The purpose of nanofabrication is to produce structures at a nanoscale that complete part of a system or device in large quantities and at low costs. There are two main approaches to nanofabrication.

Top-down method:
• Start by taking a portion of material and keep removing the piece of it you don't want until you get the desired shape and size
• This process requires a lot of patience as a lot of energy must be spent and toxic chemicals must be used. As a result, the results are quite unique and not easily duplicated
• Most common top-down techniques are optical lithography and nano imprint lithography (NIL)
• Optical lithography: standard machine used in today's semiconductor industries
• NIL: extensive production of nanoparticles for diagnostic and therapeutic applications
Bottom-up method:
• Doesn't require expensive tools to create the nanoscale structures
• Endless applications with this method include quantum dots, carbon nanotubes, and metallic nano wires.
• To create more complex devices, engineering the interactions between the components and getting the system to evolve is typically done
• Two bottom-up techniques known as self-assembly and molecular assembly, which differ by their applications
• Self-assembly: involved in protein folding, weather systems, galaxies, etc
• Molecular assembly: involved in factories, assembly lines, etc

**Nanotechnology is fascinating, but it's not perfect… yet**
There are evidently going to be numerous issues with nanofabrication as nanotechnology is a relatively new field. Some problems are regarding the fact that it can currently only be done in small amounts in laboratory settings and concerns with how nanosensors are used and unintended consequences.
More specifically, there are problems with lithography (one of the top-down fabrication method techniques) and insufficient studies and experimentation with certain applications.
With lithography techniques…
• currently not really time-effective as the work must be started from scratch each time
• not very practical for mass-production as patterns cannot be fabricated over large areas
• negatively impacts include plasmonics, solar cells and data storage
Although nanotechnology can help with enhancing drinking water quality, it is crucial to investigate potential health risks first.
• Since some of the properties of some nanomaterials are dependent on the size or surface characteristics of the particles, nanoparticles with the same chemical components as large particles may act in unexpected ways, posing new human health or environmental hazards.
With food applications, there are arising concerns regarding potential risks to human health and the environment of nano ingredients in food.

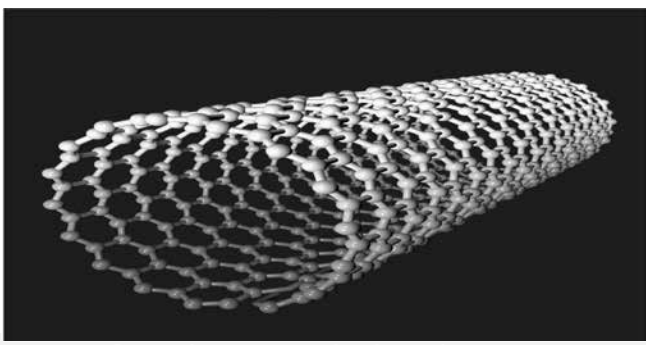
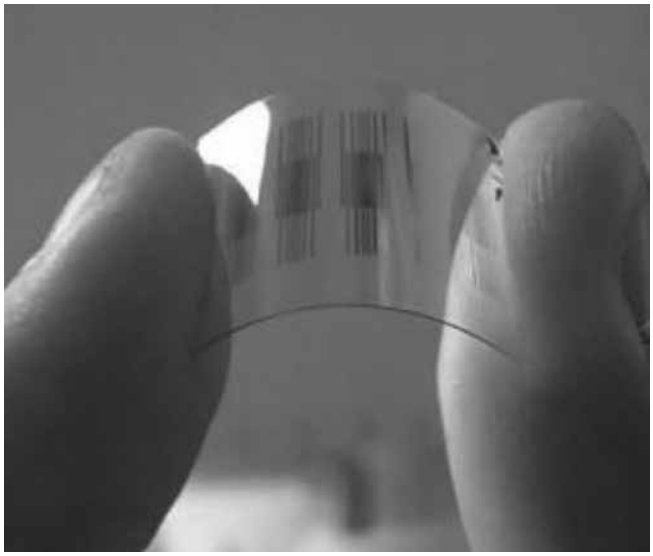


Image of a carbon nanotube-based sensor

**What are some potential solutions to these issues?**
As of today, solutions include different materials and particles to help speed up the process of the nanofabrication methods, specifically the bottom-up method as it is more practical in comparison to the top-down method.
There are many theories and studies still being done as nanotechnology and nanoscience are relatively new fields. As many more studies and experiments are conducted, we will be able to gather more of an understanding of how to improve upon the current nanofabrication processes.

**Some more additional resources to check out:**
https://www.technologyreview.com/s/411695/nanosensors-made-easy/
https://www.nature.com/subjects/nanosensors
http://www.ftf.lth.se/fileadmin/ftf/Course_pages/FFFA01/Paper-Nanofabrication.pdf



nanosensors can report on cancer biomarkers including cancer-associated proteins, circulating tumor DNA, circulating tumour cells and exosomes. Measurements of certain cancer biomarker levels allows for early detection of cancer and tumors. This also helps monitor the efficacy of the therapy.

4. New hip replacement treatment: Not only can nanosensors be used to identify problems, but also treat them. If the sensors pick up anything unfamiliar, they can be programmed through a handheld device to release a drug, killing bacteria or reducing scar-tissue growth. This ensures the healthy growth of the bone next to the implant and a more effective treatment will result.

**• "Sensors will help us to better understand the world we live.**

**How do nanosensors work?**

Let's dig in and understand how this really works!

These nanosensors work by monitoring electrical changes in the nanomaterials which can then be analyzed.

