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# Role of Nanotechnology in Agriculture with Special Reference to Pest Control

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**Abstract:**
Nanotechnology is a promising field of interdisciplinary research. It opens up a wide cluster of chances in different fields like prescription, pharmaceuticals, hardware and `agriculture. Researcher and scientific experts are effectively occupied with the synthesis of nanoparticles having unordinary properties like physical, biological, optical and others. Because of these properties, nanoparticles have gigantic applications in numerous items like drug, designing, pharmaceuticals and agricultural. Fast improvement and wide uses of nanotechnology achieved a noteworthy increment in the quantity of designed nanomaterials definitely entering our living framework. Plant Production includes a vital living component of the terrestrial ecosystem. Concentrates on the impact of built nanomaterials on plant advancement illuminate diverse courses, conduct and ability of the plants to grow up. Be that as it may, use in agriculture, particularly for plant assurance and creation is an under-investigated zone in the examination group and have not yet made it to the market. Preparatory studies demonstrate the capability of nanomaterials in enhancing plant development, plant insurance, pathogen identification and pesticide and herbicide deposit recognition. There is an awesome concern in regards to the nanomaterial which can possibly apply perilous impacts on the environment and human wellbeing and when we have a nano-pesticide, it turns into a twofold edged weapon. This review condenses the diverse uses of nanomaterials with extraordinary reference to agricultural applications and their part in pest control. Accordingly, nanotechnology would give green and productive alternatives for the control of insect pests in agriculture without hurting the nature.

**Keywords**: Nanomaterials, Nanotechnology application, Agriculture, Nanopesticides, Pesticide residue detection, Pathogen detection

## Introduction:

In 2014, [1,2,3,4,5] pointed out that nanotechnology started with the generation, manipulation and deployment of nanomaterials, representing an area holding significant promise for a wide range of applications. . Nanotechnology controls matter at the nuclear, atomic or macromolecular level to make and control objects on the nanometre scale, with the objective of manufacturing novel materials, tools and frameworks that have new properties and capacities in view of their little size [6].

Nanotechnology has turned into a powerfully creating industry with different applications in computerchips, producing medicinal determination [5, 2]. It is trusted that there are more than 800 nanomaterial products presently accessible in the market and it is relied upon to increment throughout the following years [4,7,8] . The meaning of nanotechnology depends on the prefix " nano" which is from the GREEK word significance diminutive person" [9]. More definitely "nano" implies $10^{-9}$ or one billionth part of a meter. The word nanotechnology is for the most part utilized for materials having size extent somewhere around 1 and 100 nm ; anyway, it is additionally inborn that these materials ought to show distinctive properties from mass as a consequence of their size [10]. These distinctions incorporate physical quality, substance reactivity, electrical conductance, attraction and optical impacts. Huang et al [11] stated that nanobiotechnology is the multidisciplinary incorporation of biotechnology, nanotechnology, compound preparing, material science and framework designing into biochips, atomic engines, nanocrystals and nanobiomaterials. 1t is somewhat wide and incorporates both nanotechnology-empowered materials, (for example, carbon nanotubes) and nanotechnology. The nanometre scale is ordinarily demonstrated as 1-100 nm [12] yet nanoscience and nanotechnology regularly manage objects bigger than 100 nm. This variability emerges from the interdisciplinary way of nanotechnology, which sub-atomic science, science and medicine [13,14]. In a few fields objects examined are in the 1-100 nm length scale (e.g., quantum specks), yet in different fields, for example, of nanotechnology, which molecular biology, biology and medicine [13, 14]. In some fields objects studied are in the 1-100 nm length scale (e.g., quantum dots), but in other biochips, objects have measurements in the scope of nanometres. Despite the fact that nanoscience is regularly seen as an exploration without bounds, it is really the premise for all frameworks in our living and mineral world.

Several case of nanoscience under our eyes day by day, from geckos that stroll up side down on a roof, clearly against gravity, to with radiant hues, to fireflies that gleam during the evening. Even though nanoscience is often perceived as a science of the future, it is actually the basis for all systems in our living and mineral world. . In Nature we experience some exceptional answer for complex issues as fine nanostructures to which exact functions are related. Lately, scientists have had admittance to new expository instruments to see and study those structures and related functions in depth. This has further animated the exploration in the nanoscience territory, and has catalyzed nanotechnology. So it could be said, characteristic nanoscience. is the premise for nanotechnology. More than 1300 commercial nanomaterials with far reaching of potential applications are at present accessible [15,16,17,18]. Carbon nanotubes and related materials were found in 1985 [19]. A single walled carbon nanotube has a strength to-weight proportion that is 460 times more stronger than that of steel [20, 21]. The conduct of carbon-based nano materials is useful of various ambiences and conditions [22]. Nel et al. [23] gave attention to that nanotechnology today is progressing quickly and could soon turn into a trillion –dollar industry.

"Nanotechnology" is essential innovative work that is occurring in research facilities everywhere throughout the world. "Nanotechnology" items that are available today are generally bit by bit enhanced items (utilzing transformative nanotechnology) where some type of nanotechnology empowered material as carbon nanotubes, nanocomposite structures or nanoparticles of a specific substance or nanotechnology process e.g. nanopatterning or quantum specks for therapeutic imaging which utilized as a part of the assembling procedure.. From those items we can say that this tool will use to enhance existing products by making smaller parts and better execution materials, all at a cheap cost, the quantity of organizations that will make "nanoproducts" will develop quick and soon make up the larger part of all organizations crosswise over numerous manufacturers

## Definition of nan'o•tech•nol'o•gy

So what precisely is nanotechnology? One of the issues confronting nanotechnology is the perplexity about its definition. Most definitions rotate around the study and control of marvels and materials finally scales underneath 100 nm and frequently they utilize a well known examination with a human hair, which is around 80,000 nm wide. A few definitions incorporate a reference to sub-atomic frameworks, gadgets and nanotechnology "idealists" contend that any meaning of nanotechnology needs to incorporate a reference to "practical frameworks.

. The most critical prerequisite for the nanotechnology definition is that the nano has special structure. It appears that a size restriction of nanotechnology to the 1-100 nm run ., the zone where size-dependant quantum impacts come to hold up under, would prohibit various materials and gadgets, particularly in the pharamaceutical territory, and a few specialists alert against an inflexible definition in view of a sub-100 nm size.

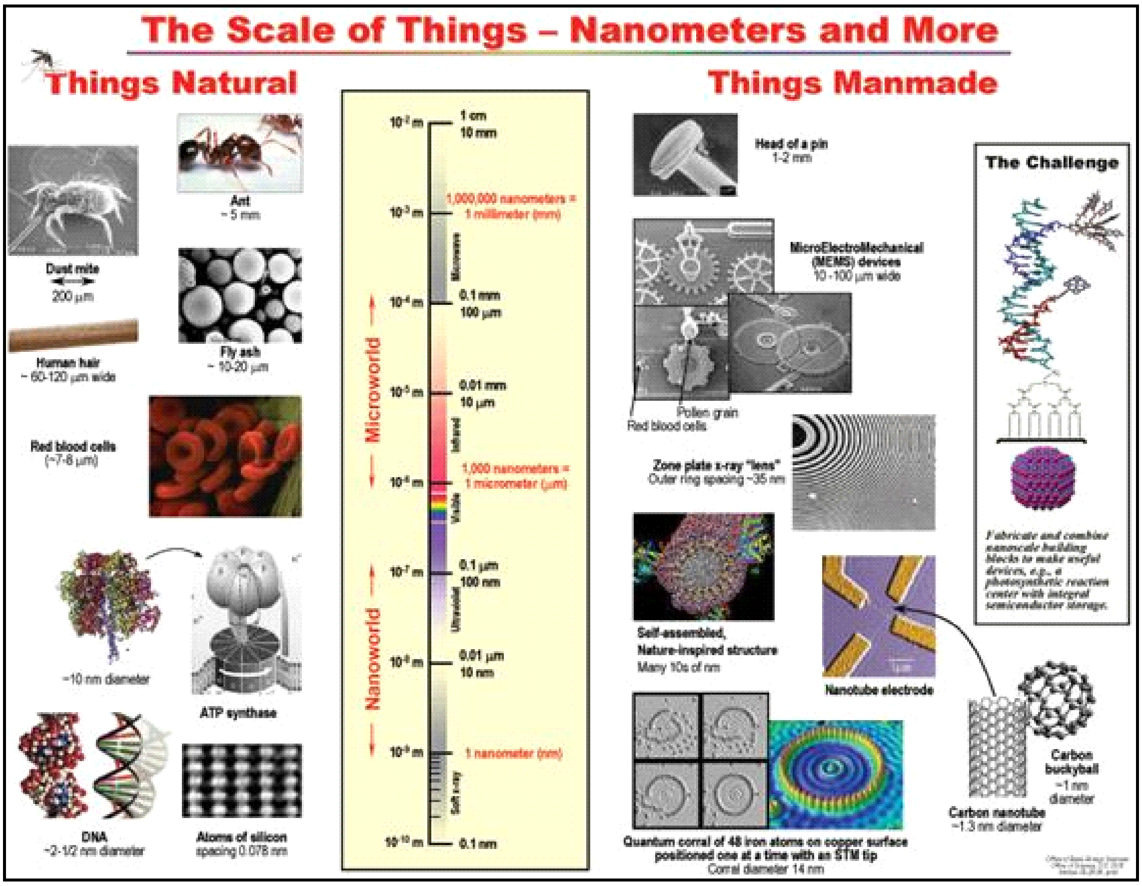
Another vital criterion for the definition is the prerequisite that the nano-structure is man-made. Else you would need to incorporate each normally shaped biomolecule and material molecule, in actuality rethinking quite a bit of science and atomic science as "nanotechnology."

The meeting of innovation with science at nano level is called Nanobiotechnology. Nanotechnology is a very interdisciplinary field of exploration. It depends on the agreeable work of scientific experts, physicists, researcher, medicinal specialists and designers. We are simply starting in comprehend the nanoscale strategies utilized as a part of nature to make self-repeating, self-observing, self-controlling and self-repairing apparatuses, materials and structures [24].

## Nanoparticles

Researchers have been considering and working with nanoparticles for quite a long time, yet the viability of their work has been hampered by their powerlessness to see the structure of nanoparticles. In late decades the improvement of magnifying instruments (microscopes) equipped for showing particles as little as atoms has permitted researchers to see what they are really going after.

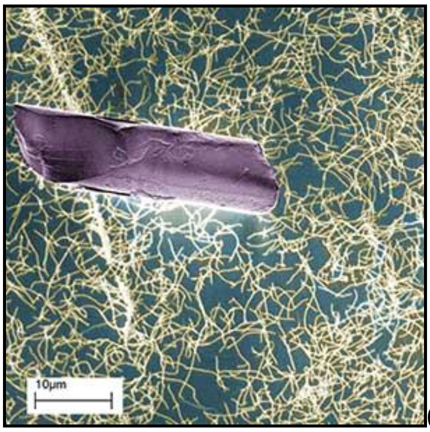
The accompanying outline titled "The Scale of Things", made by the U. S. Department of Energy, gives an examination of different articles to help you start to imagine precisely how little a nanometer is. The diagram begins with articles that can be seen by the unaided eye, for example, a subterranean insect, at the highest point of the outline, and advances to objects around a nanometer or less in size, for example, the ATP particle utilized as a part of people to store vitality from nourishment.




