.

The company's researchers used the novel approach to make part of a device that acts as a type of flash memory, which retains recent information when an electronic gadget is turned off. Such memory is commonly found in handheld computers, mobile phones and digital cameras. At the moment, for example, microchip circuitry is put on silicon wafers using a lithographic process in which the image of the design of how the wires are to be laid out is first projected on to the prepared wafers.

With the new technique, it is the polymer patterns that provide the initial stencil - in this instance, for the crystalline array used to make the flash memory. Scientists say lithography is approaching its limits because of the difficulties of focusing light at very small scales - and new technologies are required if computer power is to continue to increase at its present rate.

Nanotechnology - engineering with atoms and molecules in the realm of just billionths of a meter is one possible way forward. "We are patterning at 20-nanometre dimensions and, depending on who you talk you that are about 10 times smaller than standard lithography. While IBM used the new process to build a tiny memory device, Black underlined the technology could be useful for making microprocessor components, which are more complex.

5. FABRICATION OF CROSS - BAR LATCH

Nanoscale molecular-electronic devices comprising a single molecular monolayer of bistable[2] rotaxanes sandwiched between two 40-nm metal electrodes were fabricated using imprint lithography. Bistable current–voltage characteristics with high on–off ratios and reversible switching properties were observed. Such devices may function as basic elements for futureultradense electronic circuitry. Molecular electronics offers the tantalizing prospect of eventually building circuits with critical dimensions of a few nanometers.

An atomic force microscope (AFM) image of a cross-point molecular device fabricated with imprint lithography process is shown in Figure2. In order to achieve nanometer lateral resolution, a carbon nanotube tip was used as the AFM probe.

Only the region near the active part of the device, comprising the two crossed nanowires and their connections to the microscale wires, is shown in the image. The nanowires have a measured width of ~40 nm, which is consistent with the 40-nm width of the nanowires templates in the mold. A high-resolution image of the crossed electrodes shows the active junction area of ~40 nmX40 nm.

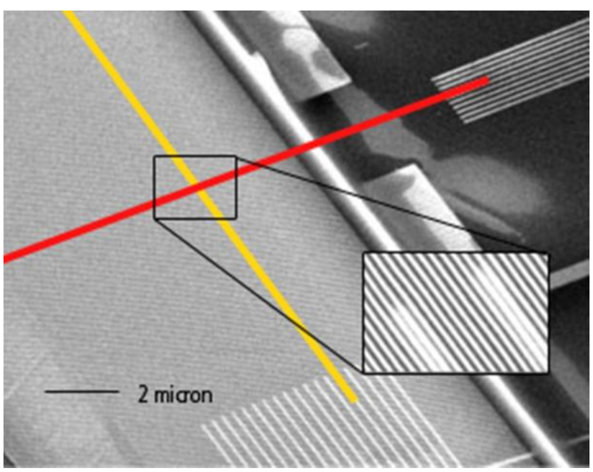
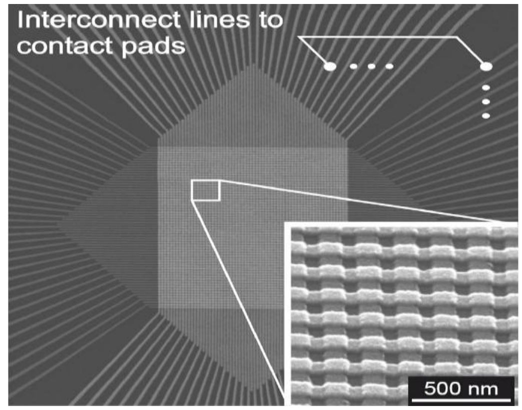


Figure 2: An atomic force micrograph of a nanoscale cross-point molecular device with an insert showing the details of the cross point.

6. DESIGN OF 64-BIT MEMORY USING CROSS - BAR LATCH

The '*highest density electronically addressable 64-bit memory*' in a space one micron square - an area so tiny that more than 1,000 could fit across the end of a single strand of human hair can be seen in this series of pictures, taken with optical and scanning electron microscopes, each image is magnified approximately 10 times more.



