Nanotechnology Usages in Energy

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The use of nanotechnology is being used to develop new ways to generate and more efficiently deliver our energy.

The power output of the sun that reaches the Earth could provide as much as 10,000 times more energy than the combined output of all the commercial power plants on the planet, according to the National Academy of Engineering. The problem is how to harvest that energy.

Heat loss through factory windows, walls, and ceilings can add thousands of dollars to building heating and cooling costs. According to the U.S. Department of Energy, in 2010, buildings consumed 41 percent of U.S. energy, mostly as space heating, air conditioning, and lighting. In comparison, industry consumed 30 percent of energy and transportation 29 percent.

Nanotechnology is being used and researched in all areas of energy: Energy Sources

- Fossil Fuels

Traditional sources of energy are typically fossil fuels (coal, oil, and natural gas) that are currently responsible for approximately 85% of the worlds' primary energy needs. However, fossil fuel use is problematic in the long run because it is being consumed faster than it is being replaced, and its use can result in environmental harm11, [12.]

- Nuclear

Besides nanotechnology being used to create "miniaturized nuclear weapons" that would have virtually no fallout, and super-efficient bioterrorism, according Jane's Defense Quarterly, which could be triggered with a super-laser nanotechnology is being used to make nuclear power plants safer by producing new materials[17] . Thermonuclear fusion promises to be a possible solution to the current energy crisis. It is produced when two atomic nuclei of light elements combine to produce heavier elements, which give off a huge quantity of energy. So that this reaction can occur, it is necessary to supply an enormous amount of energy, so that temperatures of many millions of degrees can be reached, allowing the nuclei to come close enough to overcome their natural repulsion and become condensed in a plasma state. "This plasma, which reaches temperatures near that of the stars, around 100 million degrees, does not touch the walls of the reactors because they would melt," explained one of the project researchers, Vanessa de Castro, from the UC3M Physics Department. In order to confine the plasma, it is confined within the reactor by the magnetic fields. "Even so the walls must resist some very high temperatures as well as the effects of the irradiation from the neutrons from the reaction, for which we have to produce new materials that can withstand these extreme conditions," the Professor remarked. The

International Thermonuclear Experimental Reactor (ITER) project (under construction) and its successor, demonstration fusion power plant (DEMO -- scheduled for 2035) propose development of fusion reactors that are economically viable. This work depends on, among other things, the development of these new structural materials capable of withstanding damage by irradiation and elevated temperatures resulting from the fusion reaction. The scientific community has begun to develop new reduced -activation material for use in these reactors, but it is still not known if some of them will be viable under such hostile conditions. Along these lines, one of the most important candidates is oxide dispersion-strengthened, reduced-activation ferrite steel, called oxide dispersion strengthened alloys (ODS steels). The mechanic behavior of the ODS steels depends enormously on their microstructure, which until now has not been rigorously controlled. Until recently, studies on the microstructure of these steels have been on the micrometric scale. However, the nanometric scale is more relevant in understanding the phenomena that occur under irradiation. “We are now using our knowledge in nuclear structural materials and in advanced techniques of nanoanalysis to characterize diverse new generation ODS steels on the nanonmetric scale,” noted the researchers, who have added nanometric particles to these steels (between 1 and 50 nm), which help to improve the mechanical properties and increase their resistance. The results of the research have been recently published in a special number of the journal Materials Science and Technology dedicated to the atomic scale characterization of steels.

- Regenerative: *Photovoltaics;*

Scientists at the U.S. Department of Energy’s National Renewable Energy Laboratory (NREL) have produced solar cells using nanotechnology techniques at an efficiency – 18.2% -- that is competitive. The breakthrough should be a major step toward helping lower the cost of solar energy[1].