**The U.S. National Nanotechnology Initiative (NNI) provides the following definition: (http://www.nano.gov/html/facts/The_scale_of_things.html)**

Nanotechnology is the comprehension and control of matter at measurements between around 1 and 100 nanometers, where exceptional marvels empower novel applications. Including nanoscale science, building, and innovation, nanotechnology includes imaging, measuring, displaying, and controlling matter at this length scale. A nanometer is one-billionth of a meter. A sheet of paper is around 100,000 nanometers thick; a solitary gold particle is around 33% of a nanometer in diameter across. Measurements between around 1 and 100 nanometers are known as the nanoscale. Irregular physical, substance, and organic properties can develop in materials at the nanoscale. These properties may vary in essential courses from the properties of bulk materials and single particles or atoms.

So what precisely is nanotechnology? One of the issues confronting nanotechnology is the perplexity about its definition. Most definitions spin around the study and control of wonders and materials finally scales beneath 100 nm and regularly they utilize a popular examination with a human hair, which is around 80,000 nm wide. A few definitions incorporate a reference to atomic frameworks and gadgets and nanotechnology "idealists" contend that any meaning of nanotechnology needs to incorporate a reference to "utilitarian frameworks.



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**Human hair fragment and a network of single-walled carbon nanotubes (Image: Jirka *Cech)***
***http://www.nanowerk.com/nanotechnology/introduction/introduction_to_nanotechnology_1.php***

The most important requirement for the nanotechnology definition is that the nano-structure has special properties that are exclusively due to its nanoscale proportions

**Nanomaterial Dimension**

Pumera [25] distinguished nanomaterial Type Example All three measurements < 100 nm Nanoparticles, Quantum dots, nanoshells, nanorings, microcapsules. He included that Two measurements < 100 nm Nanotubes, strands, nanowires and One measurement < 100 nm Thin films, layers and coatings as appeared in Table 1.

**Table 1. Nanomaterials categorized based on their dimensions [25]**

| Nanomaterial Dimension | Nanomaterial Type |
|---|---|
| All three dimensions < 100 nm | Nanoparticles, Quantum dots, nanoshells, nanorings, microcapsules |
| Two dimensions < 100 nm | Nanotubes, fibres, nanowires |
| One dimension < 100 nm | Thin films, layers and coatings |

Filipponi and Sutherland [26] stated that Nanomaterials ordered taking into account their measurements. What makes "nano" uncommon? "Nano" implies little, little; however why is this uncommon? There are different reasons why nanoscience and nanotechnology are so encouraging in material, designing and related sciences. In the first place, at the nanometre scale, the properties of matter, similar to vitality, change. This is an immediate outcome of the little size of nanomaterials, physically clarified as quantum impacts. The outcome is that a material (e.g., a metal) when in a nano-sized structure can expect properties which are altogether different from those when the same material is in the bulk form. Case in point, bulk silver is non-harmful, though silver nanoparticles are equipped for viruses killing upon contact.. Properties like electric conductivity, shading, quality, weight, change when the nanoscale level is come to. The same metal can turn into a semiconductor or an insulator when the nanoscale is reached. The second remarkable property of nanomaterials is that they can be manufactured atom by atom, with a process called bottom-up. The data of this manufacture procedure is installed in the material building blocks, so that these can self-assemble in the last item. At long last, nano materials have an expanded surface-to-volume contrasted with bulk materials. This has imperative results for each one of those procedures that happen at a material surface, for example, catalysis and detection. The following segments will promote talk about these properties highlighting their potential advantages in practical applications. Nanoscience and nanotechnology rely upon the uncommon properties of matter at the nanoscale level. In this setting, nanodoesn't just signify '1000 times littler then miniaturized scale, and nanotechnology is not only an augmentation of microtechnology to a littler scale. It is a whole new worldview that opens altogether new scientific chances[26].

The capacity to see nano-sized materials has opened a universe of conceivable outcomes in an assortment of enterprises and experimental tries. Since nanotechnology is basically an arrangement of systems that permit control of properties at a little scale, it can have numerous applications, for example, as the ones listed below.

## Quantum Effect

Thaxton et al.[27] Elucidated that nanomaterials don't follow after Newtonian material science, which applies to matter at bulk level. At the nanometre scale the properties of matter, similar to vitality, energy, mass, are not a continuum, as at bulk level, but rather are constructed of particular units, or quanta. Energy, for instance, in not consumed or discharged continually but rather just in products of particular, non detachable vitality units.

## Self-Assembly

Manufacture of nanomaterials should be possible in two courses as in Figure (4): by self-assembly, that is, building the nanomaterial atom by- atom (bottom-up methodology) or via "cutting" the nanomaterial out of a bulkier one (top-down approach). The idea of self-assembly together gets from watching that, in common biological procedures, particles self-assembly to make complex structures with nanoscale exactness. Cases are the development of the DNA twofold helix. In self-assembly, sub-units suddenly compose and total into steady, very much characterized structures through non covalent collaboration. This procedure is guided by data that is coded into the attributes of the sub-units and the last structure is come to by equilibrating to the type of most minimal free energy[28].

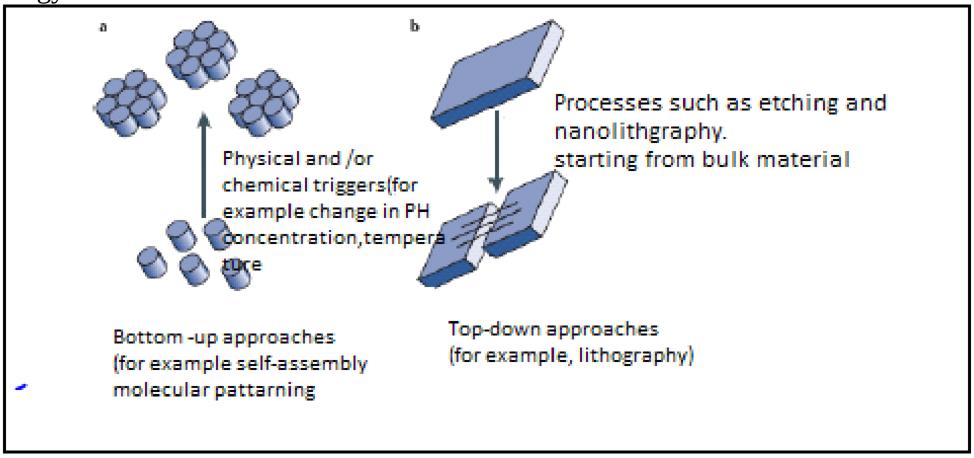


**Fig. 4: Schematic of (a) the bottom-up and (b) top-down approach. Reprinted by permission from Macmillan Publishers Ltd: Nature Reviews 2006, 7, 65-74, Copyright 2006.**

Self-assembly nano and microstructures can be made with one or more segments. Case in point, (Figure 5) demonstrates a self-assembly super lattice of magnetic and semiconductor nanoparticles. These multi-part nanocrystals gatherings have appeared to have magnetic properties which contrast from the properties of the individual components.

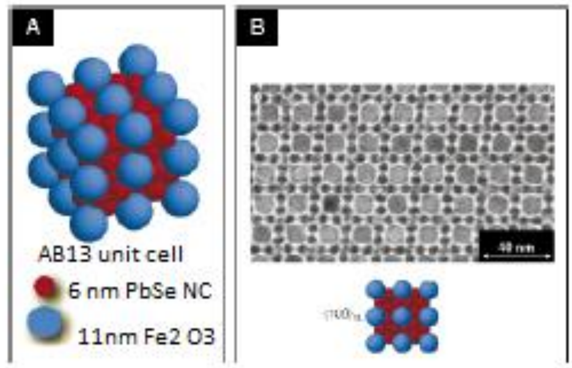


**Fig. 5: (A) Cartoon showing the cubic unit of a super lattice of magnetic (γ-$Fe_2O_3$) and semiconductor (PdSe) nanoparticles; (B) transmission electron microscope (TEM) image of the self-assembled super lattice with corresponding view. Reprinted by permission from Macmillan Publishers Ltd: Nature 2003, 423, 968-971, Copyright 2003.**

By taking after a self-assembly technique, researcher can make nanomaterials that have a few particular properties, controlled at the atomic level and intended to relate to extremely particular capacities. The point is to utilize nano-sized building squares (Fig. 6) cap can self-assembly in utilitarian 2D or 3D segments that have measurements gadgets can utilize. 'Biomimetic self-assembly' utilizes the common complementarity of some biomolecules, such DNA or proteins, to coordinate the get together of connected nanoscale parts.

The expanded surface-to-volume of nanomaterials effects the material physical properties, for example, its melting and boiling points, and its chemical reactivity. Responses that happen at the material surface are especially influenced, for example, catalysis responses, location responses, and responses that require the physical adsorption of specific species at the material's surface to start. Daniel et al [29] demonstrated that the higher surface-to-volume of nanomaterials permits utilizing less material, which has environmental and monetary advantages, and creating much scaled down gadgets, which can be convenient and could utilize less energy to work.

**Surface-To-Volume**

Nanomaterials have an expanded surface-to-volume proportion contrasted with bulk materials (Fig. 6). This implies for a given aggregate volume of material, the outer surface is more prominent in the event that it is made of a gathering of nanomaterial sub-units as opposed to of mass material Nanotechnology:

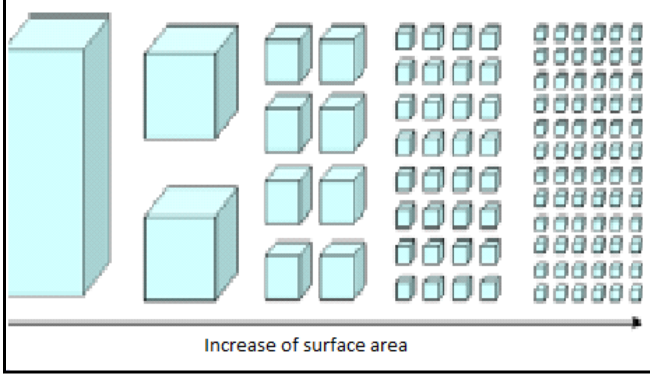


**Fig. 6. Schematic drawing showing how surface to volume increases when moving from bulk material (far left) to nano-sized particles (far right)**

## Catalysis

Fillipponi [30] Reported that catalyst is a substance that buildssynthetic response rate without being expanded or chemically changed.

Nature's catalysts are called enzymes and can gather particular final results, continually discovering pathways by which responses occur with least energy utilization. . Man-made catalysts are not all that imperativeness capable. They are every now and again made of metal particles changed on an oxide surface, wearing down a hot reactant stream (to diminish a ponder called 'stimulus hurting' which happens when species scattered in the atmosphere, for instance, CO, have the dynamic goals of the stimuli). A champion among the most indispensable properties of a force is its 'dynamic surface' where the reaction happens. The 'dynamic surface' additions when the span of the impetuses is diminished: the littler the impetuses particles, the more noteworthy the proportion of surface-to-volume (Figure 7).