Interconnect lines to contact pads in 64—bit memory

7. LIMITATIONS TO OVERCOME

All the products around us are made of atoms. The properties of these products depend on how their atoms are arranged. By rearranging the atoms of coal could be turned into diamond. Rearranging the atoms in sand and adding a few other trace elements could make computer chips.

Today's manufacturing methods are very crude at the molecular level[3]. Casting, grinding, milling and even lithography move atoms in great thundering statistical herds. It is like trying to make things out of LEGO blocks with boxing gloves on hands.

The LEGO blocks could be heaped and piled up, but fine objects cannot be created like this. Nanotechnology removes the boxing gloves and enables to snap together the fundamental building blocks of nature easily, inexpensively and in most of the ways permitted by the laws of physics[3].

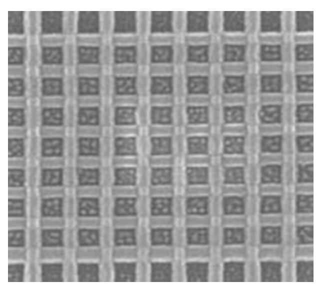


Figure 3: A close-up of a single 64-bit memory.

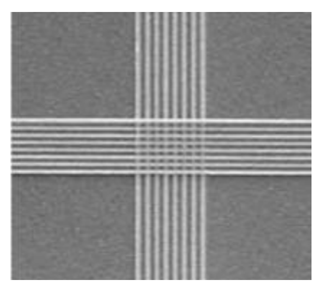


Figure 4: The crossed-wire structure of the memory.

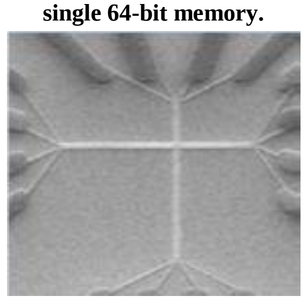


Figure 5: Nanowires leading from the test pins

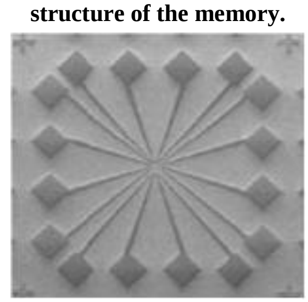


Figure 6: A single test structure with the memory

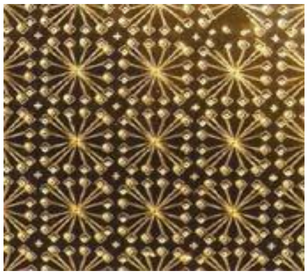


Figure 7: An array of memories with their test connections.

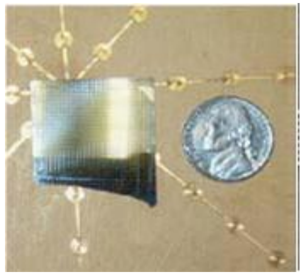


Figure 8: The wafer on which 625 memories and their test structures were simultaneously imprinted

8. DESIGN SOFTWARE

The simple molecular machines simulated so far can be easily designed and modeled using ad hoc software and molecule development. However, to design complex systems such as the molecular assembler/replicators, more sophisticated software architecture will be needed. The current NanoDesign software architecture[4] is a set of c++ classes with a tcl front end for interactive molecular gear design. Simulation is via a parallelized FORTRAN program which reads files produced by the design system. We envision a future architecture centered around an object oriented database of molecular machine[4] components and systems with distributed access via CORBA from a user interface based on a WWW universal client.

