A Review on Chemical and Physical Synthesis Methods of Nanomaterials

T. Satyanarayana[1], S.Sudhakar Reddy[2]
[1,]Assistant Professor, Department of Physics, Sreyas Institute of Engineering & Technology, Hyderabad, Telangana, India.
[2]Associate Professor, Department Of Physics, Sreyas Institute of Engineering & Technology, Hyderabad, Telangana, India.

***Abstract:** Nanomaterials and Nanotechnologies attract tremendous attention in recent researches. The synthesis of nanoparticles is an active area of academic and, more significantly, applied research in nanotechnology. Materials scientists and engineers have made significant developments in the improvement of methods of synthesis of nanomaterials. In this review various methods of preparing nanomaterials including chemical methods like Chemical reduction method, Micro emulsion/colloidal method, Sono chemical method, Electrochemical method, Solvo thermal decomposition, and Physical methods like Pulse laser ablation, Mechanical/High ball milling method, ball milling method, Mechanical chemical synthesis, Pulsed wire discharge method are discussed in detail.*
***Keywords:** Nanomaterials, Nanotechnology, chemical methods, Physical methods.*

I. INTRODUCTION

Nanotechnology is the construction and utilization of functional structures designed from atomic/molecular scale and with at least one of its characteristic dimensions in nanometers [1]. Such materials and systems can be rationally designed to exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes because of their size. Typically the width of a human hair is 30 - 40 micrometer; one nanometer is 30,000th to 40,000th a hair width. Phenomena at the nanometer scale are likely to be a completely new world. Properties of matter at the nano-scale may not be predictable from those observed at larger scales[4]. Important changes in behavior are caused not only by continuous modification of characteristics with diminishing size, but also by the emergence of totally new phenomena such as quantum confinement, a typical example of which is that the color of light emitting from semiconductor nano-particles depends on their sizes[8]. Designed and controlled fabrication and integration of nano-materials and nano devices is likely to be a revolutionary for science and technology. Nanotechnology can provide unprecedented understanding about materials and devices, and is likely to impact many fields. By using structure at the nano-scale as a tunable physical variable, it is possible to greatly expand the range of performance of existing chemicals and materials.

II. SYNTHESIS METHODS OF NANO MATERIALS

In generally synthesis of nonmaterial's can be classified two types, 1.Bottom-up approach 2. Top-down approach. In bottom-up approaches include the miniaturization of materials components (up to atomic level) with further self-assembly process leading to the formation of nanostructures[6]. During self-assembly the physical forces operating at Nano scale are used to combine units into larger stable structures. Ex: quantum dot formation during of nanoparticles from colloidal dispersion. In top-down approaches use larger initial structures, which can be externally controlled in the processing of nanostructures. Ex: ball milling and plastic deformation.[3]