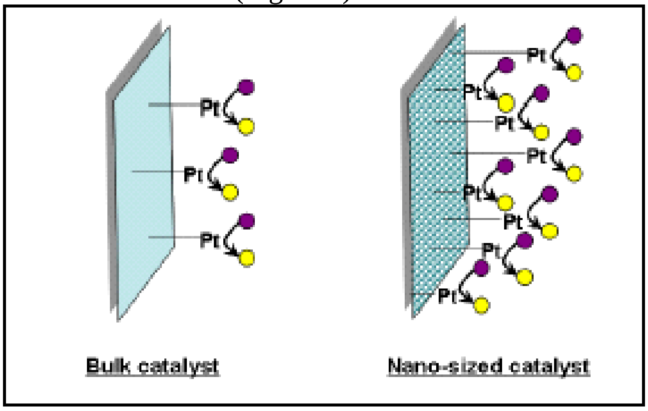


**Fig.7. Schematic showing the increased active surface of nano-sized catalyst (right) compared to a bulk catalyst. (Image credit: L. Filipponi, NANO, Aarhus University, Creative Commons Share Alike 3.0. file:///C:/Users/m/Downloads/Documents/188_Module-1-chapter-4-proofread.pdf**

The higher is the catalysts active surface, the greater is the reaction efficiency. Research has demonstrated that the spatial association of the dynamic destinations in an impetus is likewise essential. Both properties (nanoparticle size and sub-atomic structure/conveyance) can be controlled utilizing nanotechnology. Subsequently, this innovation holds extraordinary potential to grow catalyst plan with advantages for the synthetic, petroleum, car, pharmaceutical and food industry.

## Detection

Kumar and Kumbhat[31] Pointed out that the detection of a particular substance or organic compound inside a blend speaks to the premise for the operation of various gadgets, similar to chemical sensors, biosensors and microarrays. Likewise with catalysis, a recognition response happens at the material surface. The rate, specificity and exactness of this response can be enhanced utilizing nanomaterials rather than bulk materials in the recognition zone.

The higher surface-to-volume proportion of nanomaterials increases the surface range accessible for detection with a constructive outcome on the rate and on the farthest point of recognition of the response. Moreover, nanomaterials can be intended to have particular surface properties (chemical or biochemical), customized at a molecular level. Along these lines, the dynamic destinations on the material surface can go about as "locks" to distinguish particular particles (the 'keys').Figure.8. delineates this idea.

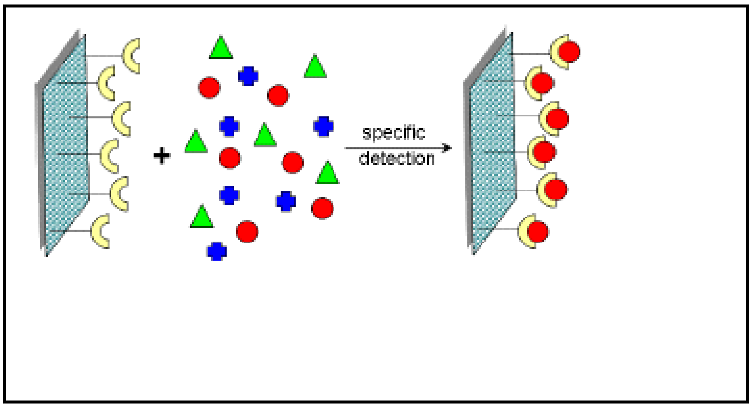


**Fig.8: Schematic showing the specific detection of an analyte within a mixture by receptor site in a nanomaterial. (file:///C:/Users/m/Downloads/Documents/188_Module-1-chapter-4-proofread.pdf).**

Nanotechnology is not all new the enthusiasm for nanoscience is not than a century, and fields like colloidal science have been broadly examined in the most recent decades. It could be said, the investigation of molecules and atoms is the premise of most scientific orders, for example, chemistry, organic chemistry and material science. Nanomaterials are not all new either: nanocrystals, nano-sized catalysts, magnetic nanoparticles have been for quite some time concentrated on throughout recent years, for an assortment of uses

Some 'nano-apparatuses' are not that late either: for case, the Atomic Force Microscope (AFM) and the Scanning Tunneling Microscope (STM) methods were initially acquainted with mainstream researchers in the mid 1980s. "Nanoscience" is accordingly an umbrella term that spreads conventional orders and in addition new and rising ones.

A "work" that discovers its underlying foundations in orders, similar to chemistry and material science, where a considerable measure of principal learning is entrenched, and that advances towards fields and applications where new information is right now being made and gathered. Therefore, nanotechnology ought to be seen as an advancement, not a transformation. http://www.nanotechproject.org/National. Nanoscience and nanotechnologies: open doors and vulnerabilities, report by The Royal Society and The Royal Academy of Engineering 2004, http://www.nanotec.org.uk/Nanotechnology: Basic Science and Emerging Technologies[32.]

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Nanotechnology is not all new, the interest in nanoscience is not all new. Researchers have been studying the atomic properties of matter for more than a century, and fields like colloidal science have been extensively investigated in the last decades. In a sense, the study of atoms and molecules is the basis of most scientific disciplines, such as chemistry, biochemistry and physics. Nanomaterials are not all new either: nanocrystals, nano-sized catalysts, magnetic nanoparticles have been long studied for years now, for a variety of applications. Some ‘nano-tools’ are not that recent either: for instance, the Atomic Force Microscope (AFM) and the Scanning Tunnelling Microscope (STM) techniques were first introduced to the scientific community in the mid 1980s. ‘Nanoscience’ is therefore an umbrella term that covers traditional disciplines as well as new and emerging ones.

Wilson et al.[32] demonstrated that a "work" that discovers its underlying foundations in orders, similar to science and material science, where a great deal of basic learning is settled, and that advances towards fields and applications where new information is at present being made and gathered.

**Nanotechnology Applications**

**1-In Different Fields of Science**

The examination on combined nanomaterials and their portrayal is a developing field of nanotechnology from the previous two decades because of their colossal applications in chemistry, biology and medicine[33.] Most of the strategies utilized is to a great degree broad furthermore include the utilization of poisonous risky chemicals, which may posture potential environmental and biological dangers organic techniques for nanoparticle amalgamation utilizing microorganisms [34, 35, 36,] enzymes [37] fungus[38] and plants and plant extracts [39,40,41,42,43] have been recommended as could be expected under the circumstances eco-accommodating contrasting option to chemical and physical techniques.

The capacity to see nano-examined materials has opened a universe of conceivable outcomes in an assortment of businesses and experimental tries. Since nanotechnology is basically an arrangement of systems that permit control of properties at a little scale, it can have numerous applications, for example, the ones recorded beneath.

**1-a Drug delivery**.

Today, most destructive symptoms of medications, for example, chemotherapy are an aftereffect of medication conveyance strategies that don't pinpoint their expected target cells precisely. Analysts at Harvard and MIT have possessed the capacity to join unique RNA strands, measuring around 10 nm in measurement, to nanoparticles and fill the nanoparticles with a chemotherapy drug. These RNA strands are pulled in to growth cells. At the point when the nanoparticle experiences a tumor cell it sticks to it and discharges the medication into the growth cell. This coordinated strategy for medication conveyance has awesome potential for treating tumor patients while creating less side destructive effects than those delivered by customary chemotherapy [44]

**1-b Fabrics.**

[45] and [46] found that the properties of natural materials are being changed by makers who are adding nano-sized segments to traditional materials to enhance execution. For instance, some garments producers are making water and stain repellent attire utilizing nano-sized bristles as a part of the fabric that causes water to dab up at first glance.

**1-c Reactivity of Materials**.

In 2009, Thaxton et al[47] determined that the properties of numerous routine materials are changed when framed as nano-sized particles (nanoparticles). This is for the most part in light of the fact that nanoparticles have a more noteworthy surface territory per weight than bigger particles; they are along these lines more receptive to some different atoms. For instance thinks about have demonstrated that nanoparticles of iron can be viable in the cleanup of chemicals in groundwater on the grounds that they respond more proficiently to those chemicals than bigger iron particles.

**1-d Strength of Materials**.

[48, 49] showed that Nano-sized particles of carbon, (for instance nanotubes and bucky balls) are amazingly solid. Nanotubes and bucky balls are made out of just carbon and their quality originates from exceptional attributes of the bonds between carbon particles. One proposed application that represents the quality of nanosized particles of carbon is the production of t- shirt weight projectile confirmation vests made out of carbon nanotubes

**1-e Micro/Nano Electro Mechanical Systems**.

The capacity to make gears, mirrors, sensor components, and in addition electronic hardware in silicon surfaces permits the production of smaller than expected sensors, for example, those used to enact the airbags in your auto. This procedure is called MEMS (Micro-Electro Mechanical Systems). The MEMS system brings about close reconciliation of the mechanical instrument with the fundamental electronic circuit on a solitary silicon chip, like the technique used to deliver PC chips. Utilizing MEMS to create a gadget decreases both the expense and size of the item, contrasted with comparable gadgets made with ordinary strategies. MEMS is a venturing stone to NEMS or Nano-Electro Mechanical Systems. NEMS items are being made by a couple organizations, and will assume control as the standard once makers make the interest in the hardware expected to deliver nano-sized components
(http://www.understandingnano.com/introduction.html )

**1-f Molecular Manufacturing**..

This gadget would utilize small controllers to position iotas and particles to assemble an article as unpredictable as a desktop PC., scientists trust that crude materials can be utilized to imitate any lifeless item utilizing this strategy just customized the replicator, and whatever he or she needed showed up. Scientists are chipping away at building up a technique called atomic assembling that may some time or another make the Star Trek replicator a reality. The device these people imagine is known as a sub-atomic fabricator; this gadget would utilize minor controllers to position particles and atoms to construct an article as intricate as a desktop PC. Specialists trust that crude materials can be utilized to recreate any lifeless article utilizing this strategy (http://www.understandingnano.com/sub-atomic manufacturing.htm)

## 2- Applications of Nanotechnology in the Field of Agriculture

Nanotechnology can possibly upset diverse segments of the agricultural and food industry with present day instruments for the treatment of disease, quick disease discovery, upgrading the capacity of plants to retain supplements and grow up and so forth. Brilliant sensors and savvy conveyance frameworks will help the agricultural industry battle infections and other crop pathogens[50] Nanotechnology will likewise secure environment in a roundabout way using elective (renewable) vitality supplies and channels or impetuses to diminish contamination and tidy up existing pollutant [51].

Nanomaterials in agriculture points specifically to diminish the amount of sprayed chemicals by shrewd conveyance of dynamic fixings, minimize supplement misfortunes in treatment[52] and increment yields through upgraded water and supplement administration. Nanotechnology determined gadgets are likewise being investigated in the field of plant breeding and genetic change [53]. Also agriculture could be a wellspring of bio-nanocomposites with upgraded physical-mechanical properties bases on rationally collected materials, similar to wheat straw and soyhults, for bio-industries purposes[54].

