Application of Nanotechnology for Environmental Problem

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Abstract
Due to extensive human economic activities and their population growth, Environment of our planet is rapidly losing its quality in its every part (air water, soil, forest etc). The air and water parts are the easily affected entities of our environment. Use of non-renewable energy for manufacturing, transportation, home etc is directly related with environmental pollution. To reverse these negative effects on the environment, many attempts have been made so far by using different approaches, although the problem is still on the rise. The approach by nanotechnology is highly promised because of the unique properties of nanomaterials. This technology has already shown the potential to treat our environment including air and water purification, solving energy crisis, protecting our skin from skin cancer, increasing agricultural production etc. In this review paper, the application of nanotechnology in air and water purification, in energy sector and in the production of sunscreen lotion and its use for skin to protect our skin from strong sun radiation have been reviewed.
Keywords: Environment; Nanotechnology; Pollution; Nanomaterials

Introduction

Environment is a collection of countless subsystems all working together. It is the surrounding medium that affects living organisms directly or indirectly. Affecting one subsystem results in disturbance of other subsystems which finally affect living organisms. Therefore, care for our environment must be our priority job because the life of all living organism is at the hand of our environment. Environmental events can be categorized as natural and manmade events. The contribution of natural events to environmental damage is almost insignificant comparing to manmade environmental events. For example, most types of pollutions are problems of our own making, which significantly contributes for most environmental problems. For instance, Burning fuel releases much of its free energy during the conversion of chemical energy into heat and then to mechanical energy [1]. To overcome this problem we must develop method of reactions that minimize the amount of released free energy during energy conversion. We can build such methods if we can control reactions at the nanoscale because reactions at this scale efficiently oxidize fuel without extracting chemical energy through thermalization. With connection to environmental pollution directly or indirectly nanomaterials have the following positive values. i) Harmful substances (toxins and some bacteria) in natural waters, wastewaters and the air can be changed into harmless substances (cleaned up) with the help of Nanomaterials. ii) These nanoscale materials can also be used for highly efficient energy conversion and storage. iii) Some cosmetics which are product of nanotechnology can be used for our skin protection from solar radiation. The strength of solar radiation reaching the earth is increasing through time because of ozone depletion which is the result of greenhouse emissions to the space surrounding the earth. Thus, applying the technique of nanomaterials holds much potential for effective pollution control and they have already shown excellent potential to solve problems in these areas [2, 3, 4].

Most of the current techniques used to clean environment from waste and hazardous substances are based upon ‘pump-and-treat’ approaches. As its name indicates when we use these methods, first we isolate or extract the contaminated part of may be soil, water, food, air, forest, rock and treat them by applying currently available conventional treatment processes. Even though, these currently in use classical methods are effective in cleaning the contaminated part of environment, however are not cost-effective as they use huge amount of energy, cannot attain the goal in short time and the removed unwanted (hazardous) substances also require further disposal [5].
In recent times, the application of nanomaterials in every sector including environment is gaining hot attention because these nanomaterials have the ability to overcome the challenges that face conventional technology. They are defined as materials, where at least one dimension is approximately in the range of 1-100nm. Actually the upper end (100nm) is not the exact line to differentiate these materials from their counter-part bulk materials, but this is the region where these nanomaterials show unusual properties which make them totally different from properties of their bulk materials [6, 7]. Their shape, crystalline structure, melting and boiling temperatures, material properties (e.g., electrical, magnetic, optical and even color) change. Because of their small size, these materials have also large surface area compared to their volume, i.e., they have large number of atoms on their outer surface than their inner part which helps them to make excellent chemical reaction with harmful substances to change them into harmless substances. All these new properties come due to quantum effects which arise from the confinement of electrons and holes in the materials. These new properties open up possibilities for targeting very specific points with very high efficient, for the problems under consideration [6, 7]. Thus, in general

technology of nanomaterials (nanotechnology) offers the potential for significant environmental benefits [8], including:

- Cleaner, more efficient industrial processes
- Improved ability to detect and eliminate pollution by improving air, water, and soil quality
- High precision manufacturing by reducing amount of waste
- Clean abundant power via more efficient solar cells
- Removal of greenhouse gases and other pollutants from the atmosphere
- Decreased need for large industrial plants
- Remediating environmental damages.

In this review the role of nanomaterials (nanotechnology) in air and water purification, environmentally friendly energy and sunscreen lotion have been reviewed.

I. Air Purification

For its essentiality to living things, we cannot compare air with other substances (e.g., water) and other quantities (e.g., energy and power) because no one can stay without air even for few seconds. The problem, however, is not the event of encountering free space (vacuum) but lack of quality of air and quality of air can be affected if hazardous substances are ejected into it. Human activities, especially from the beginning of industrial revolution period hurting air quality dramatically. At that time industries and automobiles were solely used and are still mostly using fossil fuels which are not renewable and not environmentally friendly. The particles that ejected to air from these burned fossil fuels contain substances (carcinogens) that can cause cancer or have contribution to the onset of cancer and many respiratory problems. These hazardous substances are also affecting ozone layer, which is our shield from ultraviolet radiation of the sun [4].

Nanomaterials can be used in cleaning pollution from air in two important ways. One is using nano-catalysts because they have large surface area for gaseous reactions. Catalysts make chemical reactions with hazardous substances (harmful vapors) from cars and industrial plants and change them into harmless gases [7]. For example, Catalysts currently in use include a nanofiber catalyst made of manganese oxide that removes volatile organic compounds from industrial smokestacks (outlet of steam engine). Another technique of applying nanomaterials is materials that have membranes with very small pores. With the help of these pores we can separate methane or carbon dioxide from harmful vapors [1]. Carbon nanotube (CNT) is also another type of nanomaterials and it have very huge ability to trap hazardous substances from air about hundred times faster than other methods, allowing integration into large-scale industrial plants and power stations. The highly efficient adsorptive capacity of pollutants by CNT is because of its small sized ultra pore structure and the presence of broad area of surface active functional groups of CNT which can be fabricated and designed specifically by the optimum chemical or thermal treatment of the CNT so as to have effective performance for a particular purpose [7,9]. In combination with titanium dioxide, gold nanoparticles have also been shown to convert the toxic air pollutant, sulphur dioxide, to sulphur [1]. This new technology of nanomaterials both processes and separates large volumes of gas effectively, unlike conventional membranes that can only do one or the other effectively [10].