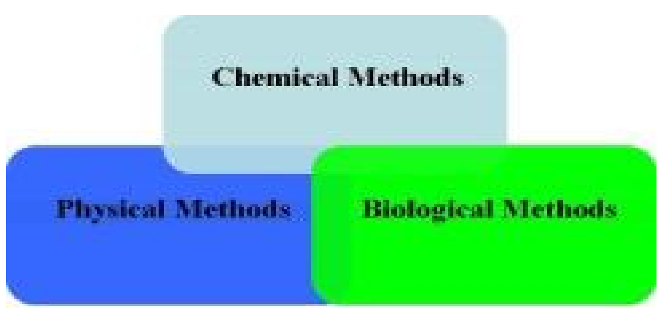

Fig-2.1: Synthesis methods of nano materials

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A. Chemical methods

1) *Chemical reduction method:*In 1857, Michael Faraday, for the first time reported a systematic study of the synthesis and colors of colloidal gold using chemical reduction route. The chemical reduction of copper salts is the easiest, simplest and the most commonly used synthetic method for copper nanoparticles. In fact, the production of nano sized metal copper particles with good control of morphologies and sizes using chemical reduction of copper salts can be achieved.[7]
2) Micro emulsion/colloidal method:In1943, Hiral et al. observed that an appropriate amount of water, oil, surfactant and an alcohol- or amine-based co-surfactant produced clear and homogeneous solutions that Hirai called Microemulsion. Microemulsion is a technique for the synthesis of nanoparticles in which two immiscible fluids such as water in oil (W/O) or oil in water (O/W) or water in supercritical carbon dioxide (W/Sc. CO2) become a thermodynamically stable dispersion with the aid of a surfactant. A typical emulsion is a single phase of three components, water, oil and a surfactant. Normally oil and water are immiscible but with the addition of a surfactant, the oil and water become miscible because the surfactant is able to bridge the interfacial tension between the two fluids. Microemulsion consists of surfactant aggregates that are in the ranges of 1 nm to 100 nm. The location of water, oil and surfactant phases affects the geometry of aggregate. The micro-emulsion is said to be oil in water (O/W) if water is the bulk fluid and oil is in less quantity, with small amounts of surfactant. Similarly, the system is said to be water in oil (W/O), if oil is the bulk fluid and water is present in less quantity. The product of oil in water and surfactant (O/W) is called micelles, which is an aggregate formed to reduce free energy. Hydrophobic surfactants in nanoscale oil and micelles point towards the center of aggregate, whereas the hydrophobic head groups towards water, the bulk solvent. The water in oil Microemulsion carries oil or organic solvent as bulk. The system is thermo dynamically stable and called reverse micelles.[7]
3) *Sonochemical method:* In the Sonochemical process, powerful ultrasound radiations (20 kHz to 10 MHz) were applied to molecules to enhance the chemical reaction. Acoustic cavitation is a physical phenomenon which is responsible for Sonochemical reaction. This method, initially proposed for the synthesis of iron nanoparticles, nowadays used to synthesize different metals and metal oxides. The main advantages of the Sonochemical method are its simplicity, operating conditions (ambient conditions) and easy control of the size of nanoparticles by using precursors with different concentrations in the solution. Ultrasound power affects the occurring chemical changes due to the cavitation phenomena involving the formation, growth and collapse of bubbles in liquid. The sonolysis technique involves passing sound waves of fixed frequency through a slurry or solution of carefully selected metal complex precursors. In a solvent with vapor pressure of a certain threshold, the alternating waves of expansion and compression cause cavities to form, grow and implode. Sonochemical reactions of volatile organometallics have been exploited as a general approach to the synthesis of various nano phase materials by changing the reaction medium. There are many theories presented by different researchers that have been developed to explain the mechanism of breakup of the chemical bond under 20 KHz ultrasonic radiations. They have explained the sonochemistry process in these theories i.e., how bubble creation, growth and its collapse is formed in the liquid. One of these theories explains the mechanism of breaking of a chemical bond during a bubble collapse. According to one of these theories, bubble collapse occurs at very high temperatures (5000K-25000 K) during the sonochemical process. Upon the collapse of the bubble, which occurs in less than a nanosecond, the system undergoes a very high cooling rate K/Sec. The organization and crystallization of nano -particles is hindered by this high cooling rate. The creation of amorphous particles is welled fined while the nano structured particles are not clear. The reaction will occur in a 200-nm ring surrounding the collapsing bubble if the precursor is a nonvolatile compound. The temperature of the bulk is lower compared to the ring, and temperature of collapsing bubble will be higher than the temperature of the ring. Sonoelectro chemical synthesis employs both electrolytes and ultra -sonic pulses for the production of nanoparticles.[9]

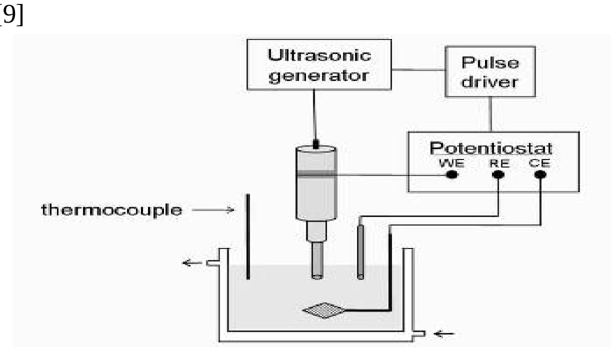

Fig-2.2: A schematic diagram of Sonochemical method.