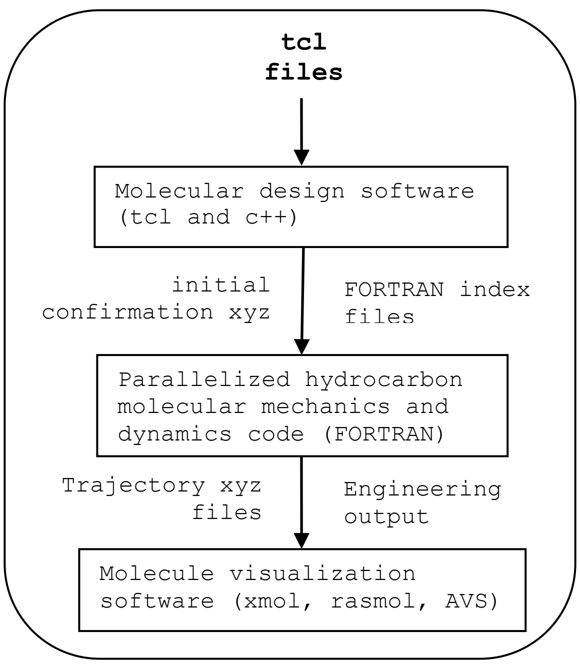


Figure 9: Current Software Architecture

9. CURRENT NANODESIGN SOFTWARE ARCHITECTURE

The current system consists of a parallelized FORTRAN program to simulate C++ was chosen for molecular design for its object oriented properties and high performance. However, c++ is a compiled language so changes to the code take a bit of time[8]. This is inconvenient when designing molecular systems; an interpreted language would be better. Tcl is meant to be used as an embedded interpreted command language in c and c++ programs. Tcl is a full featured language with loops, procedures, variables, conditionals, expressions and other capabilities of procedural computer languages. C++ programs can add new tcl functions to any tcl interpreter linked in. Thus, tcl gives us an interpreted interface to the c++ class library so molecules can be designed at interactive rates[4].

Future distributed NanoDesign software architecture. Note that each box may represent many instances distributed onto almost any machine. The software architecture based on a universal client (for example, a WWW browser), CORBA distributed objects, an object oriented database, and encapsulated computational chemistry legacy software. We are also interested in using command language fragments to control remote objects. Software that communicates this way is sometimes called agents.

10. UNIVERSAL CLIENT

With the advent of modern WWW browsers implementing languages such as Java and JavaScript, it is possible to write applications using these browsers as the user interface. This saves development time since most user interface functionality comes free, integration with the WWW is trivial, and the better browsers run on a wide variety of platforms so portability is almost free[8]. These developments suggest that a single program can function as the user interface for a wide variety of applications, including computational nanotechnology.

These applications load software (e.g. Java applets and JavaScript) into the browser when the user requests it. The applications then communicate with databases and remote objects (such as encapsulated legacy software) to meet user needs.

10.1 CORBA *(Common Object Request Broker Architecture)*

The universal browser is of little use in developing complex molecular machines if it cannot communicate with databases of components and systems and invoke high performance codes on fast machines to do the analysis. CORBA[4], a distributed object standard developed by the OMG (Object Management Group), provides a means for distributed objects.

10.2 Object Oriented Database

To develop complex molecular machines, databases of components and processes as well as complex databases describing individual systems will be required[4]. Object oriented databases appear to be better than relational databases for design systems for products such as aircraft and molecular machines.