To reduce the amount of sunlight that is reflected away from silicon solar cells and wasted, manufacturers usually add one or more layers of antireflective material, which significantly boosts the cost. But late last year, N REL scientists announced a breakthrough in the use of nanotechnology to reduce the amount of light that silicon cells reflect. It involves using a liquid process to put billions of nano-sized holes in each square inch of a solar cell’s surface. **Since the holes are smaller than the light wavelengths hitting them, the light is absorbed rather than reflected. The new material, which is called "black silicon," is nearly 20 percent more efficient than existing silicon cell designs.**

But even the latest-generation silicon panels can take in light from only a relatively narrow range of frequencies, amounting to about 20 percent of the available energy in the sun’s rays. The panels then require separate equipment to convert the stored energy to useable electricity.

But researchers at the University of Connecticut and Penn State are working on an entirely new approach, using tiny, nanoscale antenna arrays, which would take in a wider range of frequencies and collect about 70 percent of the available energy in sunlight. Additionally, the antenna arrays themselves could convert that energy to direct current, without need for additional gear.

A single nanowire that uses 10,000 times less material can capture 15 times more light and produce energy with incredible efficiency at a much lower cost. The technology could provide the basis for a new generation of highly efficient solar cells or for powering microchips and quantum computers.

Despite their size, nanowire crystals have tremendous potential for energy production. Extremely thin filaments, they concentrate the sun’s rays into a very small area in the crystal by up to a factor of 15. Because the diameter of a nanowire crystal is smaller than the wavelength of light coming from the sun, it can cause resonances in the intensity of light in and around nanowires.

When equipped with the right electronic properties, the nanowire becomes a tiny solar cell, transforming sunlight into electric current. Scientists from the Nano-Science Center at Niels Bohr Institute and at Ecole Polytechnique Fédérale de Lausanne have built a nanowire solar cell out of gallium arsenide — a material better at converting light into power than silicon. The solar cell collects up to 12 times more light than conventional flat ones[2].

No matter what sort of solar energy-collecting technology you employ, there’s still the problem of building a bunch of the devices and hooking them up in places with sun exposure. But University of Southern California chemistry professor Richard L. Brutchey and postdoctoral researcher David H. Webber have devised a technology that could turn a building into a solar collector.

They’ve created a stable, electricity-conducting liquid filled with solar-collecting nanocrystals, which can be painted or printed like an ink onto surfaces such as window glass or plastic roof panels. The nanocrystals, made of cadmium selenide instead of silicon, are about four nanometers in size—about 250 billion of them could fit on the head of a pin—so they are capable of floating in a liquid solution.

- *Wind Energy;*

Efforts to build larger wind turbines able to capture more energy from the air are stymied by the weight of blades. A Case Western Reserve University in Ohio

USA researcher has built a prototype blade that is substantially lighter and eight times tougher and more durable than currently used blade materials.

The heavier the blades, the more wind is needed to turn the rotor. That means less energy is captured. And the more the blades flex in the wind, the more they lose the optimal shape for catching moving air, so, even less energy is captured. Lighter, stiffer blades enable maximum energy and production.

- *Geothermal;*

Drilling for hydrothermal resources can sometimes trigger earthquakes, particularly when projects fracture hot bedrock around faults and inject their own water. The approach, called stimulation, led the Swiss government to shut down one such project in Basel in 2006 after it set off violent tremors, and a California company, AltaRock Energy, has put its project at The Geysers on hold.

California USA just experienced an earthquake. Some people blame deep drilling for hydrocarbon fuels (fracturing) may have caused this earthquake, which have led to the stoppage of such drilling. The same concerns exists for tapping into geothermal energy deep below the earth's surface.

Low-temperature hot springs, sometimes below 100 degrees C, are more abundant and closer to

Earth's surface, reducing the chance that drills will intersect the deep faults where large earthquakes typically begin. The water must be used in conjunction with a heat exchanger to warm special liquids like alkanes (saturated hydrocarbons such as methane) or perfluorocarbon that have a lower boiling point. As these substances evaporate, they release energy to turn turbines. Unfortunately, they release less energy than water would during this transition, making the process less efficient Researchers at the Pacific Northwest National Laboratory (PNNL) are investigating the use of nanomaterials to boost geothermal efficiency at lower temperatures. PNNL plans to have a functioning system in the laboratory producing electricity by the end of the year, researcher Peter McGrail said. If laboratory tests are successful, the technology could be ready for use on existing geothermal systems within five years, according to McGrail.

