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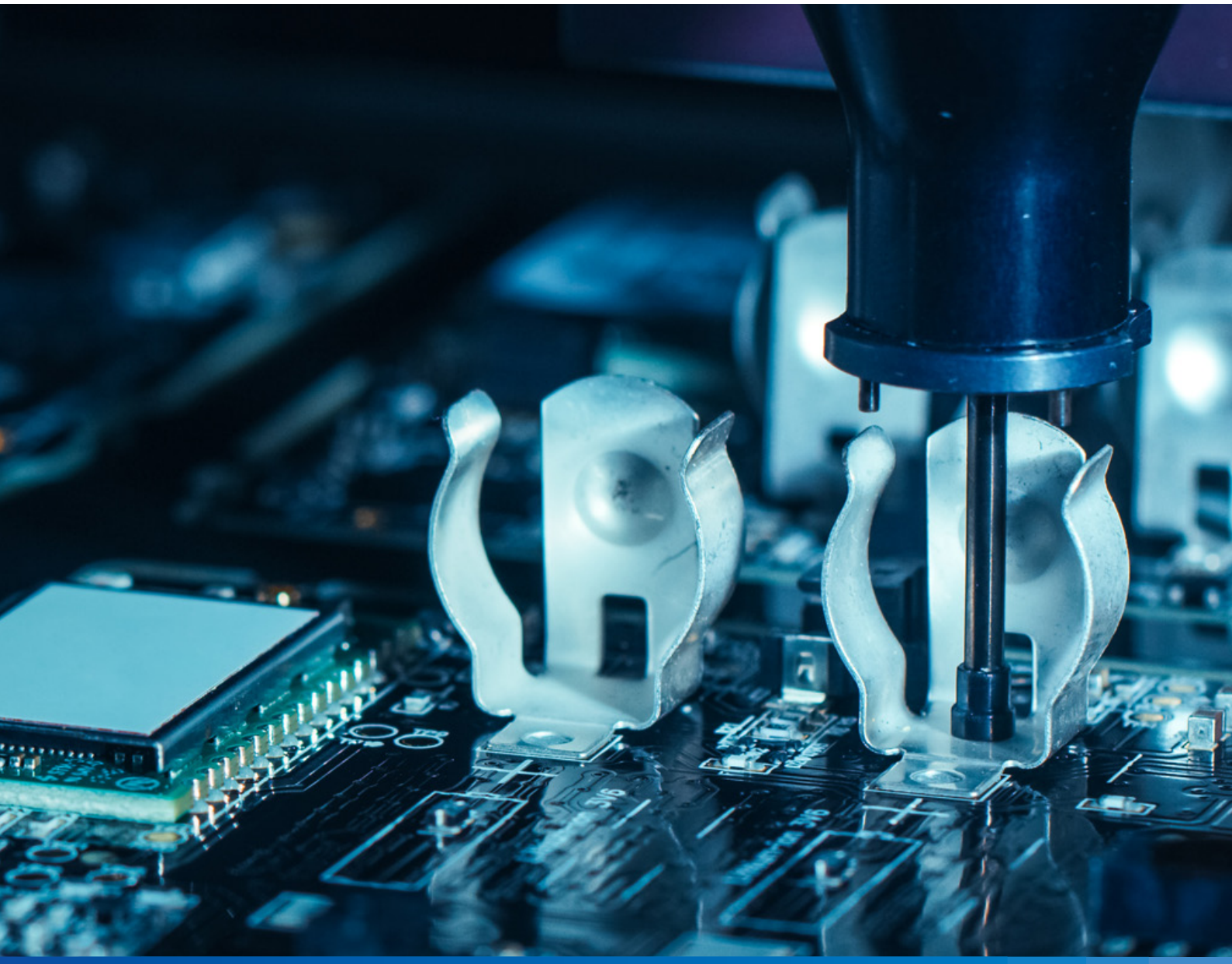

NANOTECHNOLOGY

Harnessing the power of miniaturization

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Abstract

Nanotechnology deals with dimensions and tolerances of less than 100 nm, especially the manipulation of individual atoms and molecules. It helps to manufacture lighter, stronger, cleaner, less expensive and more precise products.

Summary

Nanotechnology is the branch of technology that deals with dimensions and tolerances of less than 100 nm, especially by manipulating individual atoms and molecules. This technology has a variety of applications, starting from nano-medicine, oil & gas extraction to the reduction of chip size making the mobile devices sleeker.

- Companies are building transistors from carbon nanotubes to enable minimum transistor dimensions of a few nanometers and developing techniques to manufacture integrated circuits built with nanotube transistors.
- The size and volume of the chipsets and transistors are continuously reducing, thus making the devices sleeker and smaller. A 5 nm chip could perform about 40% faster than a 10 nm chip, given the same power settings and being 75% more power efficient.
- The technology has impacted the society, government and businesses positively with improved productivity, and close monitoring of nearly every aspect within these segments.
- IBM, TSMC, AMD, and Intel are working aggressively towards miniaturizing the chipsets, bringing them down to 3 nm by 2022.
- Overpopulation, rise in crimes and terrorism are some of the harmful effects associated with Nanotechnology.
- The wearables market, expected to grow almost 26% Y-o-Y from 2018, with worldwide shipment reaching 225 million by 2019, has been one of the key drivers to reducing the chip size.
- Molecular 3D printers, solar power, grapheme engine are some of the advancements in the field of this technology.

This white paper gives importance to chip size reduction, emphasizing on the role played by manufacturers and their perspective on various factors related to Nanotechnology.