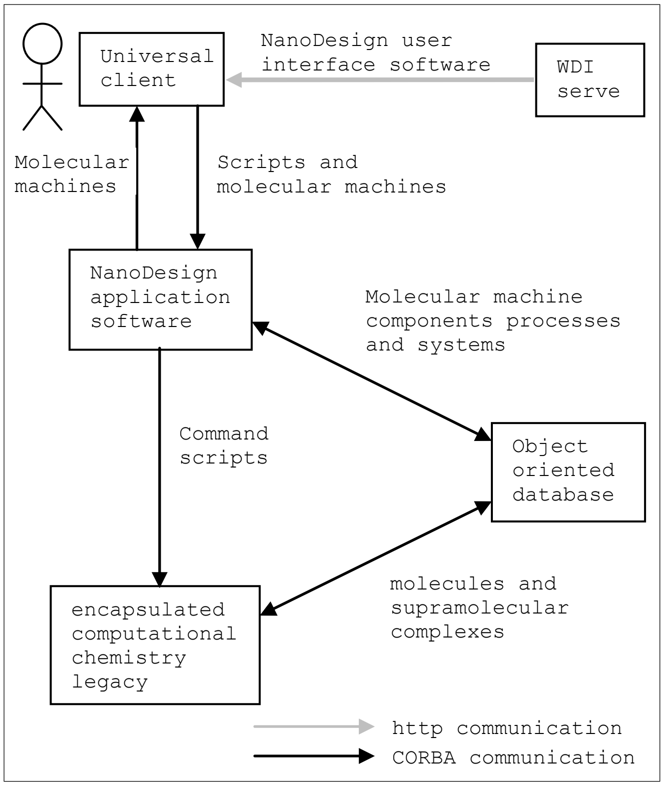


Figure 10 Proposed Future Software Architecture

11. NANO TECHNOLOGY IN MEDICINE

It will deal with the problems involved in designing and building a micro-scale robot that can be introduced into the body to perform various medical activities[1]. The preliminary design is intended for the following specific applications:

1. **Tumors.** We must be able to treat tumors; that is to say, cells grouped in a clumped mass. The specified goal is to be able to destroy tumorous tissue in such a way as to minimize the risk of causing or allowing a recurrence of the growth in the body.
2. **Arteriosclerosis.** This is caused by fatty deposits on the walls of arteries. The device should be able to remove these deposits from the artery walls. This will allow for both improving the flexibility of the walls of the arteries and improving the blood flow through them
3. **Blood clots**. The cause damage when they travel to the bloodstream to a point where they can block the flow of blood to a vital area of the body. This can result in damage to vital organs in very short order. By using a micro-robot in the body to break up such clots into smaller pieces.

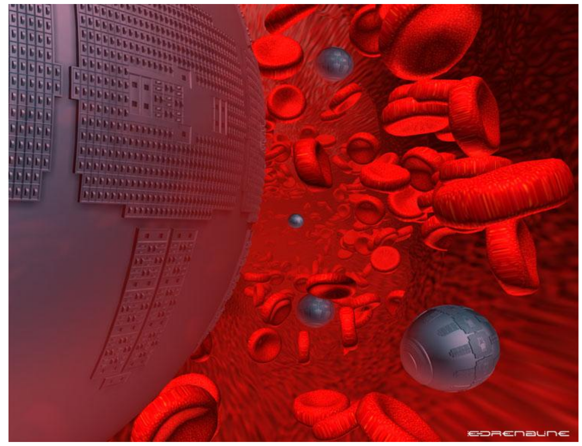


Figure 11: Nanites inspecting Red Blood cells

12. NANO DRUG DELIVERY SYSTEMS

Nano drug delivery systems are being designed using nano-particles to deliver medicine to specific parts of the body, for example to tumours. An illustration of how nano-machines interact with the cells in the body, to deliver drug, detect infections and carry out other roles in the field of Nanomedicine.

Nanites inspecting red blood cells are shown in figure 11[6]. The ultimate aim is to create a nano-shell (figure 12), full of medicine that is strong enough to journey through the body until triggered to release its contents.

Nano-shells are about 1/20th the size of a red blood cell, and are about the size of a virus. They are ball-shaped and consist of a core of silica covered by a metallic shell, either gold or silver[6]. Nano-shells are already being developed for applications including cancer diagnosis, cancer therapy, and diagnosis and testing for proteins associated with Alzheimer's disease, and drug delivery[6]. Nano-shells allow the absorption of energy and then create an intense heat that kills the tumor cells.