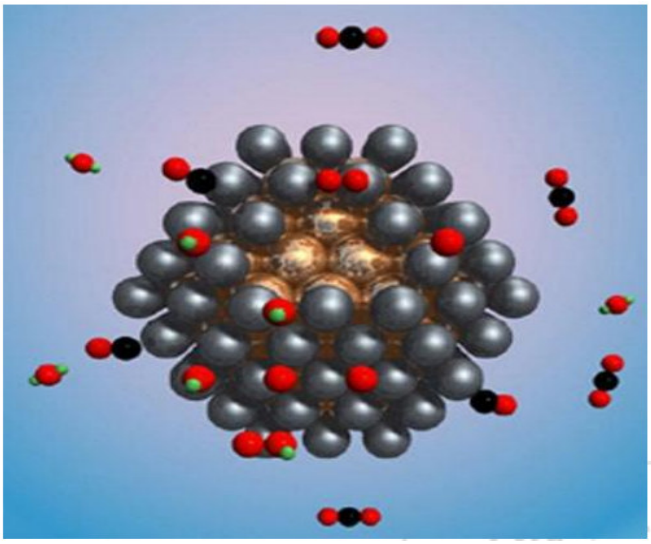


Figure 1: Nanocatalyst [7].

II. Water Purification

Clean water is enormously essential to human existence and economic growth. However, because of increasing human population, expanding agricultural activities as well as use of chemicals to increase agricultural production, its increasing demand in industrial sector and deforestation, the amount and quality of water have been under pressure [11, 12, 13]. The report given by United Nations released on March 22, 2010 on World Water Day says that water pollution kills more people than all other forms of violence including Wars which is very shocking message for scientific community in particular and for the world in general [14] 11→15. Therefore, to safe our population and sustain economic development we must not late to look for better clean water treatment method and take immediate action to minimize its diminishing rate both in quantity and quality [11, 12].

To avert these shocking effects on water in general and clean water in particular, nanomaterials have already shown the potential to present big improvements to existing water purification techniques and materials. They can also supply water treatment and purification in every part of the world including remote areas where electricity is not available [15]. These nanomaterials change harmful pollutants in water into harmless chemicals through chemical reactions because their large surface area (large number of atoms on the surface) highly increase their potential toward chemical reactions. For instance, Trichloroethene, a dangerous pollutant commonly found in industrial wastewater, can be catalyzed and treated by nanomaterials [16, 17].

Comparing to currently available conventional methods, the process of underground water purification by Nanomaterials is very easy because inserting nanomaterials into underground water sources is cheaper and more efficient than pumping water for treatment. The deionization method of using nano-sized fibers as electrodes is not only cheaper, but also more energy efficient. Traditional water filtering systems use semi-permeable membranes for electrodialysis or reverse osmosis. Decreasing the pore size of the membrane to the nanometer range can increase the selectivity of the molecules allowed to pass through. Membranes that can even filter out viruses are now available [10]. To understand how reverse osmosis works; it is helpful to understand osmosis occurs when a semi-permeable membrane separates two salt solutions of different concentrations. The water will migrate from the weaker solution to the stronger solution, until the two solutions are of the same concentration, because the semi-permeable membrane allows the water to pass through, but not the salt. In the following diagram, (a) procedure is shown. In reverse osmosis, the two solutions are still separated by a semi-permeable membrane, but pressure is applied to reverse the natural flow of the water. This forces the water to move from the more concentrated solution to the weaker. Thus, the contaminants end up on one side of the semi -permeable membrane and the pure water is on the other side [18].

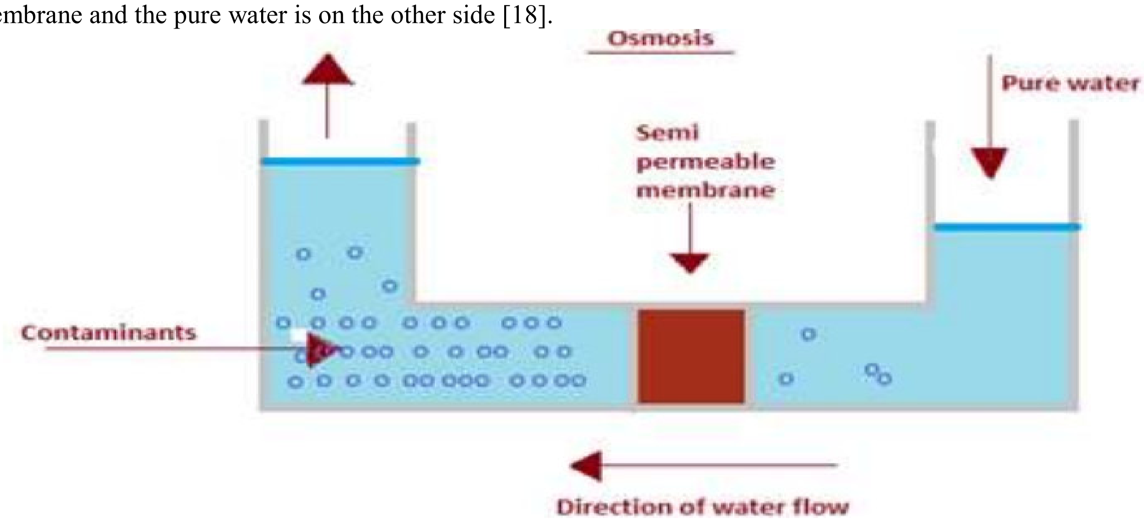


Figure 2 ….[18].

Recent developments of nanowires made of potassium manganese oxide can clean up oil and other organic pollutants while making oil recovery possible. These nanowires form a mesh that absorbs up to twenty times its weight in hydrophobic liquids while rejecting water with its water repelling coating. Since the potassium manganese oxide is very stable even at high temperatures, the oil can be boiled off the nanowires and both the oil and the nanowires can then be reused [10]. Silver nanoparticles also have been proved to be effective antimicrobial agents and can treat wastewater containing bacteria, viruses and fungi. Nano silver kills bacteria by stopping getting oxygen. This helps solve the problem of contaminated water. Nanoscale titanium dioxide can also kill bacteria and disinfect water when activated by light. Gold nanoparticle is another potentially useful material for removing contaminants, such as toxic chlorinated organic compounds, pesticides and inorganic mercury, from water. Titanium dioxide nanomaterials are commonly used in some processes to disinfect water, in addition to breaking down halogenated compounds, and removing dyes and metal toxins from drinking water and wastewater [1,19]. Carbon nanotubes (CNTs) are contributing to the development of more efficient treatment processes among the advanced water systems due to their exceptional adsorption properties [20]. The researchers point to studies which show that carbon nanomaterials are particularly suited to removing a broad range of pollutants. Carbon nanotube clusters, for example, are used to purify water by adsorbing bacteria that contaminate the water. Heavy metals, such as cadmium, as well as organic pollutants including benzene and 1,2-dichlorobenzene can also be removed from water by carbon nanotube material [1].