Barik et al [55] inspected the utilization of nanosilica as nano pesticide. The component of insect pest control utilizing nano silica depends on the way that insect pest utilized an assortment of cuticular lipids for securing their water boundary and in this way keep passing from parching. In any case, nanosilica gets ingested into the cuticular lipids by physiosorption and in this manner cause demise of insects absolutely by physical means when applied on the leaves of plant. El-Bendary and El-Helaly[56] called attention to that Silica nanoparticles is a potential new insecticide for pest control. They included that consequences of treatment of hydrophobic nano-silica in *Spodoptera littoralis* larvae demonstrated high lethal activity at all concentrations utilized parallel with focuses, high resistance in tomato plants was found against this insect-pest particularly at 300, 350 ppm, separately. It can be reasoned this is likely the primary report that exhibited that nanosilica could be utilized as a part of *Spodoptera littoralis* control.[56]

### 2 - a Precision Farming

Accuracy cultivating has been a since a long time ago sought objective to augment yield (i.e., crop yields) while minimizing input (i.e., composts, pesticides, herbicides) through observing ecological variables and applying focused on activity. Exactness cultivating makes utilization of PCs, worldwide satellite situating frameworks, and remote detecting gadgets to gauge very restricted ecological conditions, in this way figuring out if yields are developing at most extreme proficiency or unequivocally distinguishing the nature and area of issues. Exactness cultivating can likewise help in diminishing farming waste and along these lines keep environmental contamination to a minimum. Despite the fact that not completely executed yet, small sensors and checking frameworks empowered by nanotechnology will largely affect future accuracy cultivating procedures. Eventually, exactness cultivating, with the assistance of shrewd sensors, will permit improved profitability in agribusiness by giving precise data, along these lines helping agriculturists to settle on better decisions[57]. Aside from these critical applications, nanotechnology can be utilized as a part of segments like food bundling, gene transfer for crop change, nano-sustenance, and so forth[12] ( Fig.9).

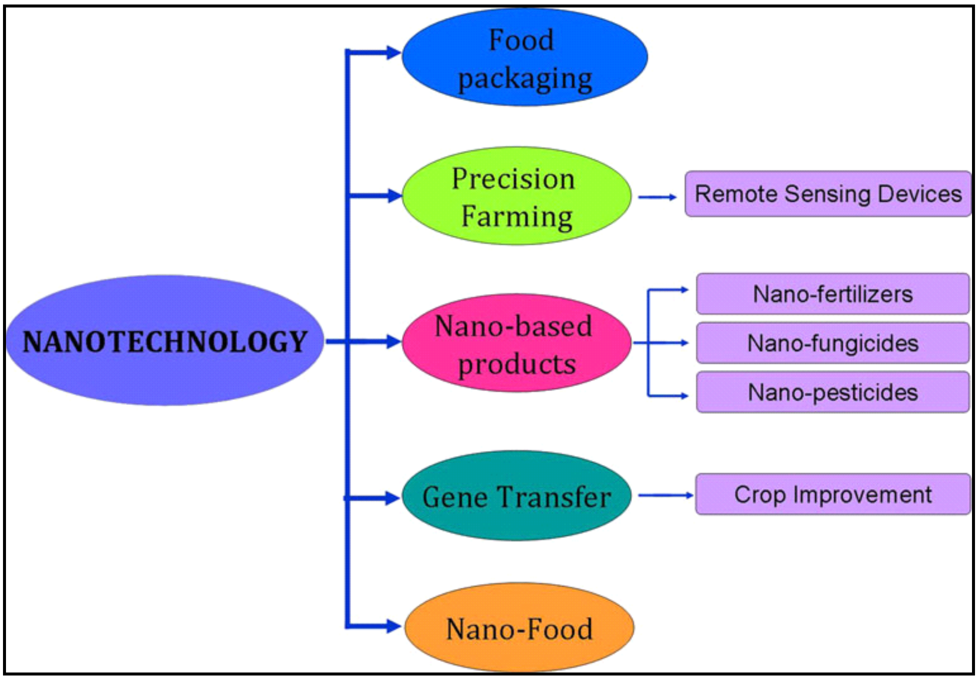


**Fig.9. Applications of nanotechnology in different fields of agriculture,[58] http://www.researchgate.net/publication/221886388**

**2-b Other applications of nanotechnology in the field of agriculture**

Nanotechnology can possibly change the diverse parts of the agricultural and food industry with present day instruments for the treatment of infections, fast illness discovery, improving the capacity of plants to assimilate supplements, and so on. Savvy sensors and shrewd conveyance frameworks will help the agrarian business battle infections and other yield pathogens [59]. Likewise, the important application is stretched out to harvest creation, manures, soil change and water purging as found in Table.2

**Table.2. Relevant applications in agricultural nanotechnology and examples of successful applications at small scale or R&D stages**

| | | | |
|---|---|---|---|
| **Crop production** | **Definition** | **Example** | **Reference** |
| Plant Protection Products | Nanocapsules, nanoparticles, nanoemulsions and viral capsids as smart delivery systems of active ingredients for disease and pest control in plants I | Neem oil(*Azadirachta indica*) nanoemulsion as larvicidal agent (VIT University,IN) | C.H. Anjali,Y.Sharma, A Mukherjee, N. Chandrasekaran, Pest Manage.Sci. 68 (2012) 158—163 |
| **Fertilizers** | Nanocapsules,nanoparticles and viral capsids for the enhancement of nutrients absorption by plants and the delivery of nutrients to specific Sites | Macronutrient Fertilizers Coated with Zinc Oxide Nanoparticles (Universityof Adelaide,AU CSIRO Land and Water,AU Kansas | N. Milani,etal., J. Agric.Food Chem. 60(2012) 3991—3998 |

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| | | StateUniversity, US) | |
| | | | |
| **Soil improvement** | | | |
| Water/liquid Retention | Nanomaterials, e.g.zeolites and nano-clays, for water or liquid agrochemicals retention in the soil for their slow release to the plants | Soil-enhancer product, basedona nano-clay component, for water retention and release (Geohumus-Frankfurt, DE) | http://www.geohumus.com/us/products.html |
| **Water purification** | | | |
| Water Purification and Pollutant Remediation | Nanomaterials, e.g.nano-clays, filtering and binding to a variety of toxic substances,including pesticides, to be removed from the Environment | Filters coated withTiO2 nanoparticles for the photo catalytic degradation of agrochemicals in contaminated waters (University of Ulster,UK) | T.A.McMurray, P.S.M.Dunlop, J.A. Byrne,J. Photochem. Photobiol. A-Chem. 182 (2006) 43—51 |
| **Diagnostic** | | | |
| Nanosensors and Diagnostic Devices | Nanomaterials and nanostructures (e.g. electro chemically active carbon nanotubes, nanofibers and fullerenes) that are highly sensitive bio-chemical sensors to closely monitor environmental conditions,plant health and growth | Pesticide detection with a liposome-based nano-biosensor (University of Crete,GR) | V.Vamvakaki,N.A. Chaniotakis, Biosens. Bioelectronics 22 (2007) 2848—2853. |
| **Plant breeding** | | | |
| Plant Genetic Modification | Nanoparticles carrying DNA or RNA to be delivered to plant cells for their genetic transformation or to trigger defence responses,activated by pathogens. | Mesoporus silica nanoparticles transporting DNA to transform plant cells (Iowa State university,US) | F.Torney,B.G.Trewyn,V.S.Y. Lin, K.Wang, Nat.Nanotechnol. 2 (2007)295—300. |
| **Nanomaterials from plant** | | | |
| Nanoparticles from plants | Production of nano materials through the use of engineered plants or microbes and through the processing | Nanofibres from wheat straw and soy hulls forbio-nanocomposite production (Canadian | A.Alemdar,M.Sain, Bioresour. Technol.99(2008) 1664—1671. |

| | | | |
|---|---|---|---|
| | of waste agricultural products | Universities and Ontario Ministry of Agriculture, Food and Rural Affairs,CA) | |

[60], http://dx.doi.org/10.1016/j.nantod.2014.09.009

**2- c Antimicrobial Agents for Plant Pathogens**

Antimicrobial action of various metal nanoparticles, especially copper and silver nanoparticles, has been examined by a few scientists against the plant pathogens. [61] have reported the antifungal movement of polymer - Nanomaterials in farming points specifically to decrease the measure of splashed synthetic items by brilliant conveyance of dynamic fixings, minimize supplement misfortunes in preparation.[52] and increment yields through advanced water and supplement administration. Nanotechnology determined gadgets are likewise being investigated in the field of plant reproducing and hereditary transformation[53] Additionally farming could be a wellspring of bio-Nanocomposites with improved physical-mechanical properties bases on regionally collected materials, similar to wheat straw and soyhults, for bio-industries purposes.[54] based copper nanocomposites against plant pathogenic fungi.[62] have considered the viability of nanosized (silica–silver nanoparticles) in the control of plant pathogenic parasites, viz. *Botrytis cinerea, Rhizoctonia solani, Colletotrichum gloeosporioides, Magnaporthe grisea*, and *Pythium ultimum*. They additionally exhibited the impact of nanobased items arranged from these nanoparticles against the fine buildup ailment of pumpkin and found that the ailment bringing about pathogens vanished from the contaminated leaves inside 3 days of spraying of this item.

Kim et al. [63] have researched the antifungal activity of three unique sorts of silver nanoparticles against the fungus *Raffaelea* sp., which was in charge of the mortality of a substantial number of oak trees in Korea. Development of parasites within the sight of silver nanoparticles was essentially hindered. Adequacy of mix of various types of nanoparticles was additionally concentrated on. It was found that silver nanoparticles brought about adverse impact on contagious hyphae as well as on conidial germination. Copper nanoparticles in pop lime glass powder indicated productive antimicrobial action against gram-positive and gram-negative microscopic organisms, and in addition parasites[64]. As per [65] silver nanoparticles were powerful against plant pathogenic growths, for example, *Bipolaris Fusarium, Phoma*.

**2-d Management of Insect Pests Using Nanotechnology**:

Nanopesticides, nanofungicides, and nanoherbicides are additionally being utilized as a part of agribusiness [66,67]. many organizations have made formulations which contain nanoparticles inside the 100–250 nm size range that can break down in water more viably than existing ones (in this manner expanding their activity). Different organizations utilized suspensions of nanoscale particles (nanoemulsions), which can be either water or oil based and contain uniform suspensions of pesticidal or herbicidal nanoparticles in the scope of 200–400 nm. These have different effects in precaution measures and in the treatment or conservation of the harvested item [68,50.]

**2-e Phytotoxicity of engineered nanoparticles to insect pests and pathogens**

Prior studies have affirmed that metal nanoparticles can be compelling against plant pathogens, insects, and pests. Thus, nanoparticles can be utilized as a part of the preparation of new formlations, for example, pesticides, insecticides, and insect repellents [55,67,66],[68]. Nanotechnology has helpful applications in nanoparticle interceded quality (DNA) exchange. It can be utilized to convey DNA and other wanted chemicals into plant tissues for security of the host plants against insect pests[58].

Porous hollow silica nanoparticles (PHSNs) stacked with validamycin (pesticide) can be utilized as proficient controlled discharge conveyance framework for water-dissolvable pesticide. Such controlled discharge conduct of PHSNs makes them promising bearers in agriculture (particularly for controlled conveyance of pesticides whose quick and in addition delayed discharge can be crucial for plants)[69].