Nanotechnology provides a wide range of new technologies for developing customized solutions that optimize the delivery of pharmaceutical products[8]. To be therapeutically effective, drugs need to be protected during their transit to the target action site in the body while maintaining their biological and chemicals properties. Some drugs are highly toxic and can cause harsh side effects and reduced therapeutic effect if they decompose during their delivery[9]. Depending on where the drugs will be absorbed (i.e. colon, small intestine, etc), and whether certain natural defense mechanisms need to be passed through such as the blood-brain barrier, the transit time and delivery challenges can be greatly different[6]. Once a drug arrives at its destination, it needs to be released at an appropriate rate for it to be effective. If the drug is released too rapidly it might not be completely absorbed, or it might cause gastro-intestinal irritation and other side effects.

The drug delivery system must positively impact the rate of absorption, distribution, metabolism, and excretion of the drug or other substances in the body[6]. In addition, the drug delivery system must allow the drug to bind to its target receptor and influence that receptor's signaling and action, as well as other drugs, which might also be active in the body. Drug delivery systems also have ever restrictions on the materials and production processes that can be used. The drug delivery material must be compatible and bind easily with the drug, and be bio-resorbable[9].

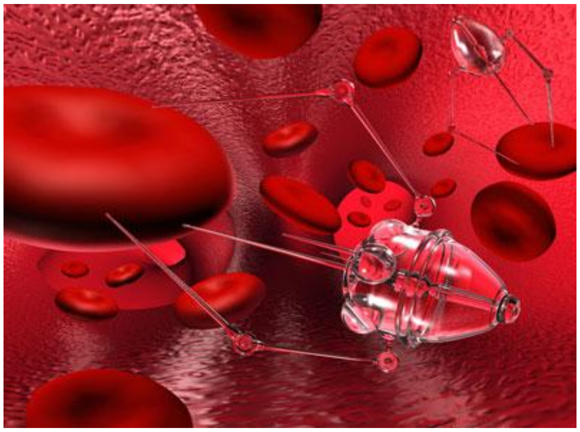
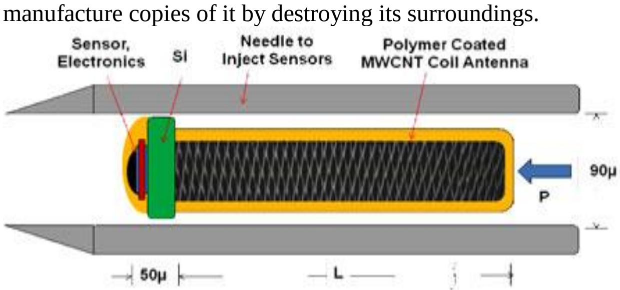


Figure 12: Nano- Shells

13. NANO TERRORISM "THE RIGHT TOOLS IN WRONG HANDS"

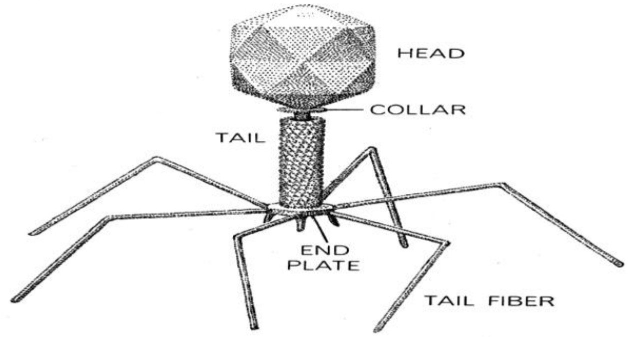
As with computers, nanotechnology and programmable assembler could become ordinary household objects. It is not too likely that the average person will get hold of and launch a nuclear weapon, but imagine a separatist launching an army of nanorobots programmed to kill on the basis of racial discrimination or sharp philosophical differences. Vast armies of tiny, specialized killing machines that could be built and dispatched in a day; nanosized surveillance devices or probes that could be implanted in the brain of people without their knowledge[5].

A small nano-machine capable of replication, could copy itself too many times. If it were capable of surviving outdoors, and of using biomass as raw material, it could severely damage the environment[9]. An effective means of sabotage would be to release a hard-to-detect robot that continued to manufacture copies of it by destroying its surroundings.