There are two types of nanosensors that differ by their sensing mechanisms: mechanical nanosensors and chemical nanosensors.

Mechanical nanosensors:

• Detect a change in the electrical conductivity in the material

• Nanomaterials that are used as nanosensors change their electrical conductivity when the material is physically manipulated

• This physical change sends a detectable response

Chemical nanosensors:

• Once an analyte has been detected, the nanosensors measure the change in electrical conductivity of the nanomaterial

• Analyte: a substance with chemical components being measured

• This change evokes a detectable response

• Examples include nanowires and nanotubes

For example, in carbon nanotube-based sensors…

• When nitrogen dioxide is present, it will strip an electron from the nanotube which causes the nanotube to be less conductive

• If ammonia is present, it reacts with water vapour and gives an electron to the carbon nanotube, making it more conductive

**How are nanosensors built?**

It's really interesting to learn how nanosensors are built.

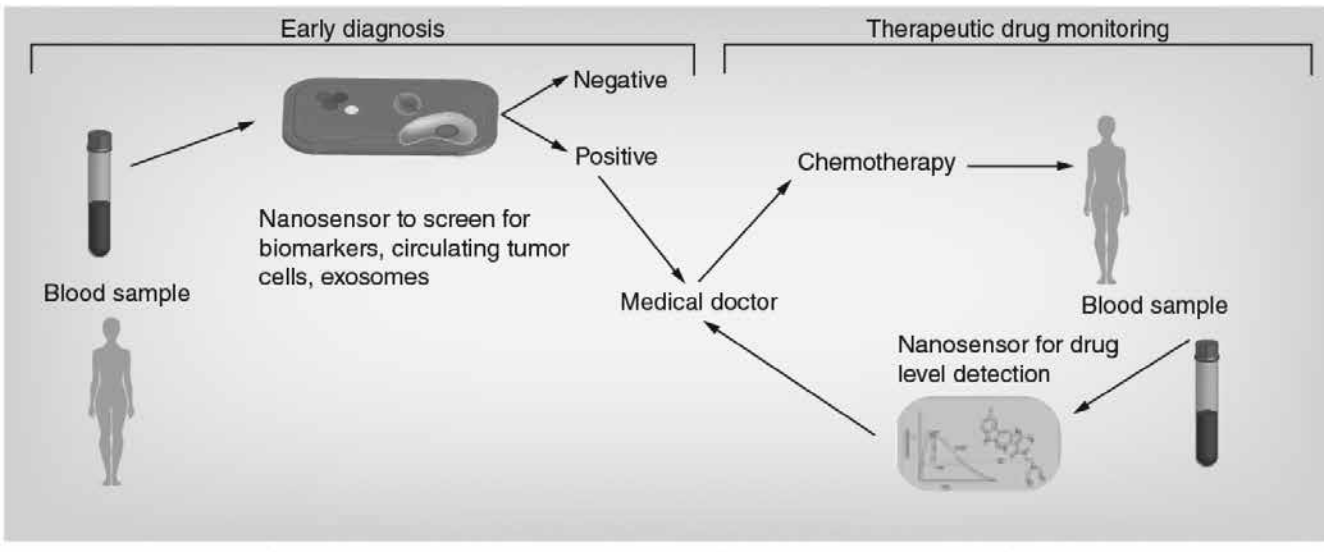



**Figure 1. Nanosensors for cancer monitoring.** Nanosensors will enable the screening of normal/diseased

SPORT
Textile


Dr. F Nayeb Morad

# Nanosensors and Nanofabrication

Imagine being able to fully heal spinal cord injuries or even improve water and air quality!

These are some of the many fields that nanotechnology can be applied in.

There are many definitions for nanotechnology but according to Google, nanotechnology is "the branch of technology that deals with dimensions and tolerances of less than 100 nanometers, especially the manipulation of individual atoms and molecules." To put this in more simpler terms, it's essentially the manipulation of the structure of matter on a nanoscale. The prefix "nano" refers to a nanometer, which is a billionth of a meter, so this nanoscale is a pretty small scale.

To provide some background…

• The idea behind nanotechnology started at an American Physical Society meeting in 1959, with a talk entitled "There's Plenty of Room at the Bottom" by physicist Richard Feynman. Feynman describes processes where scientists would be able to physically manipulate individual atoms and molecules.

Over a decade later, while exploring ultraprecision machining, Professor Norio Taniguchi formulated the term nanotechnology. The development of the scanning tunneling microscope, which allowed you to see individual atoms, began in 1981.

Using nanotechnology, scientists are creating materials at the nanoscale to enhance properties of existing objects and processes. These include stronger strength, lighter weight, greater chemical reactivity, and even magnetic permeability! This technology is applicable across many fields and enhances life in all aspects.

**What even are nanosensors?**

They don't necessarily refer to the size of sensors, but sensors that are able to work at a nanoscale. They can detect nano materials and nanoparticles and since they're so small, they can be placed on small strips of paper or any other small materials. They also improve the sensitivity and speed of detection as a result of their unique properties.

**Why are nanosensors so important?**

They can essentially be used to detect and find more information about everything around them from improving water quality to designing new ways of hip replacement treatments.

1. Detection of pesticides in drinking water: Scientists are now working on making these sensors portable. This helps water quality and improve the health of many individuals in developing regions.

2. Detecting toxic materials (e.g. nitrogen oxide) in the air around us: The sensors are small and portable, and wearable using micro fibre optics. This reduces the amount of heart problems and cancer risks in many individuals.

3. Improving efficiency of cancer diagnosis: The