As indicated by Wang et al.[70,] oil in water (nanoemulsions) can be helpful for the formulations of pesticides and these could be viable against different insect pests in farming. Additionally, vital oil-stacked strong lipid nanoparticles can likewise be helpful for the formulations of nanopesticides [69]. Nanosilica, a kind of exceptional nanomaterial, is set up from silica. It has numerous applications in solution and medication improvement. As of late, it has been observed to be helpful as catalyst and most imperative has been observed to be valuable as nanopesticide

Barik etal.[55,] have inspected the utilization of nanosilica as nanopesticide. The technique of control of insect pest utilizing nanosilica depends on the way that insect pests use an assortment of cuticular lipids for ensuring their water boundary and in this manner keep insect demise from parching. Normally, nanosilica gets retained into the cuticular lipids by physisorption and in this way (when used on leaves and stem surface) causes passing of insects simply by physical means.

. Surface charged, altered, hydrophobic nanosilica (*3–5 nm) can be effectively used to control a scope of farming insect pests and creature ectoparasites of veterinary significance [71,72] have exhibited the insecticidal effective of polyethylene glycol-covered nanoparticles stacked with garlic fundamental oil against grown-up *Tribolium castaneum* found in put away items. It has been watched that the control adequacy against adults of *T. castaneum* was around 80 %, probably due to the moderate and relentless arrival of the efficiency components from the nanoparticles.

Goswami et al.,[68] have deliberated the uses of various types of nanoparticles, viz. silver (SNP), aluminum oxide (ANP), zinc oxide, and titanium dioxide nanoparticles in the control of rice weevil and grasserie infection in silkworm (*Bombyx mori)* brought about by *Sitophilus oryzae* and baculovirus BmNPV (*B. mori* nuclear polyhydrosis virus), respectively. In their study, they performed bioassay, in which they arranged strong and fluid definitions of the previously mentioned nanoparticles; later, they used these plans on rice, kept them in a plastic box with 20 grown-up of S. oryzae and watched the impacts for 7 days. It was accounted for that hydrophilic SNP was efficient on the principal day. On day 2, more than 90 % mortality was acquired with SNP and ANP. Following 7 days of exposition, 95 % mortality and 86 % mortality were accounted for with hydrophilic and hydrophobic SNP and about 70 % of the insects were killed when the rice was treated with lipophilic SNP. In any case, 100 % mortality was seen if there should be an occurrence of ANP. Additionally, in another bioassay conveyed for grasserie disease in silkworm (*B. mori*), a critical diminishing in viral burden was accounted for when leaves were treated with an ethanolic suspension of hydrophobic alumino silicate nanoparticles.[9] have reported that nanotechnology will reform agriculture incorporating pest control sooner rather than later.. It is likewise estimated that throughout the following two decades, the "green reassessment" would be quickened by method for nanotechnology. One of the case of this innovation is nanoencapsulation. It is as of now utilized as the most vital and promising methodology for assurance of host plants against insect pests. Nanoencapsulation incorporates the utilization of an alternate sort of nanoparticles with insecticides inside. In this procedure, a compound, for example, an insecticide is gradually yet productively discharged to a specific host plant for insect pest control. Nanoencapsulation with nanoparticles can take into consideration legitimate intake of the compound into the plants not at all like the instance of bigger particles[73,74] interestingly examined the insecticidal action of nanostructured alumina against two insect pests, viz. *S. oryzae* (L.) and *Rhyzopertha dominica* (F.), which are real key pests in stored crops supplies all through the world. They reported considerable mortality following 3 days of constant exposure to nanostructured alumina-treated wheat. In this manner, when contrasted with economically accessible insecticides, inorganic nanostructured alumina may give an outskirts to nanoparticle-based advances in pest control.

## 3-**Additional Applications of Nanotechnology in the Field of Agriculture**

Nanotechnology can possibly change diverse divisions of the agricultural and sustenance industry with modern instruments for the treatment of diseases, fast ailment identification, upgrading the capacity of plants to retain supplements, and so on. Brilliant sensors and keen conveyance frameworks will help the agrarian business battle viruses and other crop pathogens[50]. Nanotechnology will likewise secure the environment in a roundabout way using elective (renewable) vitality supplies and channels or catalysts to decrease contamination and tidy up existing toxins[51].

### 3-a Insects make nanotech impression

Chinese analysts have reported a shoddy and successful approach to print nanoscale structures onto surfaces: they utilize stamps made from the gently designed wings of cicadas.

Jin Zhang, Zhongfan Liu, and partners from Peking University, Beijing, took motivation from the regular world to create their nanolithography system, which could deliver materials with helpful light-disseminating or water-repulsing properties

**Cicada with inset showing wing under magnification**
**http://www.rsc.org/chemistryworld/News/2006/November/01110602.asp**.

As Zhang et.al.[75] clarified, cicada wings - expelled from insects obtained from the backyard of his research institute - contain a minute structure of pillars few hundreds of nanometres separated. The cicada utilizes the light-reflecting properties of this nanostructure to avoid predators, Zhang told *Chemistry World*.

Fortunately, cicada wings are likewise sufficiently hardened for their nanoscale example to be engraved into a smooth polymer film. With appropriate chemical etching , the example can be reproduced on a silicon wafer;; or the engraved film can stamp a duplicate of the cicada-wing design onto gold.

The cicada wing's waxy covering makes this conceivable: it saves the wing structure as it is cleaned, and it permits the wing stamps to be neatly peeled away after the printing procedure.

The field of nanolithography at present depends on refined - however costly - strategies to example surfaces, remarked Franco Cacialli of University College, London, UK. 'The bread-and-spread innovation is optical lithography, which utilizes photosensitive materials,' said Cacialli. Be that as it may, a heap of different systems are being squeezed into administration to outline littler, altered examples; all with fluctuating degrees of cost, speed, and entanglement.

The cicada-wing approach scores on inexpensiveness and effortlessness and could create stamps covering an expansive region. Be that as it may, it can just create one example, said Cacialli. Centered particle bar lithography, however more costly, can wear down any required example in a silicon wafer.

The cicada wing's waxy covering makes this possible: it spares the wing structure as it is cleaned, and it allows the wing stamps to be perfectly peeled away after the printing strategy.

Zhang et. Al.,[75] thought about that cicada-charged nanosurfaces could be used in precision lenses, where light-reflecting properties are crucial. 'This method is a successful display of how natural nanostructures existing in the earth can be used to outline minute structures not easily accessible by standard micro fabrication development,' he said.

cicada-wing approach scores on inexpensiveness and effortlessness and could deliver stamps covering an expansive territory. However, it can just create one example, said Cacialli. Centered particle shaft lithography, however more costly, can wear down any required example in a silicon wafer.

Cicadas are not by any means the only insects with nanostructures on their wings. In nature, the scientists clarified, designs on the nanometre scale proliferate: butterflies' luminous hues ` emerge from modest pillared structures which disperse light; lotus plants repulse water because of nanometre-sized wax crystals on their surface. 'There is a great deal that nature can show us about nanotechnology,' said Liu et al.,[69]

**4-Environmental Impact of nanotechnology**

The environmental effect of nanotechnology is the conceivable impacts that the utilization of nanotechnological materials and gadgets will have on the earth. As nanotechnology is a rising field, there is awesome level headed discussion in regards to what degree mechanical and commercial utilization of nanomaterials will influence creatures and environment. Nanotechnology's ecological effect can be isolated into two viewpoints. Nanotechnological developments to help enhancing the earth, and the likelihood the novel kind of contamination and pollution that nanotechnological may bring about if discharged into environment.

**4-a Environmental applications and benefits of nanotechnology**

In the course of recent decades, respectable metal nanoparticles extended quickly with the consolidation of new nanocomposites into a scope of products and innovations. Silver nanoparticles are the most looked for in the wake of functionalizing and commercializing nanomaterial because of their novel physicochemical properties (with a high proportion of surface area to mass), electric,[76], optical, Jin et al.,[77],catalytic, Severin et al.[78] and especially antimicrobial properties[79].The nanoparticles pointed out intense antibacterial action and a significantly higher synergistic impact with erythromycin, methicillin, and ciprofloxacin[80]. Silver nanoparticles are likewise answered to have antifungal,[81] , mitigating,[82] and antiviral exercises[83].

**4-b Positive effect of nanomaterials in the Environment**

People, alongside other non-target species face genuine wellbeing dangers because of the bioaccumulation of persistent pesticides in the evolved way of life. Utilization of some industrious pesticides have brought about the turmoil of endocrine hormones, expanded danger of growths ( cancers), uncalled for working of the invulnerable framework and conceptive and formative variations from the norm in various marine and land species of animals. The broad utilization of persistent insecticides has driven additionally to the development of new insect pests and illnesses with higher invulnerability to the pesticides.

A noteworthy bit of the examination in farming nanotechnology is in the region of degradation of unsafe pesticides by changing over them into safe and valuable compounds, for example, minerals and water. This is conceivable through photocatalysis, a property showed by semiconducting oxides, whereby they assimilate photons and start redox responses, which can separate complex organic molecules into more simpler forms[84].After the effective analysis of water into H2 and O2 utilizing titania enlightened with ultraviolet light[85], there has been many research on the utilization of photocatalysis in the degradation of poisonous materials in the environment, particularly in wastewater coming about from wastes of factories because of mechanical squanders and in agricultural fields because of expanded utilization of pesticides

Soils are unpredictable mixtures of solids with particle sizes running from millimeters to nanometres. It is currently conceivable to understand these structures utilizing complex systems produced for nanotechnology, for example, transmission electron microscopy and atomic force microscopy. These methods exhibit the association of colloidal material in soils, for example, phyllosilicates and humic acids, and the revelation of new particles, for example, nanoparticles of iron oxides[86].They clarify how humic materials rebuild in light of environmental changes, for example, pH and ionic quality. Nanotechnology offers guarantee in recognizing single cells, individual DNA particles, proteins, genes and other biological structures in soils.

Much work is under advancement to expel the destructive impacts of herbicides and pesticides on plants and in the soil, essentially through photocatalysis utilizing metal oxide nanoparticles, for example, TiO2 and ZnO . Prevot[87] has reported the effective debasement of dicamba (3,6-dichloro-2-methoxybenzoic corrosive) utilizing fluid TiO2 scatterings. They utilized a barrel shaped photochemical reactor to complete the photocatalysis with illumination from a sun oriented test system comprising of a 125 W medium weight Hg light. Hermann and Guillard[88] attempted to distinguish the response middle of the road items and corruption pathways in tests grabbed from agricultural areas. They have reported the total debasement of herbicides, for example, 2,4-D (dichloro-phenoxy-acetic acid) and pesticides, for example, tetrachlorvinphos, fenitrothion, pirimiphos-methyl and fenamiphos. They likewise got a useful collaboration endless supply of enacted carbon.