Energy Change

- Electric Motors[3]

Volvo says it has made conventional batteries a "thing of the past" with a new

lightweight battery system. The Chinese-owned Swedish brand has developed new nanotechnology-derived batteries housed within thin carbon fibre storage packets. Designed to slot within the panels of the car the battery packs use nanoparticles, which include microscopic components with molecular manipulation to improve its properties. Volvo says the move could lower the weight of future electric cars and free up interior space. It uses carbon fibre to "sandwich" ultra-small nano-structured batteries and supercapacitors, which capture kinetic energy and can also be refilled using a conventional plug. These in turn feed electricity to the car's motor. The thin, light inner panels can then be fitted in different areas around the car, including under the bonnet, in the doors, in the boot lid and spare wheel housing and the roof turret. This means the batteries won't eat into the car's usable space; vehicles such as the Toyota Camry Hybrid feature a large battery bank behind the back seats which impinges on its practicality. Volvo says that if an electric car were to replace its existing battery components with the new system it could cut its kerb weight by 15 per cent - meaning a car like the Nissan Leaf, which weighs 1795 kilograms, would be about 270 kilograms lighter, thus increasing its efficiency. Volvo says it has developed an S80 experimental car that is using the technology in the boot lining in place of the regular 12-volt battery.

. Combustion Engines

Guoj un Liu of Queens University in Canada has discovered a way to use nanotechnology to reduce friction in automobile engines and machines. "The technology should be useful in a wide range of machineries other than automobile engines," says Dr. Liu, a professor in the Department of Chemistry and an expert in polymer synthesis. "If implemented industrially, this nanotechnology should help prolong machine life and improve energy efficiency." Dr. Liu's team prepared miniscule polymer particles that were only tens of nanometers in size. These particles were then dispersed in automobile engine base oils. When tested under metal surface contact conditions that simulated conditions found in automobile engines, these tiny particles were discovered to have an unprecedented friction reduction capability. Even at a low concentration, the nanoparticles performed much better than the friction additive that is currently used by many industries. They were able to reduce friction by 55 per cent more than the currently achievable rate.

- Thermo-electric

Discovered in the 19th century, thermoelectric materials have the remarkable property that heating them creates a small electrical current. But enhancing this current to a level compatible with the needs of modern technologies has revealed an extraordinary challenge[4].

Thermoelectric materials show the thermoelectric effect in a strong or convenient form. The *thermoelectric effect* refers to phenomena by which either a temperature difference creates an electric potential or an electric potential creates a temperature difference. These phenomena are known more specifically as the Seebeck effect (converting temperature to current), Peltier effect (converting current to temperature), and Thomson effect (conductor heating/cooling). While all materials have a nonzero thermoelectric effect, in most materials it is too small to be useful. However, low-cost materials that have a sufficiently strong thermoelectric effect (and other required properties) could be used in applications including power generation and refrigeration[5].

Boulder, said that these tiny pillars offer a completely new approach to transcend the limitations of thermoelectric since introduction.

The researchers have said that the new approach would play a significant role in the improvement of several technologies like solar panels, cooling equipment, conventional fossil fuel power plants and many more.

Thermoelectric effect was first discovered in the 1 800s and it provides the ability to generate electrical current from a temperature difference between one side of a material and the other. When an electric current is applied to thermoelectric material, one end of the material gets heated up while the other stays cool. But the reverse also has the same effect and overheating electrical devices weakens the current required to operate the device.

The researchers built nanoscale-sized pillars to place over a sheet of silicon as it has thermoelectric properties and is regularly used in nanotechnology. As a result, the researchers created 'nanophononic metamaterial'. Heat was transported through the material with the help of a sequence of very minimal vibrations.

Professor Mahmoud Hussein and doctoral student Bruce Davis of the University of Colorado Boulder showed that the vibrations of the pillars interacted with the vibrations of the phonons to slow down the flow of heat.

The pillar vibrations do not affect the conductivity of the electrical current, while the output of the heat is reduced by the materials. This has allowed researchers to figure out a way to convert the heat energy into something that can be used. Nearly all electronic devices are known to produce excessive heat when they run like electric stoves, laptops or cell phones, but the new technology could improve their efficiency.