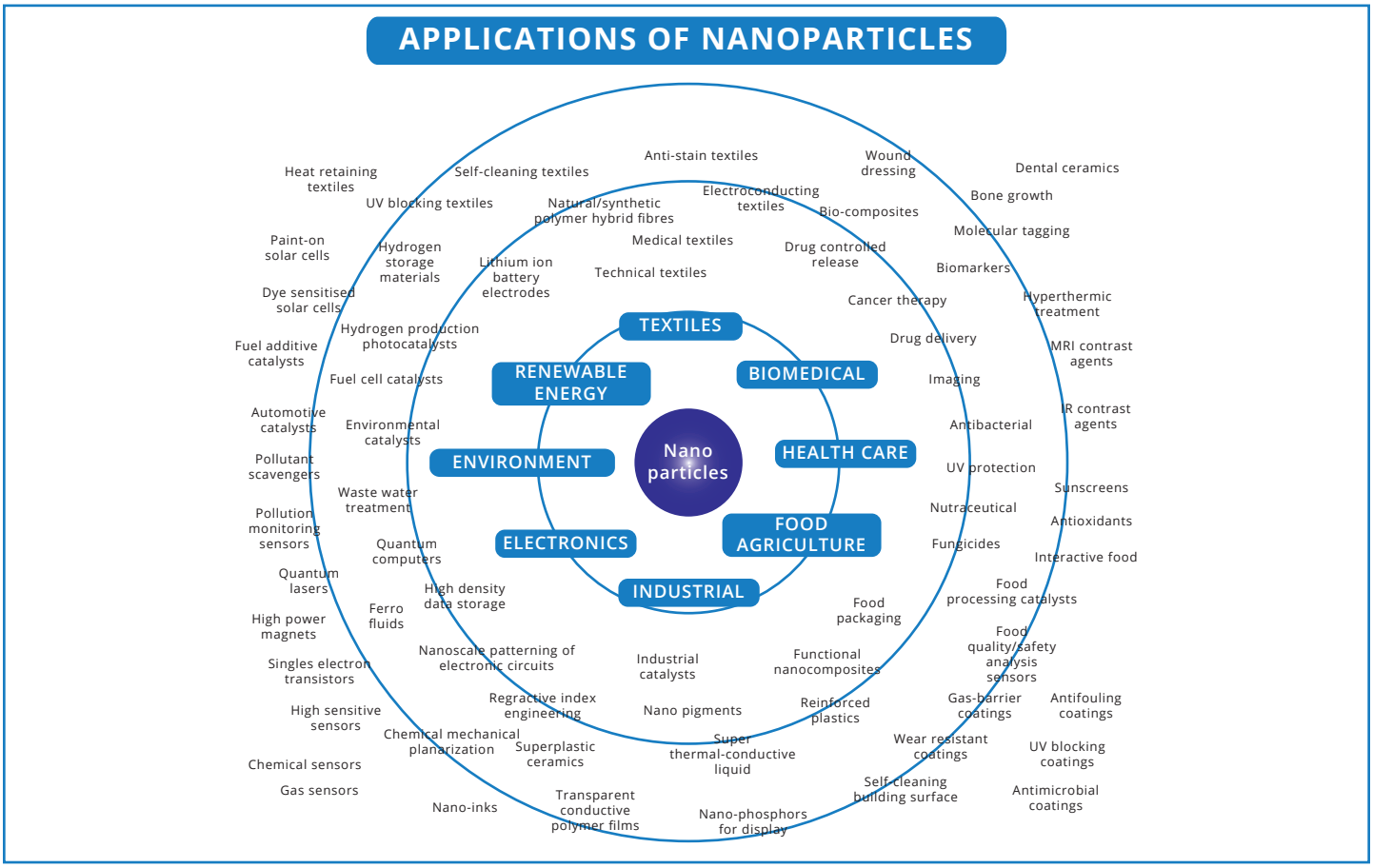
Introduction

Manufacturers have advanced their technology portfolio while entering a new era of technology. A technology that can reduce the size of the molecule dimensions and tolerances to less than 100 nm and reduce the size of the product, without affecting its performance. This technology will help to massively increase manufacturing production at significantly reduced costs. Products of nanotechnology will be smaller, cheaper, lighter, yet more functional, requiring lesser energy and fewer raw materials to manufacture.

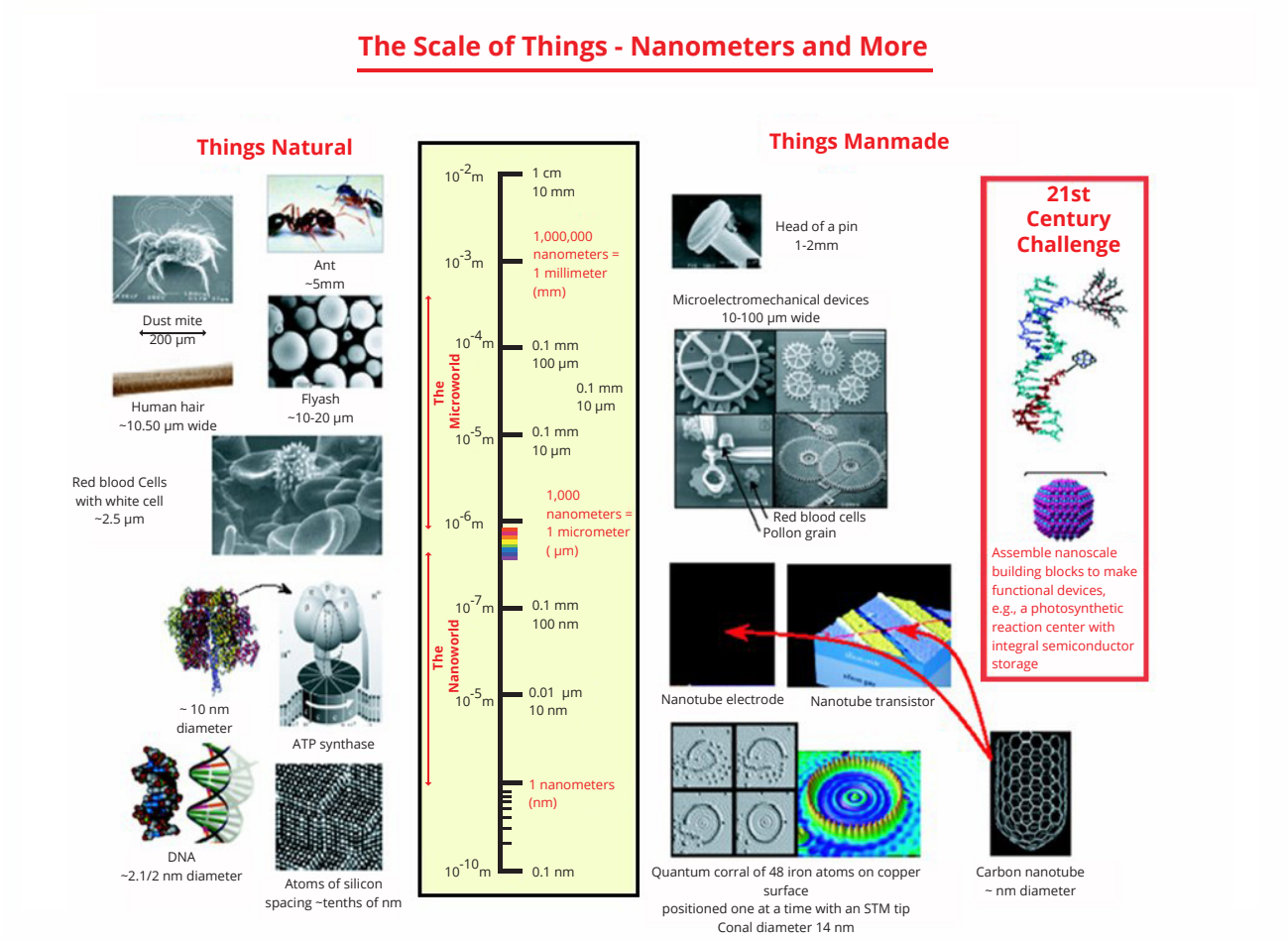
The nanometer scale is about a billionth of a meter and things this small can behave quite strangely. These unusual physical and chemical characteristics come about because there is an increase in surface area compared to volume as particles get smaller and also because they are subject to quantum effects. Many governments believe nanotechnology will bring about a new era of productivity and wealth, and this is reflected in the way public investment in nanotechnology research and development has risen during the past decade.