Rahman and Muneer[89] concentrated on the corruption energy of two pesticides, dichlorvos and phosphamidon, utilizing Degussa 25. They concentrated on various conditions, for example, pesticide concentration, catalyst fixation and the pH. As indicated by their perceptions, the expansion of electron acceptors, for example, hydrogen peroxide (H2O2) significantly expands the degradation rates of the toxins. Lhomme et al.,[90] claimed] guaranteed to be among the first to utilize titanium dioxide-covered non-woven paper for degrade pesticide, cyproconazole, considering the impact of parameters, for example, introductory focus and the measure of dissolved oxygen Their examination of the principal natural by-products focuses towards a likely attack of the hydroxyl radical on the phenyle ring, the methyl bunches and the carbon C1 of the cyproconazole. Bandala et al.,[91] reported the utilization of sun oriented photocatalysis for degradation of aldrin with three change +

Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methyl carbamate) is an extremely toxic carbamate pesticide, which is broadly utilized as an insecticide to a part of a wide assortment of field crops, including soyabean and potatoes. Mahalakshmi et al.,[92] utilized aggregate organic carbon analyser to affirm the complete mineralization of carbofuran within the sight of TiO2 and ZnO photocatalysts. Comparative tests with TiO2 and ZnO have likewise been done on an organo-phosphorus insecticide, dichlorvos (2,2-dichloroethanol dimethyl phosphate), otherwise called DDVP, which is broadly utilized in a part of the developing countries . DDVP is toxic to the point that it can be named a limited use pesticide (RUP). Evgenidou et al.,[93] reported that the degradation of DDVP utilizing photo catalysis takes after first-arrange energy as indicated by the Langmuir Hinselwood model. They have likewise watched that the addition of electron acceptors, for example, hydrogen peroxide (H2O2) or potassium persulphate (K2S2O8) increases the degradation rate within the presence of TiO2, yet impedes it within the sight of ZnO..

Degradation of water-soluble pesticides have additionally been learned at the pilot plant scale utilizing two all around characterized frameworks using solar UV light : (a) heterogeneous photo catalysis utilizing TiO2 and (b) homogenous photo catalysis by photograph fenton[94] . Photo catalysis tests utilizing TiO2 were led as a part of a sun based pilot plant with three compound explanatory authorities (CPCs) under natural illumination and homogenous photo catalysis test in a solar pilot plant with four CPC units. Nearly 100% mineralization was obtained with the total disappearance of the starting pesticides (cymoxyl, methomyl, oxamyl, dimethoate, pyrimethanil and telone). Photocatalysis degradation process has also gained popularity in the area of wastewater treatment[95]. Peral, et. al.,[96] has explained the use of photocatalysis for purification, decontamination and deodorization of air. Miles et.al.,[97] additionally clarified semiconductor-sharpened photosynthetic and photocatalytic forms for the expulsion of organics, annihilation of cancer cells, microbes and viruses.

### 4-c Adverse environmental effects of nanostructures

The expanding utilization of nanotechnology in agriculture and food materials has made worries amongst an area of the general public about the antagonistic impacts of various nanoparticles. The potential effects of nanoscale materials in air, water and soil are still not clear. Questions on whether and how much nanoscale materials connected with nanoscience and nanotechnology enter the environment stay unanswered at the present[98]. Nanoscale materials are in the same size extent as DNA, the fundamental building block of biological examples, and have the likelihood of responding with biological examples, not at all like bigger particles. The wide range of potential utilizations of nanoparticles brings up issues on the security of their utilization and unfavorable impacts on non-target species. Both examples and additionally pundits of nanotechnology are discovering it amazingly hard to advocate their convictions as there is constrained data accessible to bolster either side. It has been demonstrated that nanomaterials can enter the human body through several parts[99]. Automatic contact during creation or use is destined to happen by means of the lungs from where a quick translocation through the circulation system is conceivable to other vital organs[100]. At the cellular level, the capacity of nanoparticles to act about as a gene vector has been illustrated[101]. Carbon black nanoparticles have been seen to meddle with cell signaling[102]. Zheng et al.,[103] has shown the utilization of DNA for the size partition of carbon nanotubes. The DNA strand wraps around the carbon nanotube if the tube diameter across is fitting. While magnificent for the separation purposes, it raises a few worries over the outcomes of carbon nanotubes entering the human body[99].

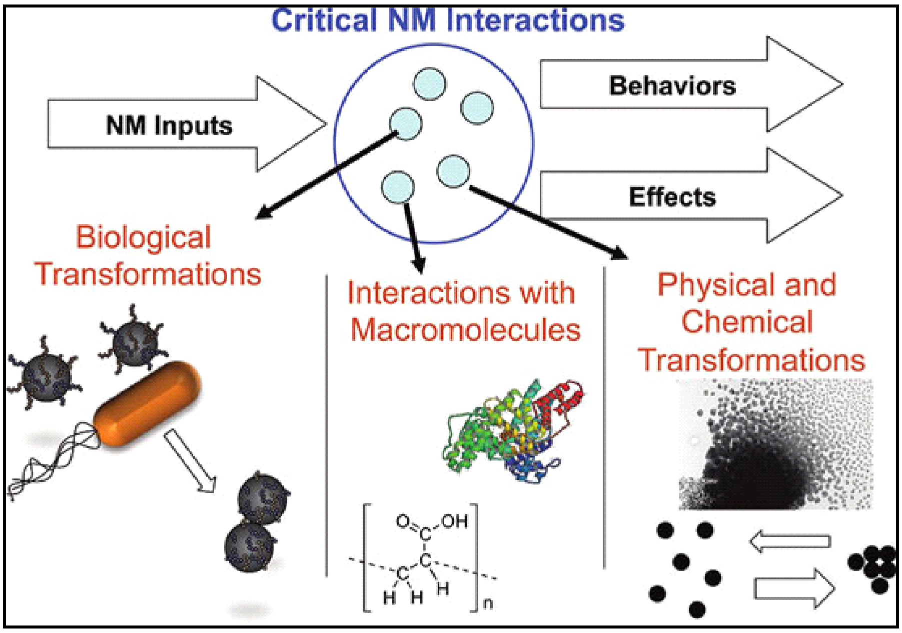


**Fig.10. Nanomaterial transformations are critical processes affecting NM interactions. Transformations include physical and chemical transformations, biologically mediated transformations, and interactions with macromolecules and biomacromolecules. Adapted from https://www.researchgate.net/figure/224955806_fig1_Figure-1-Nanomaterial-transformations-are-critical-processes-affecting-NM-interactions**

### 4- d Environmental remedation

Crane and Scott and U.S. EPA,[104, 105] expressed that Nano remedation is the utilization of nanoparticles for environmental remediation. Nano remediation has been most broadly utilized for ground water treatment with extra broad exploration in waste water treatment[106,107]. Nano remediation, likewise has been tried for soil and sediment tidy up[108]. Amid nanoremediation, a nanoparticle agent must be carried into contact with the objective contaminant under conditions that permit a detoxifying or immobilizing response.

### 4- e Nanopollution

It is created by nanodevices or amid the nano materials fabricating process. Ecotoxicological effects of nanoparticles and the potential for bioaccumulation in plants and microorganisms is a subject of concern.

Nanoparticles have the ability to work as a vehicle system of heavy metals and other environmental contaminants. Scrinis[73] raises concerns about nano-contamination, and contends that it is not at present conceivable to unequivocally anticipate or control the ecological impacts of the release of these nanoproducts in the environment.

## Conclusion

Despite the way that various potential favorable position of nanotechnology and the developing patterns in productions and licenses, agrarian applications have in its newborn child arrange and not yet made it to the business sector. The quick advance of nanotechnology in other key ventures may after some time be exchanged to agrarian applications also and encourage their improvement. The expanding utilization of nanotechnology in agriculture and food items has made worries amongst the general public about the antagonistic impacts of various nanoparticles. The potential effects of nanoscale materials in air, water and soil are still vague.

Nanotechnology then again can possibly upset the current innovations utilized as a part of different areas including agriculture. Nanotechnology may have specific arrangements against numerous related issues like insect pest control utilizing traditional applications, unfavorable impacts of synthetic pesticides, advancement of enhanced harvest assortments, and so on. Nanomaterials in various structures can be utilized for efficient control of insect pests and plans of potential insecticides and pesticides. Nanoparticle-intervened quality exchange would be helpful for the improvement of new insect resistant verities[57]. Also, nano technology can provide green and eco-friendly alternatives for insect pest management. It is assumed that in the near future nanotechnology will be available which will increase the efficacy of commercially available pesticides and insecticides and also reduce the doses level required for pest control without harming the environment[57].

## References


1. Delgado-Ramos G. C., 2014. “Nanotechnology in Mexico: global trends and national implications for policy and regulatory issues,” Technology in Society, vol. 37, no. 1, pp. 4–15.
2. Vilela Neto, O. P. 2014. “Intelligent computational nanotechnology: the role of computational intelligence in the development of nanoscience and nanotechnology,”Journal of Computational and Theoretical Nanoscience, vol. 11, no. 4, pp. 928–944.
3. Dutschk, V., T. Karapantsios, L. Liggieri, N. McMillan, R. Miller, and V. M. Starov, , 2014. “Smart and green interfaces: from single bubbles/drops to industrial environmental and biomedical applications,” Advances in Colloid and Interface Science, vol. 209, pp. 109–126.
4. Al-Halafi, A. M. .2014 “Nanocarriers of nanotechnology in retinal diseases,” Saudi Journal of Ophthalmology, 28(4): 304–309. doi: 10.1016/j.sjopt.2014.02.009
5. Safari, J. and Z. Zarnegar, 2014, “Advanced drug delivery systems: nanotechnology of health design A review,” Journal of Saudi Chemical Society, vol. 18, no. 2, pp. 85–99.
6. Leiderer P, Dekorsy T. 2008. Interactions of nanoparticles and surfaces Tag der mÄundlichen PrÄufung: 25. April. URL: http://www.ub.unikonstanz.de/kops/ volltexte/2008/5387/; URN: http://nbn-resolving.de/urn:nbn:de:bsz:352-opus-53877.
7. Safiuddin, M., M. Gonzalez, J. W. Cao, and S. L. Tighe, Vilela Neto, O. P. 2014. “Intelligent computational nanotechnology: the role of “State-of-the-art report on use of nano-materials in concrete,” International Journal of Pavement Engineering. 940-949. **DOI:**10.1080/ 10298436.2014.893327.
8. Zhou, X., M. Torabi, J. Lu, R. Shen, and K. Zhang, 2014. “Nanostructured energeticcomposites: synthesis, ignition/combustion modeling, and applications,” ACS Applied Materials and Interfaces, vol. 6, no. 5, pp. 3058–3074
9. Bhattacharyya A, Bhaumik A, Usha Rani P, Mandal S, Epidi TT 2010. Nano-particles: a recent approach to insect pest control. Afr J Biotechnol 9(24):3489–3493.
10. Taylor R, Walton DRM. 1993. The chemistry of fullerenes , Nature , 363: 685 – 693.
11. Huang J, Li Q, Sun D, Lu Y, Su Y, Yang X, Wang H, Wang Y, Shao W, He N, Hong J, Chen C. 2007. Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf. Nanotechnology 18:105104
12. Bhattacharyya A, Datta PS, Chaudhuri P, Barik BR 2011. Nanotechnology: a new frontier for food security in socio economic development. In: Proceeding of disaster, risk and vulnerability conference 2011 held at School of Environmental Sciences, Mahatma Gandhi University, India in association with the Applied Geoinformatics for Society a DOI: 10.1186/1477-3155-2-3nd Environment, Germany, 12–14 March 2011.
13. Elibol OH, Morisette DD, Denton JP, Bashir R 2003. Integrated sensors using top-down fabrication. Appl Phys Lett 83:4613–-4615.
14. Salata OV. 2004. Application of nanoparticles in biology and medicine. J Nanobiotechnology 2:3. DOI: 10.1186/1477-3155-2-3.
15. Podsiadlo P, Kaushik AK, Arruda EM, Waas AM, Shim BS, Xu J, Nandivada H, Pumplin BG, Lahann J, Ramamoorthy A, Kotov NA. 2007. “Ultrastrong and stiff layered polymer nanocomposites,” Science, vol. 318, no. 5847, pp. 80–83.
16. Henkes, Y. A. E, Chris Bauer, J. and Schaak, R. E. 2008. “Nanocrystal conversion chemistry: a unified and materials-general strategy for the template-based synthesis of nanocrystalline solids,” Journal of Solid State Chemistry, vol. 181, no. 7, pp. 1509–1523.
17. Kong,L., Tang, J. , Liu, J. , Wang, Y., Wang, L., and Cong, F. 2009. “Fluorescent nanoblocks of lanthanide complexes on nano silicon dioxide and carbon nanotube donors with ligand-antenna integration (ALI) structure,” Materials Science and Engineering C, vol. 29, no. 1, pp. 85–91