Table-1 Application of nanomaterials in contaminated water and waste water treatment [12].

Type of Nanomaterials	**Type of pollutants removed**
Carbon nano tubes	Organic Contaminant
Nano Scale metal Oxide	Heavy metals Radionucleides
Nano catalyst	PCB, Azodyes, Pesticides etc
Nano Structured catalytic	Decomposition of organic pollutant inactivation of micro organisms
Bioactive nanoparticle	Removal of Bacteria, fungi
Biomimetic membranes	Removing Salts

III. Environmentally Friendly Energy Sources

Our strong dependence on the declining supply of nonrenewable fossil fuels leads to threat from pollution, global warming, and energy crises [21]. To overcome these challenges, the search for clean and renewable alternative energy resources that meet the world's growing energy demands while simultaneously reducing green house emissions and other pollutants is one of the most top urgent actions to be taken in this 21st century to have healthy environment and for sustainable development [22, 27]. Although there is potential for the use of alternative energy sources which include solar energy, wind energy, geothermal power, biomass/biofuel, and hydrogen energy for the large-scale supply of power, the energy that can be harvested from these sources is still mainly used for small-scale powering applications [22]. The reason why these environmentally friendly energy sources are limited to small-scale powering applications is the low capacity of conventional materials to harvest renewable energies, convert them to electrical energy, transport them without any energy loss and store these energies for use [23].

To meet the world energy demand and decrease the amount of environmental pollutant from the use of energy, we thus must increase the production, conversion and transportation technology processes, storage capacity either by improving currently available materials or by designing new devices from new materials which are designed and fabricated with the help of new technology (nanotechnology) at a nanoscale level. Nanoscale materials (nanomaterials) which are product of nanotechnology are already started to provide cost-effective and environmentally clean solutions to the world's energy problems and their role is rapidly increasing in every sector including environmentally friendly energy sector [23, 24,25]. For example, with the growth in portable electronic equipment (mobile phones, laptop computers, remote sensors), there is great demand for lightweight, high energy density batteries. Nanocrystalline materials synthesized by sol–gel techniques are candidates for separator plates in batteries because of their foam-like (aerogel) structure, which can hold considerably more amount of energy than conventional ones. Nickel–metal hydride batteries made of Nanocrystalline nickel and metal hydrides are envisioned to require less frequent recharging and to last longer because of their large surface area [26]. Among the renewable resources of energy mentioned above, solar energy is one of the most abundant resources and can easily be converted to electricity by use of photovoltaic cells [27] and thus we consider only this energy in this paper.

Solar energy

Everyday sun sends out tremendous amount of energy in the form of heat and radiations called solar energy. Solar energy is a limitless source of energy which is available at no cost. The sun radiates more energy in one second than people have practiced since the beginning of time [28]. The major benefit of solar energy over other conventional power generators is that the sunlight can be directly harvested into solar energy with the use of small and tiny photovoltaic (PV) solar cell [29]. Solar radiation or simply sunlight, originates from a large nuclear fusion reactor located about 150 million kilometers from the Earth. Given the radiation comes from a thermal source, it is broadband, covering a range of wavelengths from ultraviolet through visible to the mid infrared [30].

Need for energy conversion and storage

There are at least two important reasons for the development of energy conversion and storage technologies. First, highly efficient and inexpensive energy conversion and storage is key to addressing the issues connected to the irregular nature of renewable energy sources, (e.g., solar- not available at night and cloudy days and wind-) or regionally limited (e.g., water). For more convenient, sustainable adoption in our everyday life, renewable energy sources should be converted to different energy forms, such as chemical energy in batteries that can be extracted as electricity whenever needed. Second, an on demand energy supply is central to meeting societal needs, which are increasingly mobile [31, 53].

The importance of developing new types of energy is evident from the fact that the global energy consumption has been accelerating at an alarming rate due to the rapid economic expansion worldwide, increase in world population, and ever increasing human reliance on energy based appliances. It was estimated that the world will need to double its energy supply by 2050. To this end, advanced technologies for both energy conversion (e.g., solar cells and fuel cells) and storage (e.g., Supercapacitors and batteries) are being extensively studied around the world. Nanotechnology has opened up new frontiers in materials science and engineering by creating new materials at nanoscale to meet this challenge [32, 53].

Solar Energy conversion

Energy conversion is the process of transforming one form of energy to another, which obeys by the laws of thermodynamics. Correspondingly, there exist many different energy conversion devices that can convert energy from different energy sources into useful forms (in particular, electricity and heat) to meet our needs which include solar photovoltaic (PV), thermoelectric, electrochemical and photoelectrochemical (PEC). Directly or indirectly, the sun is the source of all of energies for our planet, Earth. Even nuclear energy comes from a star because the uranium atoms used in nuclear energy were created in the fury of a nova - a star exploding. The following figure shows different energy conversion paths from solar energy to electrical energy [33, 34]. There are two routes for conversion of sunlight into useful form of energy: the solar thermal approach where by solar energy is converted to heat and solar photovoltaic approach where semiconductors are used to convert solar radiations directly into electricity [35].

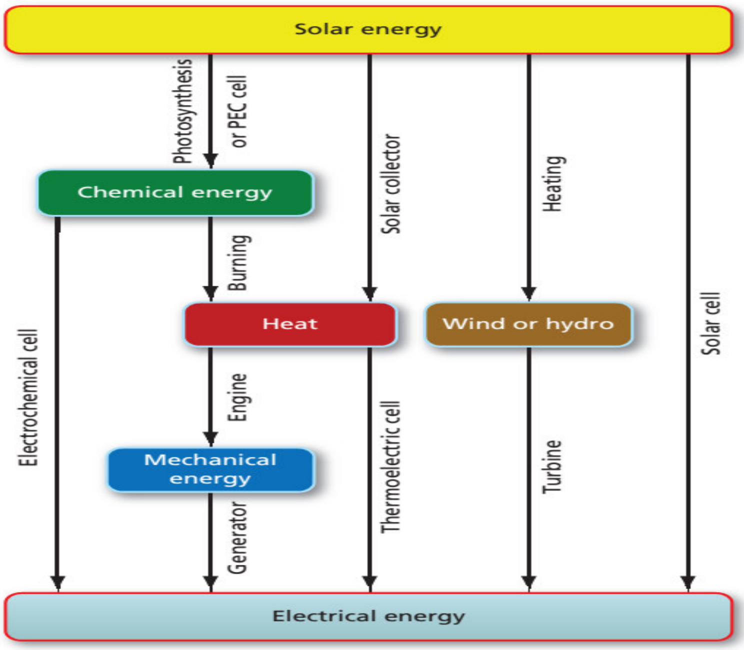


Figure 3. Different energy conversion paths from solar energy to electrical energy [33].