Concept in-body responsive device: Injectable wireless tumor sensor. (Image: Prof. Schulz)[10]

Destructive nano-machines could do immense damage to unprotected people and objects. If the wrong people gained the ability to manufacture any desired product, they could rule the world, or cause massive destruction in the attempt. Certain products, such as vast surveillance networks, powerful aerospace weapons, and microscopic antipersonnel devices, provide special cause for concern[5]



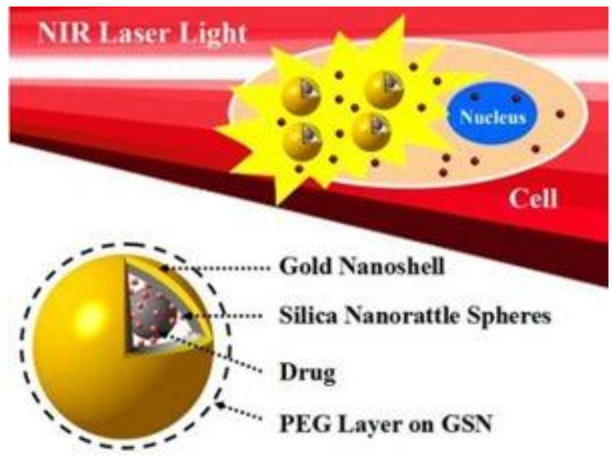


Figure 13: Circulating magnetic microsphere with antibodies to capture cancer cells for examination outside the body.[10]

14. FURTHER POSSIBLE APPLICATION

1) To cure skin diseases, a cream containing nanorobots may be used. It could remove the right amount of dead skin, remove excess oils, add missing oils, apply the right amounts of natural moisturizing compounds, and even achieve the elusive goal of 'deep pore cleaning' by actually reaching down into pores and cleaning them out. The cream could be a smart material with smooth–on, peel–off convenience[7].
2) A mouthwash full of smart nanomachines could identify and destroy pathogenic bacteria while allowing the harmless flora of the mouth to flourish in a healthy ecosystem. Further, the device would identify particles of wood, plaque, or tartar, and lift them from teeth to be rinsed away. Being suspended in liquid and able to swim about, devices would be able to reach surfaces beyond reach of toothbrush or the fibres of floss. As short lifetime medical nano-devices, they could be built to last only a few minutes in the body before falling apart into materials of the sort found in foods (such as fibre)[7].
3) Medical nano-devices could augment the immune system by finding and disabling unwanted bacteria and viruses. When an invader is identified, it can be punctured, letting its contents spill out and ending its effectiveness[7]. If the contents were known to be hazardous by themselves, then the immune machine could hold onto it long enough to dismantle it more completely.

4) Devices working in the bloodstream could nibble away at arteriosclerotic deposits, widening the affected blood vessels. Cells herding devices could restore artery walls and artery linings to health, by ensuring that the right cells and supporting structures are in the right places[7]. This would prevent most of the heart attacks.
5) Potential future breakthroughs also include use of nano-robotics and intelligent systems for environmental and nuclear waste management, use of nano-filters to separate isotopes in nuclear fuel processing, of nano- fluids for increased cooling efficiency of nuclear reactors, of nano-powders for decontamination, and of computer simulation at nanoscale for nuclear safety[7].

15. CONCLUSION

Nanotechnology is a future technology, which enables '*low-cost, high yield fabrication*'. The crossbar latch design is "well-suited to tolerate the inevitable defects that are bound to occur in the fabrication process at such tiny dimensions" because it doesn't require the same level of precision as silicon circuits.

The software required to design and model complex molecular machines is either already available, or can be readily developed over the next few years. The NanoDesign software is intended to design and test fullerene based hypothetical molecular machines and components. The system is in an early stage of development. Presently, tcl provides an interpreted interface, c++ objects represent design components, and a parallelized FORTRAN program simulates the machine. In the future, an architecture based on distributed objects is envisioned. A standard set of interfaces would allow vendors to supply small, high quality components to a distributed system.

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