Nanotechnology has provided effective and efficient solutions to a range of applications in biomedical, agriculture, industry and military applications. Nanotechnology has enabled the evolution of Nano-machines – tiny components consisting of an arranged set of molecules performing pre-determined tasks.

The interconnection of nano-devices and nano-sensors with the internet has led to the development of a new and more advanced generation standard based on IoT called 'Internet of Nano Things' (IoNT). IoNT is segmented by devices such as Nano Cameras, Nano Phones, Nanosensors, Nano Processors, Nano-Memory Cards, Nano Power Systems, Nano-Antennas, and Nano Transceivers.



Scale of Things in Nanometers (nm)



Nanotechnology is the manipulation of matter for use in particular applications through certain chemical or physical processes to create materials with specific properties. There are both "bottom-up" processes (such as self-assembly) that create nanoscale materials from atoms and molecules, as well as "top-down" processes (such as milling) that create nanoscale materials from their macro-scale counterparts.

Nanoscale materials that have macro-scale counterparts frequently display different or enhanced properties compared to the macro-scale form, where information from incidentally formed or natural nano-sized materials (such as ultrafine particulate matter) may aid in the understanding of intentionally produced nanomaterials.

Nanotechnology helps with various types of element detection, such as carbon nanotubes, zinc oxide nanowires or palladium nanoparticles, which can be used in nanotechnology-based sensors. Because of the small size of nanotubes, nanowires, or nanoparticles, a few gas molecules are sufficient to change the electrical properties of the sensing elements.

Nanotechnology Journey

1958: Richard Feynman delivers first lecture on technology and engineering at the atomic scale, 'There's plenty of room at the bottom.

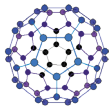
1974: First molecular electronic device patent

1981: Drexel published Molecular Engineering: molecular machinery

1981: IBM invents scanning probe microscope that measures and identifies structures at Nano-scale, and has ability to move individual atoms and molecules on surface

1958 — **1981**

1985: Curl, Kroto, Smalley discovered Bucky balls, Stable molecules that contain 50 to 500 carbon atoms in a ball, using laser vaporized carbon.



1985

1989: IBM Almaden Research Center wrote IBM with 35 Xenon atoms

1990-2000's consumer Nanotech products appear in market

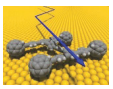
1990's Early nanotechnology companies began to operate

1991: Discovery of carbon nanotubes by Sumin Iijima at NEC Research Labs

1993: First US research lab dedicated entirely to nanoscience. Smalley at Rice University

2000: US launch of National Nano-technolo-gy Initiative (NNI)

1989 — **2000**



2003: US President Bush signs Nanotechnolo-gy R&D act - $3.7 Billion over 4 years

2003

2004: Britain's Royal Society and the Royal Academy of Engineering published Nanoscience and Nanotechnologies: Opportunities and Uncertainties advocating the need to address potential health, environmental, social, ethical, and regulatory issues associated with nanotechnology.

2005: Erik Winfree and Paul Rothemund from the California Institute of Technology developed theories for DNA-based computation and "algorithmic self-assembly" in which computations are embedded in the process of nanocrystal growth.

2006: James Tour and colleagues at Rice University built a nanoscale car made of oligo (phenylene ethynylene) with alkynyl axles and four spherical C60 fullerene (buckyball) wheels

2007: Angela Belcher and colleagues at MIT built a lithium-ion battery with a common type of virus that is non-harmful to humans, using a low-cost and environmentally benign process.

IBM used a silicon tip measuring only a few nm at its apex (similar to the tips used in atomic force microscopes) to chisel away material from a substrate to create a complete nanoscale 3D relief map of the world one-one-thousandth the size of a grain of salt—in 2 minutes and 23 seconds.

2004 — **2010**

2010: Nadrian Seeman and colleagues at New York University created several DNA-like robotic nanoscale assembly devices.

2020* — **2012**

2020*: A study funded by the National Science Foundation estimates that 6 million nanotech workers will be needed worldwide by 2020

2014: The NNI releases the updated 2014 Strategic Plan.

2012: The US Government recognizes the strategic importance of nanotechnology and plans to spend nearly $2 billion in research.

Application areas for Nanotechnology

Nanotechnology is helping to considerably improve and revolutionize many technologies and industry sectors such as IT, homeland security, medicine, transportation, energy, food safety and environmental science, among many others. The adoption of nanotechnology is growing and is expected to cater to all major industry verticals. The IoT platform acts as a medium to communicate with nanotechnology. Similarly, defense & aerospace is another major industry, which is making use of nanotechnology. It is also used in drones for drone surveillance and other such applications. The US market has dominance in North America, owing to high adoption rates in various industries.