Solar (photovoltaic) cells

A solar cell, or photovoltaic (PV) cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light [36]. As solar energy is the most abundant energy resource, it is almost guaranteed to be an indispensable part of the energy system. Compared with other energy conversion paths from solar energy to electricity, PV has a higher overall efficiency. In addition, PV is the only renewable energy source that can be used everywhere [33].

Working Principle of PV (solar) cells

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed depending on the energy they carry and the energy band gap of photovoltaic cell. Only the absorbed photons provide energy to generate electricity. When enough sunlight (energy) is absorbed by the material (a semiconductor), electrons are removed from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface.

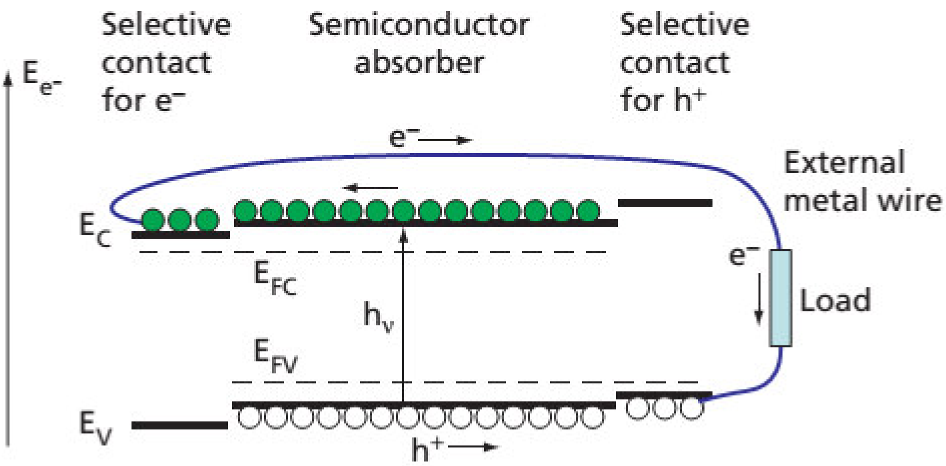


Figure 4. Working principles of a solar cell under sunlight illumination [33].

When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, electricity flows.

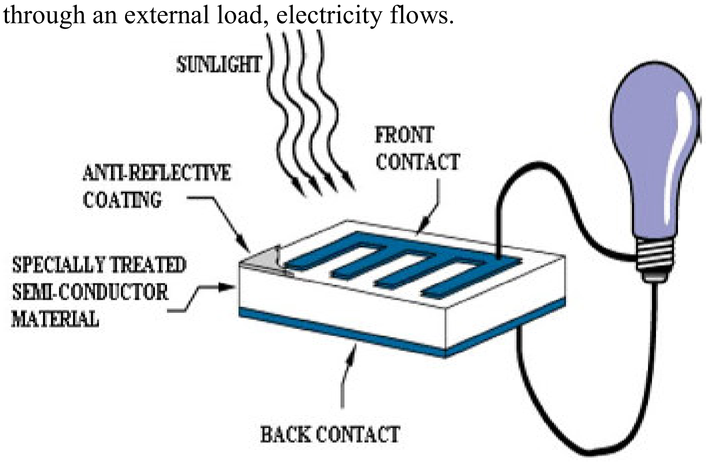


Figure 5a [34].

The performance of a photovoltaic array is dependent upon sunlight. Climate conditions (e.g., clouds, fog) have a significant effect on the amount of solar energy received by a photovoltaic array and, in turn, its performance. Most current technology photovoltaic modules are about 10 percent efficient in converting sunlight. Further research is being conducted to raise this efficiency to 20 percent. The simplest photovoltaic systems power many of the small calculators and wrist watches used every day. More complicated photovoltaic systems provide electricity to pump water, power communications equipment, and even provide electricity to our homes.

Advantages of photovoltaic systems include:

- Conversion from sunlight to electricity is direct, so that bulky mechanical generator systems are unnecessary.
- PV arrays can be installed quickly and in any size required or allowed.
- The environmental impact is minimal, requiring no water for system cooling and generating no byproducts.

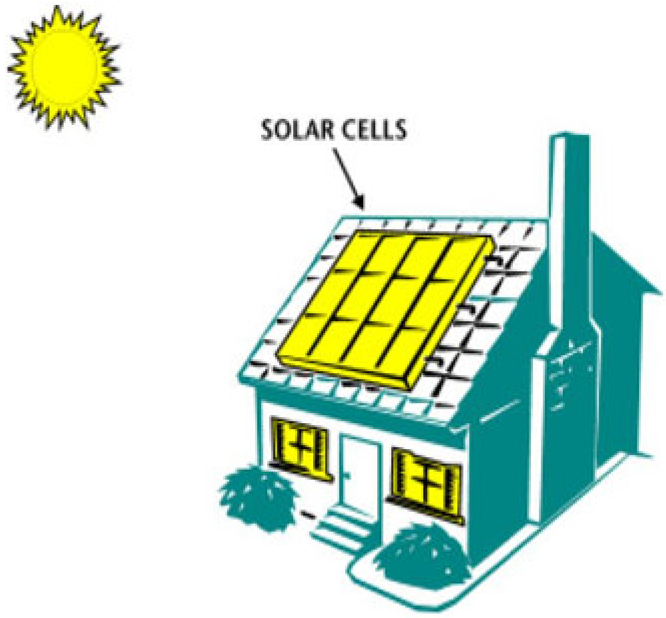


Figure 5b [34].

Photovoltaic cells, like batteries, generate direct current (DC), which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using inverters, solid-state devices that convert DC power to AC [34].