4) *Electrochemical method:* In the electrochemical synthesis method for the production of nano particles, electricity is used as the driving or controlling force. Electrochemical synthesis is achieved by passing an electric current between two electrodes separated by anelectrolyte. That is, the synthesis takes place at the electrode-electrolyte interface. The main advantages of electro chemical techniques include avoidance of vacuum systems as used in physical techniques, low costs, simple operation, high flexibility, easy availability of equipment and instruments, less contamination (pure product) and environment-friendly process (eco-friendly).Much research work has been done on the electrochemical technique in advancing the basic understanding and industrial applications, but still many aspects of this technique are under study.[10]
5) *Solvothermal decomposition:* In the Solvothermal processes, the chemical reaction takes place in a sealed vessel such as bomb or autoclave, where solvents are brought to temperatures well above their boiling points. When water is used as solvent, it is called a hydrothermal process. There are many advantages in using super critical conditions such as, simplicity, very low grain size, presence of a single phase and synthesis of high purity nanocrystals with high crystallinity and eco friendliness nature.[5]

B. Physical methods

1) *Pulse laser ablation:* In this technique, a high-power pulsed laser beam is focused inside a vacuum chamber to strike a target in the material and plasma is created, which is then converted into a colloidal solution of nanoparticles. Mostly Second Harmonic Generation (ND: YAG) type Laser is being used to prepare the nanoparticles. There are many factors that affect the final product such as the type of laser, number of pulses, pulsing time and type of solvent.

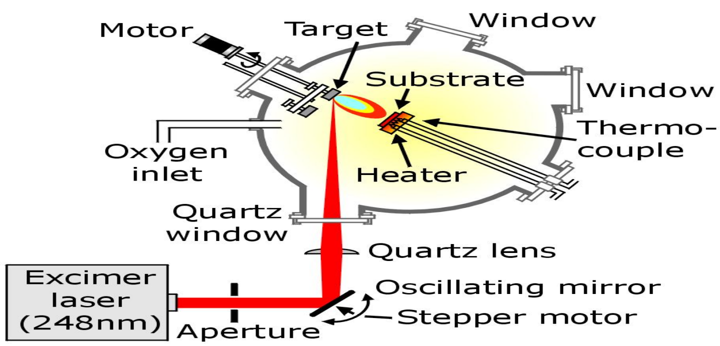

Fig-2.3: A schematic diagram of Pulse laser ablation

2) *Mechanical/High ball milling method***:** Milling is a solid state processing technique for the synthesis of nanoparticles. This technique was first used by Benjamin for the production of super alloys. In the milling process, raw material of micron size is fed to undergo several changes. Different types of mechanical mills are available which are commonly used for the synthesis of nanoparticles. These mills are categorized according to their capacities and applications. Due to mechanical limitations, it is very difficult to produce ultra-fine particles using these techniques or it takes very long time. However, simple operation, low cost of production of nanoparticles and the possibility to scale it to produce large quantities are the main advantages of mechanical milling.136 The important factors affecting the quality of the final product are the type of mill, milling speed, container, time, temperature, atmosphere, size and size distribution of the grinding medium, process control agent, weight ratio of ball to powder and extent of filling the vial.

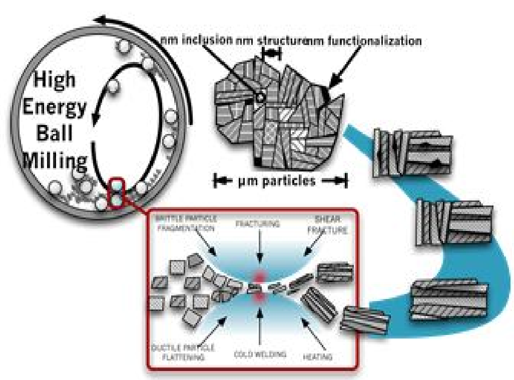

Fig-2.4: A schematic High ball milling method.