Few of the industry verticals are:

- **Healthcare:** Nanotechnology helps in tuberculosis treatment, the clinical application of nanotechnology in operative dentistry, in ophthalmology, in surgery, visualization, tissue engineering, antibiotic resistance, and immune response.
- **Energy:** The use of nanotechnology-enabled gas lift valves helps in offshore operations or the use of nanoparticles to detect microscopic down-well oil pipeline fractures. Additionally, during the drilling stage, nanoparticles can be used to change the viscosity of drilling muds, addressing the problem of thick drilling mud caking the wellbore's walls and increasing the force required for extraction.
- **Electronics:** It helps to manufacture lighter, stronger, cleaner, less expensive and more precise products, without compromising on efficiency and performance. Chip companies are reducing the chip size to make devices lighter and sleeker than the earlier versions.

Using nanotechnology, materials can effectively be made stronger, lighter, more durable, more reactive, more sieve-like, or better electrical conductors, among many other traits. Some of the application areas for Nanotechnology processes are:

Everyday materials and processes:

- Nanoscale additives can provide lightweight ballistic energy deflection in personal body armor.
- Nanoscale materials are beginning to enable washable, durable "smart fabrics" equipped with flexible nanoscale sensors and electronics with capabilities for health monitoring, solar energy capture, and energy harvesting through movement.
- Nanostructured ceramic coatings exhibit far greater toughness than conventional wear-resistant coatings for machine parts.
- Nanoscale titanium dioxide and zinc oxide have been used for years in sunscreen to provide protection from the sun while appearing invisible on the skin.

Electronics:

- Transistors, the basic switches that enable all modern computing, have become smaller and smaller through nanotechnology.
- Magnetic random access memory (MRAM) is enabled by nanometer-scale magnetic tunnel junctions and can quickly and effectively save data during a system shutdown or enable resume-play features.
- Nanoparticle copper suspensions have been developed as a safer, cheaper, and more reliable alternative to lead-based soldering and other hazardous materials commonly used to fuse electronics in the assembly process.

- Other computing and electronic products include Flash memory chips for smartphones and thumb drives, ultra-responsive hearing aids, antimicrobial/antibacterial coatings on keyboards and cell phone casings, conductive inks for printed electronics for RFID/smart cards/smart packaging, and flexible displays for e-book readers.

Medical and Healthcare:

- Better imaging and diagnostic tools enabled by nanotechnology are paving the way for earlier diagnosis, more individualized treatment options, and better therapeutic success rates.
- Nanomedicine draws on the natural scale of biological phenomena to produce precise solutions for disease prevention, diagnosis, and treatment.
- The design and engineering of advanced solid-state nanopore materials could allow for the development of novel gene sequencing technologies that enable single-molecule detection at low cost and high speed with minimal sample preparation and instrumentation.
- A nanoparticle can encapsulate or otherwise help to deliver medication directly to cancer cells and minimize the risk of damage to healthy tissue.

Energy Applications: Many scientists are looking into ways to develop clean, affordable, and renewable energy sources, along with means to reduce energy consumption and lower the toxicity burden on the environment.

- Nanotechnology is improving the efficiency of fuel production from raw petroleum materials through better catalysis.
- It is also enabling reduced fuel consumption in vehicles and power plants through higher-efficiency combustion and decreased friction.
- Wires containing carbon nanotubes are being developed that will have much lower resistance than the high-tension wires currently being used in the electric grid, thus reducing transmission power loss.
- It is enabling more efficient lighting systems, lighter and stronger vehicle chassis materials for the transportation sector, lower energy consumption in advanced electronics, and light-responsive smart coatings for glass.
- During hydraulic fracking, nanoparticles can help increase the viscosity of the fracking fluid and thus improve its rock-fracturing ability.
- Nanoparticles can reduce oil viscosity and alter wettability to improve oil mobility and hence recoverability. Magnetic nanoparticles like ferromagnetic nanofluids (also known as ‘smart’ nanofluids) can be used as crude oil tracers in estimating residual oil saturation.

Environmental Remediation:

- Nanotechnology could help meet the need for affordable, clean drinking water, through rapid, low-cost detection and treatment of impurities in water.
- Engineers have developed a thin film membrane with nanopores for energy-efficient desalination.
- Nanoparticles are being developed to clean industrial water pollutants in groundwater through chemical reactions that render the pollutants harmless.
- Nanotechnology-enabled sensors and solutions are now able to detect and identify chemical or biological agents in the air and soil with much higher sensitivity than ever before.

Future transportation:

- Nano-engineered materials in automotive products include polymer nano-composites structural parts, high-power rechargeable battery systems, thermoelectric materials for temperature control, lower-rolling-resistance tires, and high-efficiency/low-cost sensors and electronics.
- Nanoscale sensors and devices may provide cost-effective continuous monitoring of the structural integrity and performance of bridges, tunnels, rails, parking structures and pavements over time.
- Nano-engineered materials in automotive products include high-power rechargeable battery systems, thermoelectric materials for temperature control, and many other applications.

Predictions by Industry experts

It is interesting to note that Industry experts are pretty confident about the future applications of nanotechnology.

"The global nanotechnology market is expected to grow to $ 125 billion mark by 2024, at a CAGR of around 17% during the forecast period 2018-2024. The top three applications of nanotechnology are electronics, energy and biomedical, accounting for over 70% share of the global nanotechnology market."

Research & Markets

"The global defense application market for nanotechnologies was valued at nearly $ 3 billion in 2017. Automotive application captured nearly 5% share of the global nanotechnology market."

Research & Markets

"The global market for nanodevices and nanomachines is expected to grow from $736.1 million in 2018 to $1.3 billion in 2023 and then to $2.7 billion in 2028, at a CAGR of 11.6% from 2018 to 2023 and 16% from 2023 to 2028."

BCC Research

"The global healthcare nanotechnology market is expected to witness a CAGR of 15.1% during the forecast period, 2018-2023."

Mordor Intelligence

"The Internet of Nano-Things market was valued at $6.4 billion in 2017, and is expected to reach a value of $22.04 billion by 2023, at a CAGR of 22.8%, during the forecast period (2018-2023)."

Orbis Research

Players

Key players for Nanotechnology and Nanomaterials:

Impact of Nanotechnology on various segments

Society: Nanotechnology will have significant social impact in the areas of military applications, intellectual property issues, and will have an effect on employment. Analysts suggest the possibility that nanotechnology has the potential to destabilize international relations through a nano arms race and has an increased potential for bio-weaponry, thus, providing the tools for ubiquitous surveillance with significant implications for civil liberties.