In the improvement of solar cells, the development now reached next generation, i.e., first generation, second generation, third generation, fourth generation and next generation [37]. Conventional (first and second generations) solar cells have two main drawbacks: efficiencies and their expensive manufacturing cost. The first drawback, inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy then it will pass through. If it has more energy than the band gap, then that extra energy will be wasted as heat. These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell [38].

Due to high costs of first generation solar cells and toxicity and limited availability of materials as well as poor performance for second-generation solar cells as compared to the first generation, a new generation of solar cells (third generation) where emerged. This generation was very different from the previous one due to the use of novel semiconductors. Again this generation does not rely on p-n junction design as the first two generations. These new generations of solar cells are being made from variety of new materials besides silicon, including nanomaterials, silicon wires, and solar inks using conventional printing press technologies, organic dyes, and conductive plastics [37, 39, 40]. In this part of review paper quantum dots and carbon nanotubes has been discussed.

Quantum dots are the leading candidate for the third generation of solar-cell technologies (as a follow-up to silicon and thin-film solar cells). Quantum dots are tiny spheres of semiconductor nanomaterials measuring only about 2–10nm in diameter [37, 39, 40]. Previously unachievable with bulk semiconductors, the QDs allow energy level matching between desired donor and acceptor materials which are crucial in designing efficient photovoltaic devices because Quantum dots (QDs) have the advantage of tunable bandgap as a result of size variation as well as formation of intermediate bands [32, 41, 42].

Unlike conventional materials in which one photon generates just one electron, quantum dots have the potential to convert high-energy photons into multiple electrons. Quantum dots work the same way, but they produce three electrons for every photon of sunlight that hits the dots. Electrons move from the valance band into the conduction band the dots also catch more spectrums of the sunlight waves, thus increasing conversion efficiency to as high as 65 percent. Another area in which quantum dots could be used is by making so-called a hot carrier cells. Typically the extra energy supplied by a photon is lost as heat, but with a hot carrier cells the extra energy from the photons result in higher-energy electrons which in turn leads to a higher voltage [38].

Generally, the following are advantages of Semiconductor Quantum Dot as Sensitizer:

- ✓ Quantum confinement allows for energy gap tunable across the solar spectrum.
- ✓ Higher optical absorption resulting from quantum confinement.
- ✓ Larger intrinsic dipole moment which may lead to rapid charge separation and band alignment.

Due to their potentially low cost, simple manufacturing process and high production rate, organic materials have the potential to make a major impact on the PV market. The absorption coefficient of organic semiconductors is very high which allows light to absorb within a very thin layer leading to low cost solar cells. In addition, the efficiency of organic solar cells increases with temperature, while most conventional inorganic solar cells lose efficiency with increasing temperature. Different organic materials including organic molecules, conjugated polymers and four typical carbon materials (e.g., amorphous carbon, fullerenes, CNTs and graphene) are used for both organic and organic-inorganic hybrid solar cells. Among these, recent research on CNTs indicates it is a potential material for the organic and hybrid solar cells. Moreover, CNTs exhibit interesting optoelectronic, physical and chemical properties, required for many viable applications, although large scale commercial production will still need the development of robust CNT sorting and handling protocols [43]. Especially, CNTs' unique property of electrical conductivity, in addition to their low cost, makes them an ideal candidate as a superlative counter electrode Dye-Sensitized Solar Cells (DSSCs). The use of CNTs in DSSCs as a counter electrode further lowers the cells' cost, making them an even more viable option in the solar energy spectrum.

- ✓ A distinguished advantage DSSCs have over typical silicon-based cells is their improved ability to harvest sunlight without direct contact with sunlight.
- ✓ Allows for interesting applications such as placing translucent cells in windowpanes of buildings, or traditional rooftops to generate power [44].

Investigation of single-wall carbon nanotube (SWCNT)–polymer solar cells has been conducted towards developing alternative, lightweight, flexible devices for space power applications [43].

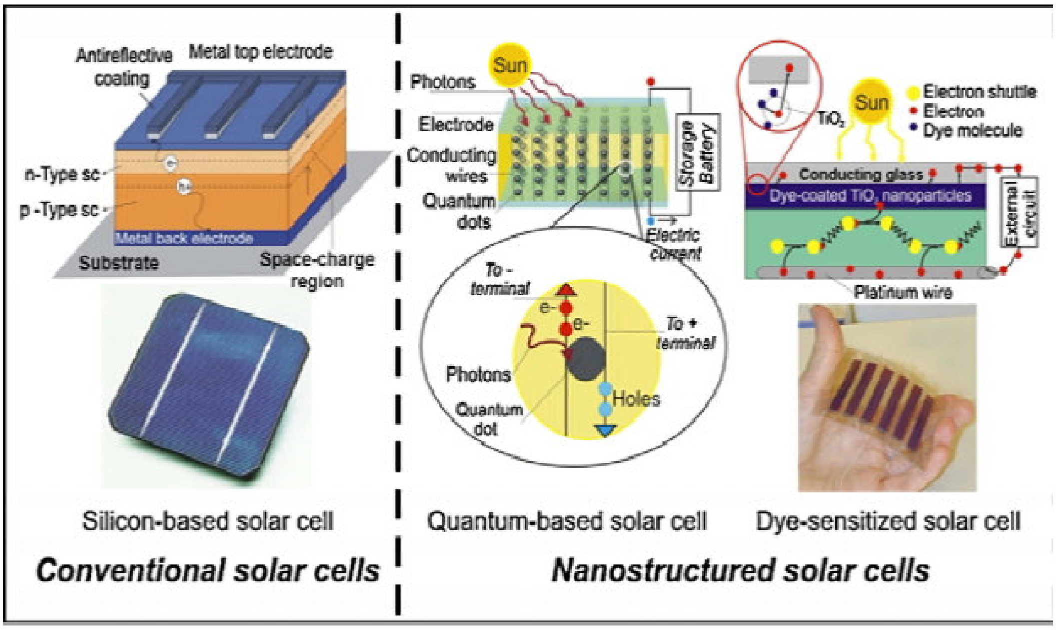


Figure 6.Evolution of photovoltaic technology from conventional to nanostructured solar cells [21].

Energy storage

Harvesting or generating energy is only half of the solution for energy crisis. For complete solution in energy crisis it has to be stored for later use. Nanomaterials (e.g., graphene) have been attracting significant interest as potential game-changers for energy storage. One driver for this is the high surface area of many nanomaterials, which increases the ability to store charge within a given volume. Graphene – which is formed from layers of carbon a single atom thick – has a tremendous surface area for a given amount of material, and has created a lot of excitement about graphene-based Supercapacitors and anodes for lithium ion batteries [45].