3) *Mechanical chemical synthesis***:** In this process, chemical reaction is induced by mechanical energy. The chemical forerunners are mostly a mixture of chlorides, oxides and/or metals that react during milling or subsequent heat treatment to produce a composite powder in which ultrafine particles in a stable salt matrix are dispersed. These ultrafine particles are recovered by washing with suitable solvent from selective removal of the matrix. [6]

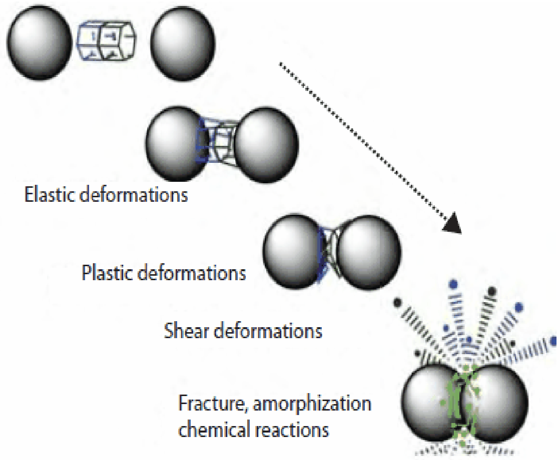

Fig-2.5**:** Deformations in the material trapped between two colliding balls during ball milling.

4) *Pulsed wire discharge method:* Pulsed wire discharge (PWD) is a physical technique to prepare nanoparticles. Compared to all the other previously mentioned methods, metal nanoparticles synthesis by the PWD technique follows a completely different mechanism. In PWD, a metal wire is evaporated by a pulsed current to produce a vapor, which is then cooled by an ambient gas to form nanoparticles. Preparations of metal, oxide and nitride nanoparticles by PWD has been reported this method have potentially a high production rate and high energy efficiency

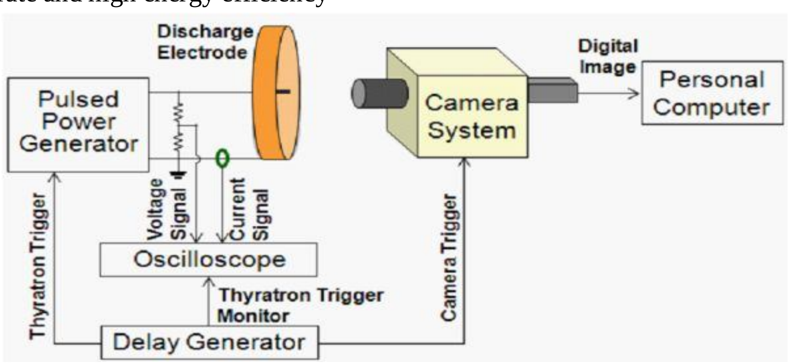

Fig-2.6: A schematic diagram of Pulsed wire discharge

This process is not used conventionally for common industrial purposes because it is not only very expensive but also impossible to use explicitly for different metals. It is mainly useful for those metals of high electrical conductivity that are easily available in the thin wire form.[9]

III. CONCLUSION

Nanotechnology could impact the production of virtually every human made object from automobiles, electronics, advanced diagnostics and surgery, to advanced medicines and tissue/bone replacements. If, for example we like to build electronic devices using the atom-by-atom engineering, we have to understand the interaction among atoms/molecules, how to manipulate them, how to keep them stable, how to communicate signals among them, and how to face them with the real world. This goal requires new knowledge, new tools and new approaches. The nanometer scale is conventionally defined as 1 to 100 nm. One nanometer is one billionth of a meter (10-9). The size range is set normally to be minimum 1 nm to avoid single atom or very small groups of atom being designated as nano objects. Therefore nano-science and nanotechnologies deal with at least clusters of atoms of 1nm size. The upper limit is normally 100 nm, but this is a “fluid” limit; often objects with greater dimensions (even 200 nm) are defined as nanomaterials. Nano-science is the study of materials that exhibit remarkable properties, functionality and phenomena due to the influence of small dimensions. Today's nanotechnology harnesses current progress in chemistry, physics, material science, biotechnology and electronics to create novel materials that have unique properties because their structures are determined on the nanometer scale. Some of these materials have already found their ways into consumer products, such as sun screens and stain resistant plants. Others are being intensively researched for solutions to humanity's greatest problems diseases, clean energy, clean water, etc. The products of advanced nanotechnology that will become available in coming decades promise even more revolutionary applications than the products of current and near-term nanotechnology.

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