- Fuel Cells6, [7]

Catalysts are used with fuels such as hydrogen or methanol to produce hydrogen ions. Platinum, which is very expensive, is the catalyst typically used in this process. Companies are using nanoparticles of platinum to reduce the amount of platinum needed, or using nanoparticles of other materials to replace platinum entirely and thereby lower costs.

- **Energy Distribution**

Nanotechnology will help to improve the efficiency of electricity transmission wires. There are numerous nano-materials and other nano-related applications relevant to electricity transmission. Aluminum conductor steel reinforced (ACSR) wire is the standard overhead conductor against which alternatives are compared. In 2010, the development of new overhead conductors increased the capacity of existing Right (s) of Ways (ROWs) by five times that of ACSR wire at current costs and developed nano-material based metal-matrix overhead conductor known as the aluminum conductor composite reinforced (ACCR) wire, which is designed to resist heat sag and provide more than twice the transmission capacity of conventional conductors of similar size. The difference is that ACCR wire is based on the use of aluminum processed in new ways to create high-performance and reliable overhead conductors that retain strength at high temperatures and are not adversely affected by environmental conditions[8].

Transmission Losses**:** The electrical resistance in conventional electric transmission lines causes power losses when converting electrical power into heat. Reducing the electrical resistance would cut the losses in transmission lines and allow electricity from power plants to be used in more widespread locations. Researchers at Rice University are working to develop wires containing carbon nanotubes that would have significantly lower resistance than the wires currently used in the electric transmission grid. The so-called *armchair quantum wire* (armchair shape seen in the lattice of metallic-type carbon nanotubes) would be composed of carbon nanotubes woven into a cable.

- **Energy Storage**

The major drawbacks of today's carbon anode lithium-ion batteries are two-fold: they have modest lithium-loading capacity that limits the amount of energy they store per gram of anode material, and their performance suffers as ambient temperature drops.

Gary Rubloff, who is the director of the University of Maryland's NanoCenter is also voicing a common consumer's concern, "Renewable energy sources like solar and wind provide time-varying, somewhat unpredictable energy supply, which must be captured and stored as electrical energy until demanded. Conventional devices to store and deliver electrical energy — batteries and capacitors — cannot achieve the needed combination of high energy density, high power, and fast recharge that are essential for our energy future."

Nanotechnology is also being favored to increase the efficiency of energy storage, taking up more energy and holding it for longer. This can be achieved by coating the electrodes with nano-particles which increases surface area, allowing more current to flow between the electrode and the chemicals in the battery. In addition the liquid part of the batteries can be separated from the solid electrodes when the battery is not in use, so it holds its charge for longer. It may well be common place in the years to come that a household contains an energy storage device to act as buffer from fluctuations in energy availability, such as when the wind stops blowing, or there is limited sunlight.

Lockheed Martin engineers addressed both of these issues by designing nano-infused electrodes that can tolerate much higher loadings of lithium. And when matched with newly designed electrolytes that optimize electrode performance and commercially available cathodes, the batteries retain their performance characteristics over a wider range of operational temperatures. Test results on the electrodes and batteries built with nanosilicon anodes show superior performance:

- Over 300 percent greater capacity compared to existing carbon anode materials

- 70 percent retention of discharge capacity over 300 charge/discharge cycles

- 80 percent reduction in anode weight

Characterized by fast charge and discharge capabilities over hundreds of thousands of cycles, super- capacitors serve in a wide range of commercial power storage applications, including light-rail regenerative breaking systems, load leveling in electric and hybrid electric vehicles, as well as in utility- scale power grids. Now, innovative technology developed by Lockheed Martin's wholly-owned subsidiary Applied NanoStructured Solutions, LLC (ANS), is set to enable super-capacitors with significant improvements in performance characteristics:

- Up to 200 percent improvement in specific capacitance

- Three-fold boost in high-rate capability

- At least a 15 percent improvement in low-rate capability

- Three- to four-fold enhancement of through-plane conductivity

ANS's new technology can infuse substrates in a continuous, high-volume manner with highly crosslinked matrices of carbon nanostructures (CNS). The resulting paper-like CNS super-capacitor material works in both organic and aqueous solutions. ANS is now exploring commercial development with major power system and super-capacitor manufacturers.