Currently, electric energy demand exceeds 20 TWh/year and it is growing at a rate of about 3% per year. Growing concerns about energy security and the environment are driving a global shift away from fossil fuels, toward renewable, carbon-neutral energy sources such as wind and solar [44].

Along with energy production, renewable energy systems such as solar or wind require the ability to store energy for reuse on many different scales [28]. Thus, energy storage is a critical component of manufacturing, of the service industry, of the future renewable energy industry, and of all the portable electronics with which we have become obsessed. Without modern energy storage, using lithium-ion (Li-ion) batteries, the decade of the smart phone, iPad, and iPod would not have progressed like it did. Besides entertainment, energy storage plays a critical role in high-tech manufacturing where it is essential to have an uninterruptable power source of constant frequency [47].

Materials used for energy storage

There are four main electrochemical devices that used for energy storage which include battery, Supercapacitors (SC), fuel cells and capacitor [48, 49]. In this paper Supercapacitors and batteries are reviewed.

Supercapacitors

Supercapacitors (SCs) are compact electrochemical capacitors that can store a high amount of energy which can then be discharged at rates demanded by different specific applications. SCs are finding application in consumer electronics, hybrid electric vehicles, industrial power management, defense industry, communication, etc. Energy in SCs is stored in two possible ways: electrochemical double-layer capacitance (EDLC) and Faradaic pseudo-capacitance, which involves redox processes [50].

The current challenge for SCs nowadays is to improve their energy density and lower their fabrication costs without sacrificing their high power capability [51]. For that purpose, new electrode materials and electrolytes are being developed with help of nanotechnology that resulted in to give excellent character for SCs. The following are **great features to these new** SCs**:**

- ✓ They can be charged and discharged one million times.
- ✓ They are much safer than many current batteries such as Lithium-ion.
- ✓ They take up the same space as present batteries, in some cases even less.
- ✓ Battery density just as good as present battery technology.
- ✓ The super capacitor lifetime vastly exceeds that of batteries currently in use, for example, the batteries in use by the telephone communication sector.
- ✓ Are able to withstand some fairly harsh environments [52].

The simplified structure of a SC is composed by two electrodes (positive and negative), an electrolyte, two current collectors and a separator membrane. The electrodes are constituted by conductive materials with a large specific surface area and/or by electrochemically active materials. The electrolyte is an ionically conducting medium that exists between both electrodes and has the main function of transporting ions until the surface of the electrodes. The separator is an ion-permeable electron-insulating membrane; i.e.it allows the migration of electrolyte ions and electrically isolates the two electrodes. The current trend in textile SCs is to replace liquid electrolytes by solid-gel ones that act both as electrolyte and separator. Finally, the current collectors are connected to the electrodes and are responsible for the electrons transport [51].

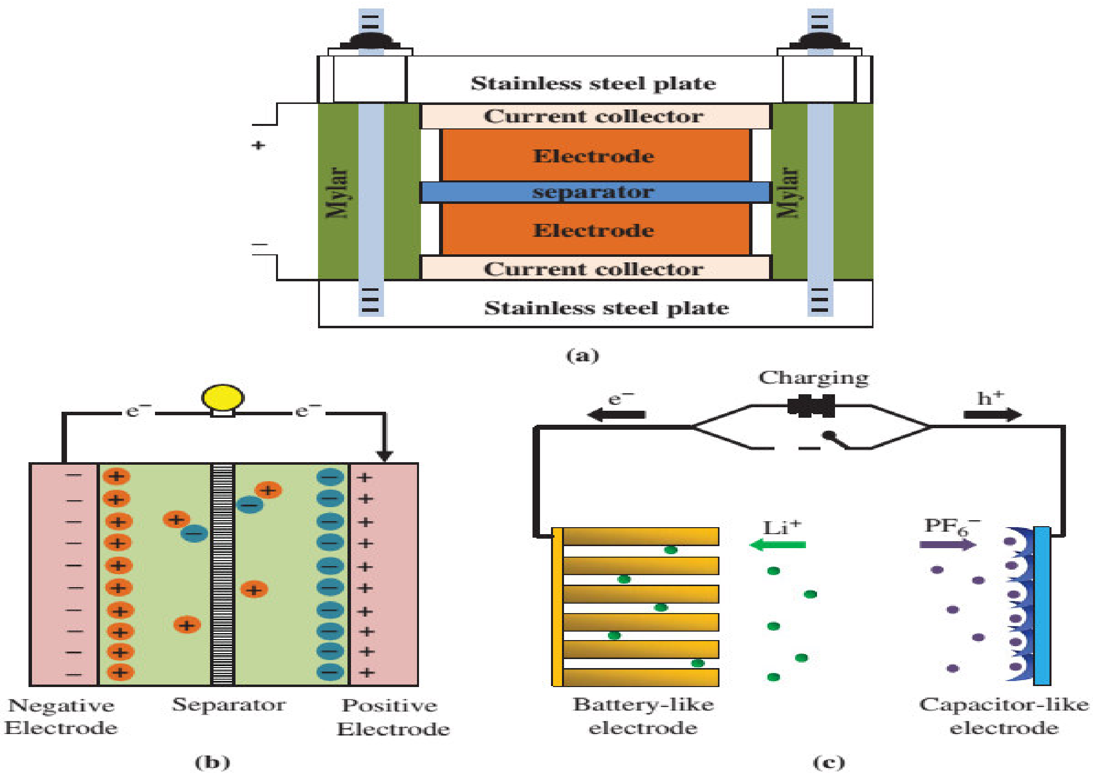


Figure 7. Schematic drawings: (a) general configuration of Supercapacitors devices; (b) symmetric and (c) asymmetric Supercapacitors [49].

Depending upon the electrodes used, Supercapacitors can be broadly classified as an EDLC, a pseudo-capacitor, and a hybrid capacitor (See Figure 8 below) [50].

In **EDLCs**, the capacitive charging occurs in the electrode/electrolyte interfaces and charge is stored electrostatically by a non-Faradaic mechanism. There is no charge transfer between the electrodes and the electrolyte which enables a longer cycle life. Therefore, EDLCs usually have higher power density when compared to batteries of similar dimensions. Carbon (nano) materials have been the most widely used electrode materials in EDLCs [49].