- **Military Applications:** The potential military applications include nanorobotics, AI and molecular manufacturing. More socially disruptive weapon systems are to be expected from molecular manufacturing, a potential future form of nanotechnology that would make it possible to build complex structures at atomic precision. Molecular manufacturing might be used to cheaply produce, among many other products, highly advanced, durable weapons. Being equipped with compact computers and motors, these might be increasingly autonomous and have a large range of capabilities.
- **Intellectual property issues:** On the structural level, critics of nanotechnology point to a new world of ownership and corporate control opened up by nanotechnology. Corporations are already taking out broad-ranging patents on nanoscale discoveries and inventions. For example, two corporations, NEC and IBM, hold the basic patents on carbon nanotubes. It has wide range of uses and look set to become crucial to several industries - from electronics and computers, to strengthened materials, to drug delivery, and diagnostics.
- **Employment:** During the improvement of nanotechnology, firms are likely to have high demands for scientists, engineers, and technicians, who have to build and integrate new ideas into processes and products.

Government: Nanotechnology has been helping the government in a large scale. Miniaturization technique and Advanced surveillance technologies such as cameras, listening devices, tracking devices, and face and pattern recognition systems, help the government to collect, store and examine data to keep track of the citizens.

Business: Business processes will be affected positively with plenty of new developments and innovations with the help of nanotechnology. This technology has the potential to realign society, change businesses and affect economics at the structural level. New business models, design tools and manufacturing strategies may emerge highly efficient and at much reduced price points.

- **Electronics:** With the help nanotechnology, the cost of fabrication lines for making computers are reduced. The emergence of a nanochip would deliver over 50 GHz of speed with the processing power of ten supercomputers for the price of a quartz watch and smaller than that of a key chain. High optical and electrical conductivity is mainly required in various semiconductor and electronic devices, touchscreens, LEDs, and OLEDs to enhance processing efficiency.
- **Industrial:** Miniaturized sensors can be used in many devices in the industrial process making the work automatic. With automation, work will become easier to manage and monitor in real-time.
- **Healthcare:** Biosensors, nanoprobes, and quantum dots have the potential to detect individual exposures and tissue distributions of toxins. The development of smart sensors would allow their use in population-based epidemiology studies aimed at developing better prevention tools.

Investment and Funding

The President's 2019 Budget in the US, allocates nearly $1.4 billion for the National Nanotechnology Initiative (NNI), a continued investment in basic research, early-stage applied research, and technology transfer efforts that will lead to the breakthroughs of the future.

NNI Budget, by Agency, 2017-19 (in $ millions)

Agency	2017 Actual	2018 Estimated*	2019 Proposed
CPSC	1.9	1.0	1.0
DHS	0.4	0.4	0.3
DOC/NIST	80.7	70.1	57.9
DOD	143.3	143.7	125.9
DOE**	341.2	327.2	324.1
DOI/USGS	0.1	0.1	0.0
DOJ/NIJ	2.0	1.7	1.7
DOT/FHWA	0.3	1.5	1.5
EPA	10.7	10.7	4.5
HHS (total)	472.3	469.1	464.3
FDA	11.6	12.5	12.5
NIH	449.6	445.5	440.7
NIOSH	11.1	11.1	11.1
NASA	9.5	7.8	6.0
NSF	465.7	420.8	387.7
USDA (total)	24.2	23.3	20.7
ARS	3.0	3.0	2.0
FS	6.2	5.3	3.7
NIFA	15.0	15.0	15.0

Source: Nano.Gov 2018

* 2018 numbers are based on annualized 2018 continuing resolution levels and are subject to change based on final appropriations and operating plans. ** DOE: Department of Energy

Nanotechnology companies that received funding in 2018

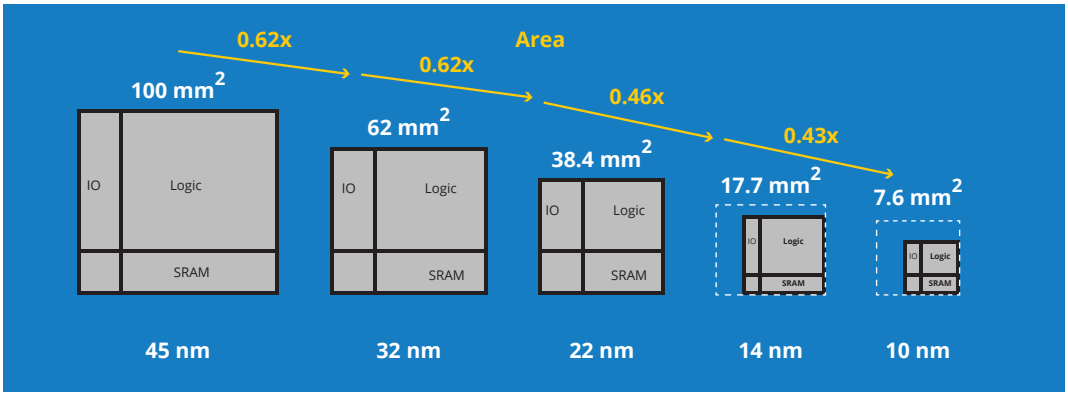
Organization Name	Total Funding Amount ($ million)	Last Funding Amount ($ million)
Oxford Nanopore Technologies	679	100
Nantero	121.1	29.7
Liquidia Technologies	99.3	25.5
DigiLens	60	25
Abionic	27.7	20.3
StoreDot	146	20
Lyncean Technologies	19.7	13.7
NuMat Technologies	22.3	12.4
Nanotech Industrial Solutions	12	12
Onconano Medicine	17.6	11.7
Nano-C	11.5	11.5
Oxford Photovoltaics	53.4	10.7
BlueWillow Biologics	92.8	10
Pixelligent	54.7	7.6
Nanomech	39.6	7