- Chemical

From study of Mg-based nanostructure materials synthesized by different techniques-ball milling, hydrogen plasma metal reaction, catalyzed chemical solution synthesis methods, it is found that

the absorption and desorption kinetics can be significantly improved by nanostructure and catalyst but the MgH2-Mg desorption thermodynamics does not change in the size range of 5 to 300 nm for Mg materials, which means it is difficult to make Mg-based materials to desorb hydrogen below 150^{o}C. However, Mg-based materials are very promising to be used for high temperature energy storage[13].

Energy Usage

- Insulation

New coatings, using nanoparticles, offer a highly effective combination of benefits, which include thermal insulation, corrosion resistance, mold resistance, moisture resistance, UV resistance, chemical resistance, flame resistance, and lead encapsulation. Insulation materials are providing thermal insulation protection used in outdoor products including Footwear and Apparel. Nanotechnology can be used to develop high performance thermal insulation for building envelope construction. The thermal resistivity of open porous insulating material increases when its effective pore size decreases. This well established principle creates the opportunity for nanoporous materials to be used as the 'core material' for extremely effective vacuum insulation panels

- Air Conditioning

In a warming world, the reliance on energy-intensive air conditioning has become an increasing problem. Air conditioning is especially a problem in cities, which have a lot of heat-retaining surfaces, contributing to what is called the "urban heat island effect. Professor Geoff Smith and Dr Angus Gentle of the University of Technology, Sydney, Australia say they have created a coating that can be used as an efficient heat pump and reduce the need for energy-guzzling air conditioning. It relies on a phenomenon known as "night sky cooling", in which energy absorbed by surfaces during the day is emitted back into the atmosphere. During the day, radiation from the Sun is absorbed by surfaces which heat up. At night absorbed radiation is emitted but overall, the Earth's temperature will depend on how much of this radiation actually leaves the atmosphere and goes back into space. The problem is nearly all the heat given off from the Earth's surface at night is actually reabsorbed by the atmosphere and re-emitted back to the earth's surface. Certain atmospheric gases, especially CO2 and water vapour, increase the radiation absorbed, which is why there is a concern about the global warming potential of anthropogenic CO2. Smith and Gentle's invention takes advantage of the fact that certain wavelengths of radiation emitted from the Earth are less likely to be reabsorbed by the atmosphere. These wavelengths - between 7.9 and 13 micrometres - are more likely to escape all the way back into space than others. Smith and Gentle have found that a mixture of silicon carbide and silicon dioxide nanoparticles emit heat radiation at wavelengths that best take advantage of this atmospheric 'window'. They have found a surface coated with the 50- nanometre sized particles can get down to 15 degrees cooler than ambient temperature in Sydney. Smith says the nanoparticle coating could be used to make a kind of reverse solar collector. Air, or water, would flow in channels beneath a plate coated with the nanoparticle mixture. Rather than absorbing the radiation for heating purposes, the set up would emit radiation, cooling air or water that could then be pumped through buildings to cool them. As well as cooling buildings, the technology could also be used as a coating on refrigerators, especially in remote areas. The technology would mainly work at night, but could sometimes work on the shady side of buildings, Smith says[14].

- Construction

Nanotechnology has a significant impact in the construction sector. Several applications have been developed for this specific sector to improve the durability and enhanced performance of construction components, energy efficiency and safety of the buildings, facilitating the ease of maintenance and to provide increased living comfort. Though self-cleaning feature has been possible to attain using micron sized coatings and surface treatments e.g. TeflonTM, polysilazane based coatings, etc. now this feature has become a marketing tool / motto for nanotechnology applications, especially for consumer markets like construction, textile, etc.