18. Mehta RJ, Zhang Y, Karthik C, Singh B, Siegel RW, Borca-Tasciuc T, Ramanath G. 2012. A new class of doped nanobulk high-figure-of-merit thermoelectrics by scalable bottom-up assembly Nat Mater. 10;11(3):233-40. doi: 10.1038/nmat3213.
19. Baughman, R. H, Zakhidov, A. A. and. de Heer, W. A. 2002. “Carbon nanotubes—the route toward applications,” Science, vol. 297, no. 5582, pp. 787–792.
20. Jinquan Li, Li Li, Hanqing Chen, Qing Chang, Xudong Liu, Yang Wu, Chenxi Wei, Rui Li, Joseph K. C. Kwan, King Lun Yeung, Zhuge Xi, Zhisong Lu & Xu Yang. 2014. Application of vitamin E to antagonize SWCNTs-induced exacerbation of allergic asthma. Scientific Reports 4, Article number: 4275. doi:10.1038/srep04275.
21. Jinquan, D. B., Laurence, R. , Reed, K. L., Roach, D. HReynolds, , G. A. M. and Webb, T. R. 2004. “Comparative pulmonary toxicity assessment of single-wall carbon nanotubes in rats,” Toxicological Sciences, vol. 77, no. 1, pp. 117–125.
22. Qi H. and Hegmann, T. 2008. “Impact of nanoscale particles and carbon nanotubes on current and future generations of liquid crystal displays,” Journal of Materials Chemistry, vol. 18, no. 28, pp. 3288–3294.
23. Nel A., Xia T, Madler I., Li N. 2006. Toxic potential of materials at the nano level. Science . 311: 622 - 627.
24. Prasanna, B.M. 2007. NANOTECHNOLOGY IN AGRICULTURE ICAR National Fellow, Division of Genetics, I.A.R.I., New Delhi – 110012
25. Pumera,M. 2010. Graphene-based nanomaterials and their electrochemistry. Chem. Soc. Rev., 39, 4146-4157`
26. Filipponi, Luisa and Sutherland, D. 2013. Nanotechnolgies Principles, Applications, Implications and hand- on Activities. Handbook(416pp.) DOI: 102777/76945.
27. Thaxton, C.S., Elghanian,R., Thomas,A.D., Stoeva, S.I., Lee,J.S., Smith,N.D., Schaeffer, AJ., Klocker,H., Horninger,W., Bartsch,G., and Mirkin.C.A. 2009. Nanoparticle-based bio-barcode assay redefines “undetectable” PSA and biochemical recurrence after radical prostatectomy. Proc. Nat. Acad. Sci. U. S. A. 106(44):18437–18442, doi:10.1073/pnas.0904719106.)
28. Filipponi Luisa & Sutherland D. 2007. Nanotechnology a brief introduction. file:///C:/Users/m/Downloads/Documents/Download07ab.pdf
29. Daniel L. S., Ferreira P. Ashby, .F. 2009. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects,527pp, http://www.bookreder.com/nanomaterials-nanotechnologies-and-design.html Fillipponi L. 2006. Applications of Nanotechnology: Catalysis. http://www.nanocap.eu/Flex/Site/Downloaddfc2.pdf?ID=4519
30. Kumar,N., Kumbhat,S. 2016. Essentials in Nanoscience and Nanotechnology.. Engineering & Materials Science, 488 pages. ISBN: 978-1-119-09611-5.
31. Wilson, M., Kannangara, K., Smith, G., Simmons, M., Raguse. B. 2002. Nanotechnology: Basic Science and Emerging Technology. 290pp. ISBN 9781584883395.
32. https://www.crcpress.com/Nanotechnology-Basic-Science-and-Emerging-Technologies/Wilson-Kannangara-Smith-Simmons-Raguse/p/book/9781584883395.
33. Song JY, Kim BS. 2008. Rapid biological synthesis of silver nanoparticles using plant leaf extracts. Bioprocess Biosyst Eng , 32: 79-84.
34. Klaus T, Joerger R, Olsson E, Granqvist CG. 1999. Silver-based crystalline nanoparticles, microbially fabricated. J Proc Natl Acad Sci USA. 96: 13611-13614.
35. Nair B, Pradeep T. 2006. Coalescence of nanoclusters anormation of submicron crystallites assisted by Chandran SP, Chaudhary M, Pasricha R, Ahmad A, Sastry M. 2006. Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract. Biotechnol Prog (22) Jae YS. Beom SK.; 22: 577-583.
36. Konishi Y, Uuga T. 2008. Bioreductive deposition of platinum nanoparticles on the bacterium Shewanella algae. J Biotechnol , 128: 648-653
37. Willner I, Baron R, Willner B. 2006. Growing metal nanoparticles by enzymes. J Adv Mater 18: 1109-1120.
38. Vigneshwaran N, Ashtaputre NM, Varadarajan PV, Nachane RP, Paraliker KM, Balasubramanya RH. 2007. Biological synthesis of silver nanoparticles using the fungus Aspergillus flavus. Mater Lett ; 61: 1413

39. Shankar, S.S., Rai, A., Ankamwar, B.,Singh, A., Ahmad, A. and Sastry, M. 2004. Biological synthesis of triangular gold nanoprisms Nat. Mater., 3, pp. 482–488. doi:10.1038/nmat1152
40. Chandran,S. P., Minakshi Chahary., Renu Pasricha., Absar Ahmad and Murali Sastry. 2006. Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract. Biotechnology Progress , 22 :577- 583.
41. Jae YS. Beom SK. 2009. Rapid biological synthesis of silver nanoparticles using plant leaf extracts. Bioprocess Biosyst Eng ; 32: 79-84.
42. Ahmad N, Sharma S, Singh VN, Shamsi SF, Fatma A, Mehta BR. 2011. Biosynthesis of silver nanoparticles from Desmodium triflorum: a novel approach towards weed utilization. Biotechnol Res Int 2011; 454090
43. Dubey M, Bhadauria S, Kushwah BS. 2009. Green synthesis of nanosilver particles from extract of Eucalyptus hybrida (Safeda) leaf. Dig J Nanomat Biostruct; 4(3): 537-543.
44. Farokhzad ,O.C, Cheng , J., Teply, B.A., Sherifi, I.,Jon, S., Kantoff, P., W. Richie, J. P. and Langer, R. 2006. Targeted nanoparticle-aptamer bioconjugates for cancer chemotherapy in vivo. The National Academy of Sciences of the USA, vol. 103 no. 16, 6315–6320, doi: 10.1073/pnas.0601755103.
45. Ovalle-Serrano, S., Carrillo, V., Blanco-Tirado, C., Hinestroza, JP., Combariza, M.Y., 2015. Controlled synthesis of ZnO particles on the surface of natural cellulosic fibers: effect of concentration, heating and sonication., Cellulose , 22, 3, 1841-1852
46. Ozer, R., Hinestroza, JP, 2015. One-step growth of isoreticular luminescent metal-organic frameworks on cotton fibers, RSC Advances , 5 (20), 15198-15204
47. Thaxton, C.S., R. Elghanian, A.D. Thomas, S.I. Stoeva, J.S. Lee, N.D. Smith, A.J. Schaeffer, H. Klocker, W. Horninger, G. Bartsch, and C.A. Mirkin.2009. Nanoparticle-based bio-barcode assay redefines "undetectable" PSA and biochemical recurrence after radical prostatectomy. Proc. Nat. Acad. Sci. U. S. A. 106(44):18437–18442, doi:10.1073/pnas.0904719106.)
48. Wang Q,H., Yan M. and Chang R.P.H.(2001). Flat panel display prototype using gated carbon nanotube field emitters . Appl. Phys. Lett. 78, 1294 (2001); http://dx.doi.org/10.1063/1.1351847
49. Dillon, A.C., Gennett, T., Alleman,J.L., Jones, K.M., Parilla,P.A. and Heben M.J.(1999). Optimization of Single -Wall Nanotube Synthesis For Hydrogen Storage. National Renewable Energy Laboratory, Golden, CO 80401-3393 (USA)file:///C:/Users/m/Downloads/Documents/31288.pdf
50. Rickman D, Luvall J, Shaw J, Mask P, Kissel D, Sullivan D (2003) Precision agriculture: changing the face of farming. Geotimes 48(11):28–33.
51. Tungittiplakorn W, Cohen C, Lion LW (2004) Engineered polymeric nanoparticles for bioremediation of hydrophobi contaminants. Environ Sci Technol 39(5):1354–1358. doi:10.1021/es049031a
52. Gogos A., Knauer K. and Bucheli, T.D. ( 2012).Nanomaterials in Plant Protection and Fertilization: Current State, Foreseen Applications, and Research Priorities . J. Agric. Food Chem. 2012, 60 ( 39), pp 9781 – 9792
53. Tomey.F., Trenyn B.G., Lin,V.S.Y., long. K. (2007). Nat. Nanotechnolo. 2, 295-300.
54. Alemdar,A., and Sain A. (2008). Mesoporous silica nanoparticles deliver DNA and chemicals into plants. Technol. 99, 1664-1671.
55. Barik TK, Sahu B, Swain V (2008) Nano-silica—from medicine to pest control. Parasitol Res 103:253–258.
56. El-bendary, H. M. and El-Helaly, A. A.(2013). First record nanotechnology in agricultural: Silica nanoparticles a potential new insecticide for pest control. App. Sci. Report. 4 (3), 2013: 241-246.
57. Joseph, T., & Morrison, M. (2006). Nanotechnology in agriculture and food, a nanoforum. Report org. Düsseldorf, Germany. http://www.nanoforum.org/dateien/temp/nanotechnology%20in%20agriculture%20and%20food.pdf?08122006200524. Accessed 17 June 2009.
58. Rai, M., and Ingle A. (2012). Role of nanotechnology in agriculture with specia reference to management of insect pests Applied Microbiology and Biotechnology, Volume 94, Issue 2, pp 287–293, doi:10.1007/s00253-012-3969-4.
59. Rickman D, Luvall JC, Shaw J, Mask P, Kissel D, Sullivan D. 1999. Precision agriculture: changing the face of farming. Geotimes feature article. www.ghcc.msfc.nasa.gove/precisionag/. Accessed 19 November, 2011
60. Parisi,C., Vigani, M., Rodríguez-Cerezo, E., 2015. Agricultural Nanotechnologies: What are the current possibilities?. Nano Tody. 10, 124-127. http://dx.doi.org/10.1016/j.nantod.2014.09.009. file:///F:/nano/Agricultural%20Nanotechnology%2021.1.2015.pdf