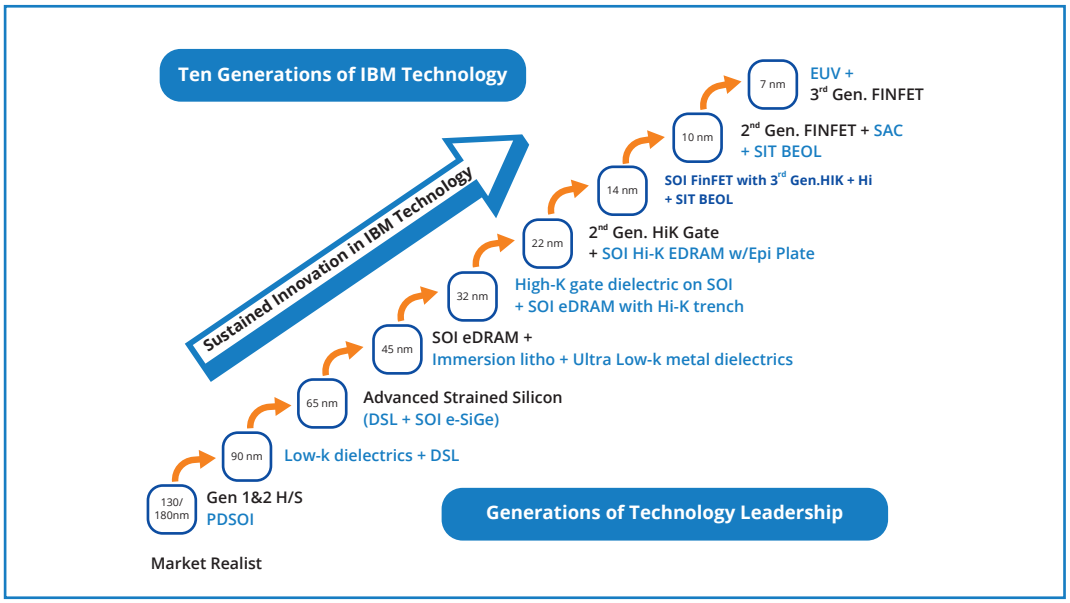
Miniaturization of Chipsets

Nanotechnology has contributed to major advances in computing and electronics, resulting in faster, smaller, and more portable systems that can manage and store a larger amount of information. Transistors, the basic switches that enable all modern computing, have also been reduced in size using nanotechnology to fit in the diminished architecture.

Companies are building transistors from carbon nanotubes to enable minimum transistor dimensions of a few nanometers and developing techniques to manufacture integrated circuits built with nanotube transistors. Using electrodes made from nanowires would enable flat panel displays to be flexible, as well as thinner than the current flat panel displays. Researchers are also looking towards making integrated circuits with features that can be measured in nanometers (nm), such as the process that allows the production of integrated circuits with 22 nm wide transistor gates.

In the last 30 years, between 1989 and 2018, the semiconductor size has reduced from 1000 nm to 7 nm and is expected to further reduce to 5 nm by 2020. In 2014, Intel created a 14 nm transistor, while IBM created the first 7 nm transistor in 2015, and Lawrence Berkeley National Lab demonstrated a 1 nm transistor in 2016. Building transistors from carbon nanotubes enable minimum transistor dimensions of a few nanometers and the development of techniques to manufacture integrated circuits built with nanotube transistors. The size of the chipset is inversely proportional to the number of transistors used to manufacture them (e.g. IBM used 20 billion transistors inside the 7 nm chipset and around 30 billion transistors inside 5 nm chips).





A 5 nm chip could perform about 40% faster than a 10 nm chip, given the same power settings and also 75% more power efficient. The size of the chipsets and transistors are continuously reducing thus making the devices sleeker and smaller. The chipsets are also getting used in the wearable devices, making them smart devices. A small transistor indicates that there could be more transistors per chip. With more transistors, there could be more pipelines in each core or even more cores per chip. Usually, more pipelines and more cores indicate higher performance (throughput instead of latency).

The manufacturers may integrate more functional units into one chip. For example, more and more companies have on-chip memory, whose bandwidth and speed is much faster. With several future applications in the offing, nanotechnology is expected to be widely adopted by various industry verticals globally. The technology is applicable to all internal system within a device, which includes its wiring system.

Nanotechnology has already paved its way towards the wearables market with a chipset designed by OriginGPS, Nano Spider, which supports very compact applications where size is key, like smart watches, trackers, digital cameras, and a wearable device. It is a fully integrated and very sensitive GPS receiver module that is very small. This product has low noise amplifiers, temperature controlled crystal oscillator, surface acoustic wave, a real-time clock, radio frequency shielding, and a power management unit. It helps to continuously track every GPS satellite, providing real-time positioning data using the standard industry format, according to the US National Marine Electronics Association (NMEA) standards.

Nanotechnology in Electronics Industry

Nanochip

A nanochip is a small-sized electronic integrated circuit that can only be measured properly on the nanometer scale. Miniaturization of electronic and computer components has always been a primary goal of engineers. The smaller an electronic system can be made, the more the processing power that can fit into a given physical volume, the less the energy that is required to run it, and the faster it can work.

APAC is expected to present profitable opportunities in the nanochip market in the near future. This is largely due to the increase in adoption of advanced smartphones, rising R&D expenditure by market players, and rising use of nanochip technology across the growing healthcare industry vertical.

The major manufacturers of nanochip are Intel, Samsung, Taiwan Semiconductor Manufacturing (TSMC), Global Foundries, Qualcomm, microchip technology, NXP Semiconductors, Broadcom, Toshiba, SK Hynix, and Micron Technology among others.

Nanowire

A nanowire is a nanostructure, with the diameter of the order of a nanometer. Nanowires can be defined as structures that have a thickness or diameter minimized to tens of nanometers or less, and an unconstrained length. Nanowires can be used for transistors, which are used widely as the fundamental building element in currently used electronic circuits. Due to the high aspect ratio, if the gate dielectric is wrapped around the nanowire channel, the channel electrostatic potential will be good, which will help in turning the transistor on and off efficiently.

Due to the unique one-dimensional structure with remarkable optical properties, the nanowire also opens new opportunities for realizing high-efficiency photovoltaic devices. The nanowire solar cells are less sensitive to impurities due to bulk recombination, and thus silicon wafers with lower purity can be used to achieve acceptable efficiency, leading to the reduction on material consumption.

This is particularly beneficial for efficient collection of photo-generated carriers, when core and shell segments are engineered to be thinner than minority carrier diffusion lengths.

Graphene

Graphene is an allotrope of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice. It can be considered as an indefinitely large aromatic molecule, the ultimate case of the family of flat polycyclic aromatic hydrocarbons. It is a very strong material tested, that conducts heat and electricity efficiently, and is nearly transparent.

It can self-repair holes in its sheets when exposed to molecules containing carbon, such as hydrocarbons. The ballistic thermal conductance of graphene gives the lower limit of the ballistic thermal conductance, per unit circumference and length of carbon nanotubes.