To increase the efficiency of EDLCs, it is required to modify the pore size, pore structure, surface properties and conductivity of the electrode materials. Carbon‐based nanomaterials are used as EDLCs electrodes due to their high surface area and electronic conductivity. Capacitance values of many tens of farads per gram of the electrode material are achieved in some materials, such as activated carbon, graphene, carbon nanotube, and so on [53].

On the other hand, in **pseudo-capacitors the** energy storage process involves charge transfer between the electrode and the electrolyte by means of reduction oxidation reactions, ion intercalation/deintercalation and electrosorption (Faradaic mechanisms). The charge transfer process is similar to that of a battery, but the transfer rates are higher since in pseudo-capacitors electrochemical reactions occur at the surface and in the bulk near the surface of the electrodes instead of propagating into the bulk material. Due to the nature of the storage mechanism, pseudo-capacitors present higher capacitance than EDLCs, albeit (although, despite) their lower power density. Both cycle life and storage capability thus fall between those of batteries and EDLCs. The pseudo-capacitive electrode materials most commonly used are transition metal oxides/hydroxides and electrically conducting polymers [51].

Hybrid capacitors emerged as a novel solution to overcome the limitations of EDLCs and pseudo-capacitors, combining both abovementioned charge storage mechanisms in a single device. This can be accomplished through the use of composite or hybrid materials composed by an EDLC-type and a pseudo-capacitor-type component as electrodes, the so-called composite or symmetric hybrids. Hybrid capacitors can also be classified as asymmetric hybrids when they couple two electrodes with different storage mechanisms: in one of the electrodes, only an electrostatic process occurs, whereas in the other electrode redox reactions or a combination of non-Faradaic and Faradaic processes occur. Finally, the third type of hybrid capacitors are battery-type hybrid capacitors, where one of the electrodes is a material containing Li^+ ions to enable Li^+ intercalation/deintercalation similarly to battery mechanism [51].

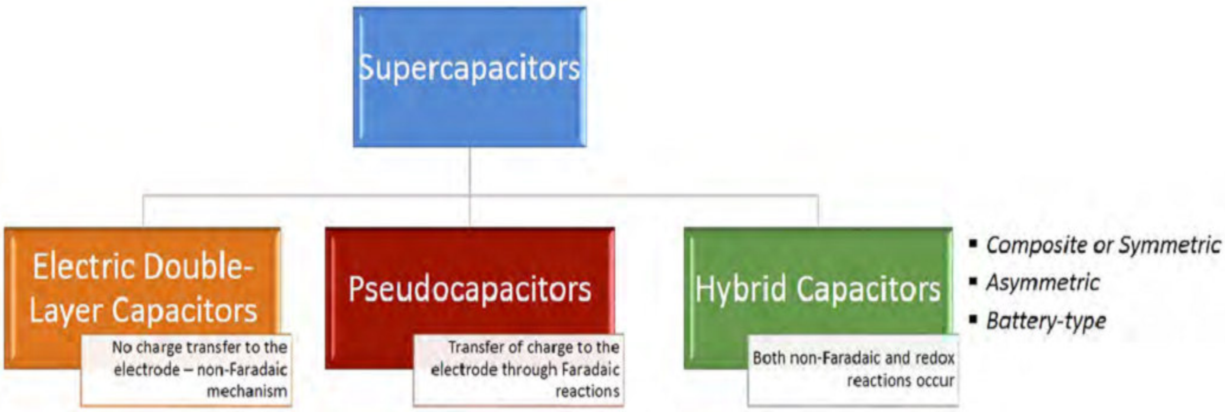


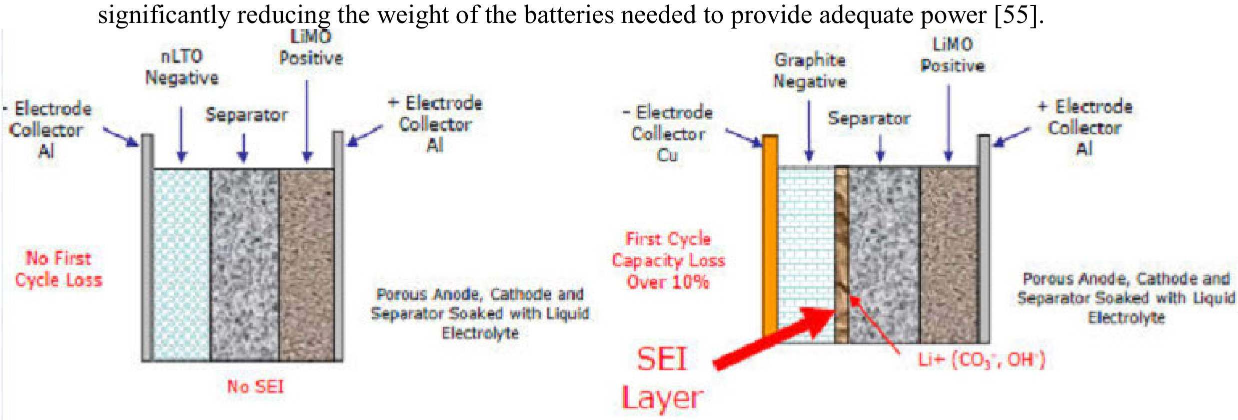
Figure 8.Flow-chart of SCs taxonomy [51].

Batteries

Nowadays electric batteries represent the most common energy storage methods for portable devices. They store the energy in a chemical way and they are able to recover it into electrical form. They consist of two electrodes (anode and cathode) and one electrolyte which can be either solid or liquid; in the redox reaction that powers the battery, reduction occurs at the cathode, while oxidation occurs at the anode. This energy storage form has changed substantially throughout the years, even though the basic principles have been known since the invention by the Italian physicist Alessandro Volta in year 1800. The first type was consisting in a stack of zinc and copper disk separated by an acid electrolyte. Thanks also to the boost of mobile phones during the last years they have evolved to the Nickel-Cadmium (Ni-Ca) and Nickel Metal Hydrate (Ni-Mh) which dominated the market until the developments of Lithium batteries. This latter class rapidly gained market thanks to the higher specific energy (150-500 Wh/Kg versus 50-150Wh/Kg of NiMh, NiCa) and are nowadays one of the most common batteries available in the market. They can further be divided into another two subclasses which are Lithium Ion (Li-Ion) batteries and Lithium Polymers (Li-Po) batteries (which basically are an evolution of the Li-Ion) [56]. Li-ion batteries are composed of three layers: an anode, a cathode, and a porous separator, which is placed between the anode and cathode layers. The anode is composed of graphite and other conductive additives. The cathode is composed of layered transition metal oxides (e.g., lithium cobaltite ($LiCoO_2$) and lithium iron phosphates ($LiFePO_4$)) [54].