61. Cioffi,N., Toisi,L., Ditaranto, N., Sabbatini,L., Zambonin, P.G., Tantillo,G., Ghibelli, L., D'Alessio, M., Bleve-Zacheo, T., Traversa,E. 2004.Antifungal activity of polymer-based copper nanocomposite coatings, Appl. Phys. Lett. 85, 2417 http://dx.doi.org/10.1063/1.1794381
62. Park H-J, Kim S-H, Kim H-J, Choi S-H (2006) A new composition of nanosized silica silver for control of various plant diseases. Plant Pathol J 22(3):295–302.
63. Kim SW, Kim KS, Lamsal K, Kim Y-J, Kim SB, Jung M, Sim S-J, Kim H-S, Chang S-J, Kim JK (2009) An in vitro study of the antifungal effect of silver nanoparticles on oak wilt pathogen Raffaelea sp. J Microbiol Biotechnol 19:760–764.
64. Esteban-Tejeda L., Malpartida F., Esteban-Cubillo A., Pecharroman C., Moya J., 2009. Antibacterial and antifunfal activity of a Soda-lime glass containing copper nanoparticales. Nanotechnology. 20(50):505701.
65. Jo Y-K, Kim BH, Jung G (2009) Antifungal activity of silver ions and nanoparticles on phytopathogenic fungi. Plant Dis 93(10):1037–1043.
66. Gajbhiye M,, Kesharwani J, Ingle A, Gade A, Rai M. 2009. Fungus-mediated synthesis of silver nanoparticles and their activity against pathogenic fungi in combination with fluconazole. Nanomed Nanotechnol Biol Med 5(4):382–386.
67. Owolade OF, Ogunleti DO. 2008. Effects of titanium dioxide on the diseases, development and yield of edible cowpea. J Plant Prot Res 48(3):329–336.
68. Goswami A, Roy I, Sengupta S, Debnath N (2010) Novel applications of solid and liquid formulations of nanoparticles against insect pests and pathogens. Thin Solid Films 519(3):1252–1257.
69. Liu F, Wen L-X, Li Z-Z, Yu W, Sun H-Y, Chen J-F (2006) Porous hollow silica nanoparticles as controlled delivery system for water-soluble pesticide. Mater Res Bull 41(12):2268–2275.
70. Wang L, Li X, Zhang G, Dong J, Eastoe J (2007) Oil-in-water nanoemulsions for pesticide formulations. J Colloid Interface Sci 314(1):230–235.
71. Ulrichs C, Mewis I, Goswami A. 2005. Crop diversification aiming nutritional security in West Bengal: biotechnology of stinging capsules in nature's water-blooms. Ann Tech Issue State Agri Technol Serv Assoc ISSN 1–18
72. Yang F-L, Li X-G, Zhu F, Lei C-L. 2009. Structural characterization of nanoparticles loaded with garlic essential oil and their insecticidal activity against Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). J Agri Food Chem 57(21):10156–10162.
73. Scrinis,G. 2007. Nanotechnology and the environment. The Nano Atomic reconstruction of Nature " Chain Reaction 97: 23 -26.
74. Stadler T, Buteler M, Weaver DK. 2010. Novel use of nanostructured alumina as an insecticide. Pest Manage Sci 66(6):577–579.
75. Zhang, J. and Zhongfan Liu 2006, (Insects make nanotech impression). Royal Society of Chemistry. on line, DOI: 10.1002/smll.200600255. http://www.rsc.org/chemistryworld/ News/2006/ November/ 01110602.asp
76. Tricoli A, Pratsinis SE. 2010; Dispersed nanoelectrode devices. Nat Nanotechnol. 5(1):54–60.
77. Jin R, Cao YC, Hao E, Métraux GS, Schatz GC, Mirkin CA. 2003. Controlling anisotropic nanoparticle growth through plasmon excitation. Nature.;425(6957):487–490
78. Severin N, Kirstein S, Sokolov IM, Rabe JP. 2009. Rapid trench channeling of graphenes with catalytic silver nanoparticles. Nano Lett. 9(1):457–461.
79. Chen M, Yang Z, Wu H, Pan X, Xie X, Wu C. . 2011. Antimicrobial activity and the mechanism of silver nanoparticle thermosensitive gel. Int J Nanomedicine; 6:2873–2877.
80. Devi LS, Joshi SR. 2012. Antimicrobial and synergistic effects of silver nanoparticles synthesized using soil fungi of high altitudes of eastern Himalaya. Mycobiology; 40(1):27–34
81. Chladek G, Mertas A, Barszczewska-Rybarek I,3 Nalewajek,T., Żmudzki, J., Król,W., and Łukaszczyk, J. 2011. Antifungal activity of denture soft lining material modified by silver nanoparticles-a pilot study. Int J Mol Sci.;12 (7):4735–4744.
82. Martínez-Gutierrez F1, Thi EP, Silverman JM, de Oliveira CC, Svensson SL, Vanden Hoek A, Sánchez EM, Reiner NE, Gaynor EC, Pryzdial EL, Conway EM, Orrantia E, Ruiz F, Av-Gay Y, Bach H. 2012. Antibacterial activity, inflammatory response, coagulation, and cytotoxicity effects of silver nanoparticles. Nanomedicine.;8(3):328–336.
83. Mohammed F.A., Ao,Z., Girilal,M. Chen,L., Xiao,X., Kalaichelvan,PT., and Yao, X. 2012. Inactivation of microbial infectiousness by silver nanoparticles-coated condom: a new approach to inhibit HIV- and HSV-transmitted infection. Int J Nanomedicine.; 7:5007–5018

84. Ullah R, Dutta J 2008. Photocatalytic degradation of organic dyes with manganese-doped ZnO nanoparticles. J Hazard Mater 156:194.
85. Fujishima A, Honda K. 1972. Electrochemical photolysis of water at a semiconductor electrode. Nature 37:28. doi:10.1038/238037a0.
86. Wilson MA, Tran NH, Milev AS, Kannangara GSK, Volk H, Lu GRM. 2008. Nanomaterials in soils. Geoderma 146:291–302.
87. Prevot AB, Fabbri D, Pramauro E, Rubio AM, de la Guardia M. 2001. Continuous monitoring of photocatalytic treatments by flow injection. Degradation of dicamba in aqueous $TiO_2$ dispersions. Chemosphere 44:249–255. doi:10.1016/S0045-6535(00)00168-5.
88. Herrmann JM, Guillard C 2000. Photocatalytic degradation of pesticides in agricultural used waters. Surface Chem Catalysis 23:417
89. Rahman MA, Muneer M. 2005. Photocatalysed degradation of two selected pesticide derivatives, dichlorvos and phosphamidon in aqueous suspensions of titanium dioxide. Desalination 181:161–172
90. Lhomme L, Brossilon S, Woolbert D. 2007. Photocatalytic degradation of a triazole pesticide, cyproconazole, in water. J Photochem Photobol 188:34–42
91. Bandala ER, Gelover S, Leal MT, Arancibia-Bulnes C, Jimenez A, Estrada CA (2002) Solar photocatalytic degradation of aldrin. Catal Today 76:189–199. doi:10.1016/S0920-5861(02)00218-3
92. Mahalakshmi M, Arabindoo B, Palanichamy M, Murugesan V. 2007. Photocatalytic degradation of carbofuran using semiconductor oxides. J Hazard Mater 143:240–245. doi:10.1016/j.jhazmat.2006.09.008.
93. Evgenidou E, Fytianos K, Poulios I. 2005. Semiconductor-sensitized photodegradation of dichlorvos in water using $TiO_2$ and ZnO as catalysts. Appl Catal B Environ 59:81–89. doi:10.1016/j.apcatb.2005.01.005
94. Oller I, Gernjak W, Maldonado MI, P'erez-Estrada LA, S'anchez-P'erez JA, Malato S. 2006. Solar photocatalytic degradation of some hazardous water-soluble pesticides at pilot-plant scale. J Hazard Mater B 138:507–517
95. Hermann JM. 1999. Heterogeneous photocatalysis: fundamentals and applications to the removal of various types of aqueous pollutants. Catal Today 53:115
96. Peral J, Domenech X, Ollis DF. 1997. Heterogeneous photocatalysis for purification, decontamination, and deodorization of air. J Chem Technol Biotechnol 70:117–140
97. Mills A, Punte L, Stephan M. 1997. An overview of semiconductor optocatalysis. J Photochem Photobiol A 108:1–35
98. Hornyak GL, Tibbals HF, Dutta J, Moore JJ. 2009. Introduction to nanoscience and nanotechnology. CRC Press, Taylor & Francis Group, FL
99. Hoet PHM, Brüske-Hohlfeld I, Salata OV. 2004. Nanoparticles: known and unknown health risks. J Nanobiotechnol 2:12.
100. Nemmar A, Vanbilloen H, Hoylaerts MF, Hoet PH, Verbruggen A, Nemery B. 2001. Passage of intratracheally instilled ultrafine particles from the lung into the systemic circulation in hamster. Am J Respir Crit Care Med 164:1665
101. Xiang JJ, Tang JQ, Zhu SG, Nie XM, Lu HB, Shen SR, Li XL, Tang K, Zhou M, Li GY 2003. IONP-PLL: a novel non-viral vector for efient gene delivery. J Gene Med 5:803
102. Brown DM, Donaldson K, Borm PJ, Schins RP, Dehnhardt M, Gilmour P, Jimenez LA, Stone V 2004. Calcium and ROS-mediated activation of transcription factors and TNF-alpha cytokine gene expression in macrophages exposed to ultrafine particles. Am J Physiol Lung Cell Mol Physiol 286:L344.
103. Zheng .M., Jagota A., Semke E.D., Diner. B.A., McleanR.S., Lustig, S.R., Richardson, R.E. & Tassi, N.G. 2003. DNA-assisted dispersion and separation of carbon nanotubes. Nature Materials 2, 338 – 342. doi:10.1038/nmat877.
104. Crane, RA. And Scott, TB. 2012. Nanoscale zero-valent iron: future prospects for an emerging water treatment technology. J Hazard Mater. 2012 Apr 15;211-212:112-25. doi: 10.1016/ j.jhazmat.2011.11.073. Epub 2011 Nov 28.
105. *U.S. EPA (2012-11-14).* "Nanotechnologies for environmental cleanup". Retrieved 2014-07-29.
106. U.S. EPA. Remediation: Selected Sites Using or Testing Nanoparticles for remedation". Retrieved 29.7. 2014
107. Theron, J.; Walker;J.A., Cloete,T.E. 2008. Nanotechnology and Water Treatment Applications and Emerging Opportunities." Critical Reviews in Microbiology 34 (1): 43–69. Doi: 10.1080/ 10408410701710442. ISSN 1040- 841X. retrieved 29.7. 2014.

108. Gomes, Helena I; Celia Dias-Ferreira; Alexandra B. Ribeiro. 2013. Overview of on sito and ex sito remediation technologies for PCB- contaminated soils and sediments and obstacles for full scale application"Science of the total Environment. 445 -446; 237-260. doi:10.1016/j.scitotenv. 2012.11.098. ISSN 0048- 9697, Retrieved 29.7.2014.

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