"Nanoparticles of TiO_2, Al_2O_3 or ZnO are applied as a final coating on construction ceramics to bring this characteristic to the surfaces. TiO_2 is being used for its ability to break down dirt or pollution when exposed to UV light and then allow it to be washed off by rainwater on surfaces like tiles, glass and sanitaryware. ZnO is used to have UV resistance in both coatings and paints. Nanosized Al_2O_3 particles are used to make surfaces scratch resistant. These surfaces also prevent / decelerate formation of bad smells, fungus and mould.

"Basic construction materials cement, concrete and steel will also benefit from nanotechnology. Addition of nanoparticles will lead to stronger, more durable, self-healing, air purifying, fire resistant, easy to clean and quick compacting concrete. Some of the nanoparticles that could be used for these features are nano silica (silica fume), nanostructured metals, carbon nanotubes (CNTs) and carbon nanofibers (CNFs). Current pressure to reduce CO_2 emissions from the manufacture of cement is guiding research to use nanotechnology to alter the processing conditions of cement, therefore reducing these emissions. Concrete structures also make profit from nano-enhanced coatings that prevent graffiti and other unwanted stains to adhere on to it. In addition to these materials, new lightweight, flame-retardant, self-healing and resilient construction materials, e.g. new nanocomposites, are expected to be helped in their development by nanotechnology.

"Nanotechnology will also have a considerable impact on glass and therefore on windows. For marketing purposes, these windows are commonly called smart windows which implies that they are multifunctional through their energy saving, easy cleaning, UV controlling and photovoltaic features.

"Nanotechnology could allow the development of materials with better insulation properties, intelligent structures capable of optimizing the use of energy. New insulating materials have been developed with the help of advances in nanotechnologies. These insulating materials are: nanofoams, nanostructured aerogels and vacuum insulated panels (VIPs).

A review by scientists at Rice University[18] has looked at the benefits of using nanomaterials in construction materials but also highlights the potentially harmful aspects of releasing nanomaterials into the environment. The team compiled a list of current use of nanomaterials in various building applications and also highlighted potential and promising future uses:

Carbon nanotubes – Expected benefits are mechanical durability and crack prevention (in cement); enhanced mechanical and thermal properties (in ceramics); real-time structural health monitoring (NEMS/MEMS); and effective electron mediation (in solar cells).

Silicon dioxide nanoparticles – Expected benefits are reinforcement in mechanical strength (in concrete); coolant, light transmission, and fire resistance (in ceramics); flame-proofing and anti-reflection (in windows).

Titanium dioxide nanoparticles – Expected benefits are rapid hydration, increased degree of hydration, and self-cleaning (in concrete); superhydrophilicity, anti-fogging, and fouling- resistance (in windows); non-utility electricity generation (in solar cells). *Iron oxide nanoparticles* – Expected benefits are increased compressive strength and abrasion-resistant in concrete.

Copper nanoparticles – Expected benefits are weldability, corrosion resistance, and formability in steel.

Silver nanoparticles – Expected benefits are biocidal activity in coatings and paints. *Quantum dots* – Expected benefits are effective electron mediation in solar cells.

One particular area for nanotechnology in the construction industry is concrete, specifically research on how to reinforce concrete to improve its mechanical performance. The video below shows how researchers are using nanosilica to strengthen concrete:

Another research focus is on how to reduce the time cement takes to harden by increasing its reactivity.

- Lighting

Physicists at Wake Forest University in North Carolina, USA and Trinity College Dublin in Ireland developed a new type of electric lighting that improves on many of the current commercial and display lighting technologies. Professor David Carroll, director of Wake Forest's Center for Nanotechnology and Molecular Materials. The light is made of three layers of a moldable polymer blended with a small amount of multiple-walled carbon nanotubes. When stimulated by an electric current, the nanotubes in the matrix glow, giving off a bright white light similar to the sunlight. The material is versatile enough to be made in any color and any shape, including two-by-four-foot panels that can replace office lighting, or bulbs with standard sockets sockets to fit household lamps and light fixtures. The researchers say the nanotube/polymer lights are at least twice as efficient as compact fluorescent light (CFL) bulbs, similar to the efficiency of light-emitting diode (LED) lights. However, the polymer plastic will not shatter, nor do the lights contain mercury like CFLs. The nanotube/polymer lights also emit a more natural white light than LEDS that give off a bluish tint[15].