The goal for electrical energy storage systems is to simultaneously achieve high power and high energy density to enable the devices to hold large amounts of energy, to deliver that energy at high power, and to recharge rapidly [55]. One way for enhancement of the battery capacity is using nanotechnologies for increasing and structuring the surface area of the electrodes (for example by depositing nanomaterials or by growing nanostructures such as nanotubes) [56]. Generally, using nanotechnology in the manufacture of batteries offers the following benefits

- ✓ Reducing the possibility of batteries catching fire by providing less flammable electrode material.
- ✓ Increasing the available power from a battery and decreasing the time required to recharge a battery. These benefits are achieved by coating the surface of an electrode with nanoparticles. This increases the surface area of the electrode there by allowing more current to flow between the electrode and the chemicals inside the battery. This technique could increase the efficiency of hybrid vehicles by significantly reducing the weight of the batteries needed to provide adequate power [55].



(a) (b)

Figure 9. Comparison between nano structured battery (a) and traditional graphite battery (b). The abbreviation SEI is solid electrolyte interface [57].

IV. Sunscreen lotion

Ultraviolet (UV) radiation from the sun is the main cause of skin cancer especially in tropical areas where (UV) A/B radiation is stronger. Both UVA (320-400nm) and UVB (290-320nm) can pass through the ozone layer and induce skin cancer, with UVA penetrating deeper into the skin to reach the dermis [58, 59]. The UV radiation energy from the sun as it passes through the skin is absorbed by DNA, lipids, and proteins, causes skin cancer directly or indirectly by damaging DNA that controls internal body operations including normal cell multiplication. High-energy UVB rays cause direct damage to DNA (formation of thymine dimers) that has mutagenic potential and requires protection by DNA repair mechanisms. Indirect damage caused by both UVA and UVB radiation leads to the formation of reactive oxygen species (oxidative DNA damage), and activation of inflammatory cytokines. Collectively, these molecular insults result in sunburn, hyper pigmentation, premature aging, and photo carcinogenesis [10, 58, 59]. Ozone levels, cloud cover and height, environmental pollutants, altitude, latitude and the seasons of the year are the main environmental factors that influence the intensity of the UV radiation reached the Earth's surface. Under normal environment (environment which is free from pollution), ozone layer holds back approximately 100% of the UVC radiation (200-290 nm) and 90% of the UVB, while all the UVA radiation reaches the Earth's surface. The ozone layer has been declining from time to time, due to the emission of chlorofluorocarbons which resulted in the direct increase in the amount of UV radiation reached to the Earth [58].

Sunscreen lotion reduces the amount of ultraviolet (UV) radiation reaching our skin by filtering it with a chemical barrier that absorbs and/or reflects the UV rays away from our skin. No sunscreen lotion provides 100% protection against UV radiation, and some UV radiation will always reach our skin, damaging the cells below. This damage builds up over time and can increase our risk of melanoma and other skin cancers. If UV levels are 3 or above, sunscreen lotion should always be used in conjunction with other forms of sun protection such as clothing, hats and shade [26, 60]. A number of nanomaterials types are already in use, including nanoemulsions and nanoparticles of minerals present in our natural environment, such as titanium dioxide (TiO_2), zinc oxide (ZnO), alumina, silver, silicon dioxide, calcium fluoride and copper. The unique properties and behavior of nanomaterials mean that nanotechnologies could profoundly transform industry and everyday life. Nanoemulsions used to preserve active ingredients, such as vitamins and anti-oxidants, and their lightness and transparency [61]. In formulation of cosmetics, Titanium dioxide (TiO_2) and Zinc Oxide (ZnO) nanopigments are the main compounds used as highly efficient UV-filters, able to reflect and scatter the visible part of solar radiation while absorbing UV light. Due to their unique properties, they are extensively used in sunscreens [62]. For example, it has been proved that Sunscreen lotions containing nano-TiO_2 and/or ZnO provide enhanced sun protection factor (SPF) while eliminating stickiness. Lotions that contain these nanocompounds have the advantage of skin blocks as they protect the skin by sitting onto it rather than penetrating into the skin. Thus they block UV radiation effectively for prolonged duration. Additionally, they are transparent, thus retain natural skin color while working better than conventional skin-lotions [26, 60]. Nano silver containing cleanser soap was claimed to have bactericidal and fungicidal properties and was found useful in treating acne and sun damaged skin. To prevent transmission of infectious diseases high efficacy within short exposure time, are important parameters. Nanosilver in concentration of 15 mg per liter in hand wash was found satisfying both parameters very effectively [63].

CONCLUSION

Environment, which is a collection of many subsystems, has been in danger from the beginning of modern human economic activities (from industrial revolution period) and the problem is still on the raise at alarming rate despite the cause of the problem is already known to human beings. Ejection of greenhouse gases from industries and vehicles, large human population growth which compute for their need on limited resources and energy demand as well as the way they produce and use energy for their economic activities all lead to climate change that resulted in some main environmental problems, global warming and seasonal change. Many governments, non-governmental organizations and scientific communities have been taking many attempts to reverse the problem. Environmental problems can be tackled mainly by two approaches: by reducing or totally stopping the amount of greenhouse gases and waste as well as hazardous materials that ejected to environment. These can be achieved by using renewable energy sources and disposing waste substances very properly. Currently about 90% of our energy need is from fossil fuels which is non-renewable and is not environmentally friendly energy source because it produces greenhouse gases during its combustion. Even though, currently available methods are effective in cleaning the contaminated part of environment (e.g. air, water, soil etc), however are not cost-effective as they use huge amount of energy, cannot attain the goal in short time and the removed unwanted (hazardous) substances also require fuk2rther disposal. If we apply nanotechnology, we can overcome energy sector and environmental pollution problems due to the following unusual properties of nanomaterials. Firstly, reactions at nanoscale efficiently oxidize fuel without extracting chemical energy through thermalization so that complete combustion occurred during energy production and utilization thus release of greenhouse gases to the environment can be dramatically reduced. These nanoscale materials can also be used for highly efficient energy collection, conversion, storage and transportation. Secondly, due to their small size these nanomaterials have high surface area to volume ratio (large number of atoms on their surface than their interior part) which helps them to make excellent chemical reactions with harmful substances to change them into harmless substances.

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