Others

Currently, nanotechnology-based semiconductor materials are becoming the base of our modern lifestyle due to the production of materials with extremely large surface area to volume ratio, which indicates that the electronics device we are using is small and more efficient than what we used before. Nowadays, the semiconductor industry is becoming a key tool for energy harvesting with increasing efficiency as well.

One of the most important areas that semiconductors were used is for solar energy harvesting to create solar cells. Solar cells or photovoltaic materials are the ones which are produced by nanotechnology, by increasing its efficiency of photon trapping and converting to electric energy by making the material quantum dot, quantum wire and quantum well.

Partnerships

- **Nano Global - ARM:** Nano Global, an Austin-based molecular data company, has announced that it is developing a chip using IP from ARM, the world's leading Semiconductor IP Company. The system-on-chip (SoC) will yield highly-secure molecular data that can be used in the recognition and analysis of health threats caused by pathogens and other living organisms.
    - By collaborating with Nano Global, ARM is taking an active role in developing and deploying technologies that will move us one step closer to solving complex health challenges.
- **Imec - ORCHID:** The world-leading research and innovation hub in nano-electronics and digital technologies Imec has joined ORCHID, a European initiative that will establish an European infrastructure to enable coordinated development, production and implementation of Organs-on-Chips. Organs-on-Chips combine human mini-organs with microelectronics, microfluidics, and nanosensors.
    - This technology, which is already providing new platforms for drug discovery, is poised to deliver applications in personalized medicine and safety pharmacology, and offers alternatives to conventional animal testing.

- **ASML Holding NV – IBM:** Governor of new York, Mr. George E. Pataki has announced that **ASML Holding NV** and **IBM** have created a $400 million nanochip R&D at the Albany Center of Excellence in Nanoelectronics. The new International Multiphase Partnership for Lithography Science and Engineering (IMPULSE) is ASML's first R&D center outside of Europe and will bring together a network of over 50 high tech companies from across New York.

Announcements and Future plans

- In 2017, IBM Research and partners GlobalFoundries and Samsung had created transistors for a 5 nm semiconductor chip by using the standard FinFET architecture.
- In 2017, Taiwan Semiconductor Manufacturing Co. (TSMC) had planned to spend more than $20 billion to build the world's most advanced 3 nm chip facility, in Taiwan in the early 2020s.
- TSMC, the world's largest contract chipmaker and a key Apple supplier, is expected to begin making cutting-edge 5 nm chips in small quantities in the first half of 2019 and 3 nm chips in 2022.
- TSMC's 2nd Gen 7 nm manufacturing technology (CLN7FF+, N7+) will use extreme ultraviolet lithography for four non-critical layers, mostly in a bid to speed up production and learn how to use ASML's Twinscan NXE step-and-scan systems for HVM.
- AMD has announced its next-generation of gaming GPUs in Jan 2019, the AMD Radeon VII, which is built on enhanced 2nd-gen AMD Vega architecture. The GPU is built on 7 nm process and is claimed to offer 25% more performance at the same power as previous Vega graphics.
- Kirin 990, the very first 7 nm SoC chipset is likely to be introduced in 2019, will support 5G networks, owing to its Balong 5000 5G modem.
- Intel announced its long-delayed Ice Lake processors at CES 2019, the first to use Intel's 10 nm manufacturing process in substantial quantities, with shipments expected in 2020.

Key drivers in Electronics Industry:

- Manufacturers have planned for more sleeker smartphones in the near future, which would require smaller chipsets and minimal and small internal wirings.
- With the growing demand for a smartwatch in the market, the wearable market is expected to grow in the near future.
    - According to Gartner, the wearable market is poised to grow by almost 26% by 2019 compared to 2018, with worldwide shipment reaching 225 million.
- IoNT as a concept, will help all the miniaturized sensors and chipsets within various devices to communicate among each other, providing smarter technical options.

Impact of Nanotechnology on Products

- **Decreasing weight and increasing strength:** Strengthening the structure of materials such as plastic, steel, concrete, and even fabrics, by using nanotechnology, increases the strength while decreasing the weight of products. Nanoparticles, nanotubes, and nanofibers can be considered to the most important option to strengthen the structure of composites.
- **Decreasing size and reducing energy consumption:** The global trend in the production of electronic devices is in such a way that producers seek to reduce the size of equipment and increase speed and efficiency at the same time. Therefore, companies work on the implementation of nanostructures such as carbon nanotubes and nanowires as the connector in various electrical devices.
- **Improving efficiency:** In many products such as monitors, nanotechnology is used as common technologies, resulting in the improvement of the product. Adding nanomaterial to surfaces such as glass or fabric, creates new behaviors such as self-cleaning, helping to improve the efficiency of the existing products.
- **Making smart:** One of the most important achievements of nanotechnology in industrial products is to make them smart and get real-time data for each process.
- **Decreasing costs:** Nanotechnology has decreased the cost of production of sustainable energies in recent years. It has been realized that by decreasing the cost of production of solar cells, high capacity batteries, capacitors with high stability, and by the presentation of cheaper methods to produce hydrogen from water, one can reduce the overall cost of production.
- **Improving productivity of equipment and sensors:** The use of nanomaterial in sensors has significantly increased the accuracy and sensitivity of the devices to the extent that a small amount of the desired material can be detected at short notice.

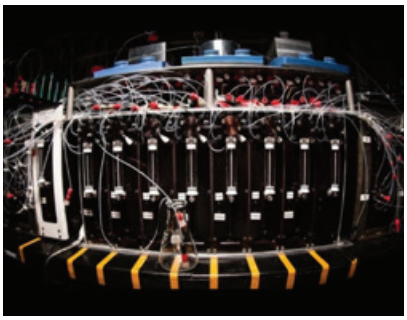
Risks associated with Nanotechnology

Nanotechnology, if uncontrolled or misdirected, could potentially harm or even annihilate human population. Below mentioned are the potentially harmful effects associated with nanotechnology:

- **Overpopulation:** It has been suggested that advancements in nanotechnology could eliminate all forms of genetic diseases and slow down aging. This could augment the health span of humans at least tenfold. If such an increase in longevity does not reduce births, the human race would expand exponentially that could lead to exhaustion of resources, and rise in geographic and social tensions.
- **Rise in crime and terrorism:** With nanotech advancements, biological and chemical weapons could become deadlier, and easier to be concealed. The risks would rise especially when such weapons become easily available in the black market, or if it easily gets manufactured in a home factory. For instance, in theory, Nano-factories could produce an intelligent anti-personnel weapon the size of an insect that could carry a lethal dose of botulism.
- **Disparity between haves and have-nots:** Initially, nanotech developments are likely to be expensive and would be protected by layers of laws, patents, and anti-competitive barriers. As such, the benefits of lower costs are likely to just pass to the owners of the technology. In such a situation, poverty and income disparity could inflate creating social unrest.