- Manfacturing

Various manufacturers are using nanotechnology to make products with improved capabilities or to reduce their manufacturing cost. This page provides examples of how nanotechnology is helping manufacturers today.

Researchers at Northwestern University have developed a desktop nanofabrication tool. The desktop tool uses beam-pen lithography arrays to create nanoscale structures. Researchers at the University of Pennsylvania have developed a technique to make AFM tips from diamond. The nanoscale diamond tips last much longer than AFM tips made of silicon and the researchers envision these tips being used to etch or deposit material in nano- manufacturing processes. MesoCoat has developed a nanocomposite coating called CermaCladTM that can be applied to pipes used in the oil industry pipes to provide resistance to corrosion. The process for applying the nanocomposite is faster and can be done at a lower temperature than is possible using conventional methods. The result is the production of lower cost pipes with equivalent corrosion resistance. Researchers at Rice University have demonstrated that atomically thin sheets of boron nitride can be used as a coating to prevent oxidation. They believe this coating could be used for coating parts that need to be light weight, but work in harsh environments, such as jet engines. ArcelorMital is producing a kind of steel that contains nanoparticles. This material allows them to make thinner gauge, lighter beams and plates. These steel beams and plates are about same weight as aluminum, but can be produced a lower cost. ArcelorMital is marketing this light weight steel to car manufacturers. Researchers have produced yarn from carbon nanotubes coated with diamond. They believe this material can be used in thin saw blades that reduce the waste produced when cutting high cost material, such as sawing silicon ingots into wafers for the semiconductor or solar industries. IMEC and Nantero are developing a memory chip that uses carbon nanotubes. This memory is labeled NRAM for Nanotube-Based Nonvolatile Random Access Memory and is intended to be used in place of high density Flash memory chips. Nanosolar is building solar cells using semiconductor nanoparticles applied in a low temperature printing process. This process results in lower cost solar cells than conventional high temperature manufacturing processes[16].

Nanotechnology Risks and Safety9, [10]

Occupational safety and health risks associated with manufacturing and using nanomaterials are not yet clearly understood, according to the National Institute for Occupational Safety and Health. The rapid growth of nanotechnology is leading to the development of new materials, devices, and processes that lie far beyond the current understanding of environmental and human impact. Many nanomaterials and devices are formed from nanometer-scale particles (nanoparticles) that are initially produced as aerosols or colloidal suspensions. Exposure to these materials during manufacturing and use may occur through:

- Inhalation
- Dermal (skin) contact
- Ingestion

Minimal information is currently available on dominant exposure routes, potential exposure levels, and material toxicity. What information does exist comes primarily from the study of ultrafine particles (typically defined as particles smaller than 100 nanometers). Workers within nanotechnology-related industries have the potential to be exposed to uniquely engineered materials with novel sizes, shapes, and physical and chemical properties, at levels far exceeding ambient concentrations.

According to the DOE Protecting Human Subjects Newsletter No. 13, Spring 2006, human experimentation will attempt to answer the following questions:

- What happens to the nanoparticles we are already inhaling every day?
- Can we trace the path of nanoparticles in the body?
- Can we extract nanoparticles from body fluids?
- Can we protect workers and the environment from released nanoparticles?
- How do nanoparticles affect basic cellular processes?
- Are nanoparticles absorbed through the skin?

Some of the few new developments by:

ConsERV, a product developed by the Dais Analytic Corporation, uses nanoscale polymer membranes to **increase the efficiency of heating and cooling systems** and has already proven to be a lucrative design.

A New York based company called Applied NanoWorks, Inc. has been developing a consumer product that utilizes **"white" LED technology to generate light**.

Rice University scientists have unveiled a revolutionary new technology that uses nanoparticles to **convert solar energy directly into steam**.

Clothing that generates electricity. Researchers have developed piezoelectric nanofibers that are flexible enough to be woven into clothing. The fibers can turn normal motion into electricity to power your cell phone and other mobile electronic devices.

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