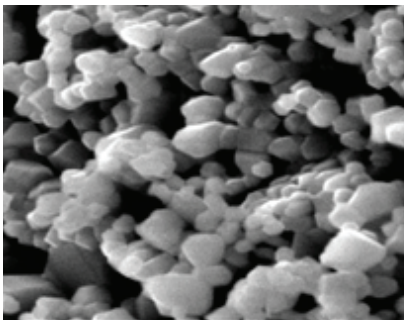
- **Conflicts over lifestyles and religious beliefs:** Certain products which are banned in different countries (such as alcohol in Muslim societies), could easily be produced in personal Nano-factories that could lead to disruption in those societies.
- **Grey Goo:** Grey goo is a hypothetical scenario involving molecular nanotechnology in which out-of-control self-replicating robots consume all biomass on Earth, while building more of themselves, a scenario which is known as ecophagy.

Major breakthrough advancements in Nanotechnology



Molecular 3D Printers

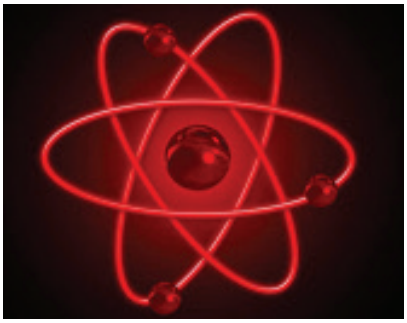
The medical doctor Martin Burke, at the University of Illinois, developed a new kind of 3D printer that is able to 3D print molecules. It is expected to not only revolutionize the use of 3D printing for healthcare, but the whole medical industry. The printer is able to print at a new scale, with chemicals. Each of the chemical building blocks has connectors, and the role of the molecular printer is to automate the process to connect the building blocks together and then create a chemical reaction. The hard part for Burke and his team was the clean-up of the byproduct and to correctly isolate the molecule after the chemical reaction. But they succeeded, giving life to a remarkable prototype of the 3D molecular printer.



Solar Power

The photovoltaic cell was a major breakthrough in generating clean electricity from sunlight. However, the technology is highly inefficient and is unlikely to replace coal or nuclear power for a long time. To change the scenario, a team at the University of California at San Diego, developed a new Nano-material back in 2014 that could possibly convert 90% of the captured sunlight. With particle sizes ranging from 10 nm to 10 µm, the multiscale structure traps and absorbs light more efficiently and at temperatures greater than 700 degree Celsius.

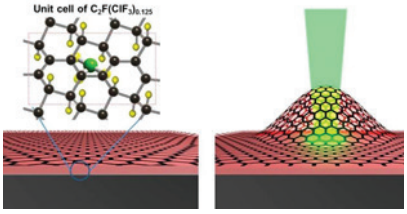
The proposed process actually transfers the heat to molten salt, which is then used to create steam. By storing the molten salt overnight, one can keep making power even when the sun is down.



The atomic engine

While heat engines are common and there are several examples in a large scale, the ability to convert the heat energy into mechanical motion at the atomic level is an extraordinary achievement.

The tiny engine was made by taking a calcium ion and enclosing it within an electrical trap. The ion is then heated which later starts to oscillate. The experiment based on the atomic engine may not yet have practical applications today, but it certainly proves at what scale mechanical energy storage and transmission can happen.



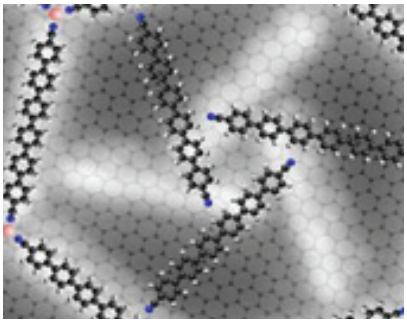
The Graphene engine

A team of scientists created a nanoscale device that works a bit like a two-stroke engine. It is based on a special configuration of carbon called “graphene” that is only one nm thick.

It doesn’t look like a full-scale engine, and unlike a full-scale internal combustion engine, it has very little exhaust matter. In the device, the sheet of graphene is combined with chlorine fluoride molecules and a laser is then fired in rapid pulses. The spot where the laser hits rapidly blisters and cools, acting as a piston. This means one could use laser light to provide a nanoscale power source that could operate on a molecular level.

Tiny switches

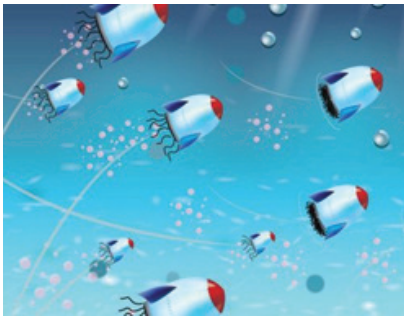
A team of researchers at the University of Glasgow created molecular-scale switches that could dramatically increase data storage without the need to increase the size of devices. This technology was created in 2008 but hasn’t still become feasible for the mainstream.



Nanorotor

Scientists have been able to create nanoscale rotors from a single molecule. The feat is impressive, as at the nanoscale, the rotor does not experience friction at all as it spins. Turns outs that the air does not interact with the rotor in the same way it does on a human scale.

TNano rotors could be used to power all sorts of nanoscale devices. For instance, the flow of blood through one’s veins could provide power to implanted devices or nanobots themselves.



Nanorockets

Scientists have demonstrated the first complete movement regulation of a motorized Nano-vehicle” inside the human body. These tiny machines could prove to be an effective treatment for drug delivery in the human body.

Self-propelled catalytic micro and nano-motors have been the subject of intense study for some years, but chemists have struggled to figure out how to provide a few key crucial functionalities. Knowing how to hit the brakes was the biggest dilemma. However, chemists at Radboud University, the Netherlands have figured out how to build in effective speed-regulation mechanisms so that a Nanorocket can be controlled remotely.

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