International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 12 Dec 2021, pp: 812-816 www.ijaem.net ISSN: 2395-5252

Physical Methods of Nanoparticles Preparation – An Overview

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Submitted: 01-12-2021 Revised: 11-12-2021 Accepted: 14-12-2021

ABSTRACT: Nanotechnology and Nanoparticles have brought a revolution in material science. The properties specially volume changes dramatically at nanoscale (below 100nm). Researchers in various fields like physics, chemistry, material science, and engineering are eagerly working on nanomaterials because of their lot of current and futuristic applications. The use nanoparticles to produce nanocomposites with other suitable materials opened a new window. Synthesis of nanoparticles may be physical or chemical and top-down or bottom-top. Significant improvements were made in synthetic methods of nanoparticles in last couple of decades. In this review various physical methods for preparation of nanoparticles including Sputtering Method, Plasma Method, Pulsed Laser Ablation Method, Mechanical, Exploision and nanolithographic techniques are discussed.
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KEYWORDS: Nanotechnology, nanoparticles, nanomaterials, nanocomposites, plasma, laser, physical methods.

I. INTRODUCTION

A lot of research has been carried in last couple of decades to develop advanced methods for nanoparticles preparation. The properties of nanoparticles are determined by their mean diameter, coefficient of polydispersity and standard deviation. The important properties of nanoparticles viz. size, physical and chemical properties are dependent on growth mechanism. The growth mechanism of nanoparticles preparation is complex and dependant on viscosity, concentration of medium and temperature, etc. There are two main approaches have been used so far for preparation of nanoparticles viz. bottom-up and top-down. The Bottom-up approach is the method involves aggregation of material from smaller level: atom or molecule to cluster with much better particle size control. While the Top-down approach involves disintegration of material from bigger level but comparatively less control over particle size. A brief overview is given in this article.

II. PHYSICAL METHODS FOR NANOPARTICLES PREPARATION

1. **Thermal Evaporation-Condensation:-** It is top-down method which for used for synthesis metal and alloy nanoparticles. This was very fist technique used for synthesis of nanoparticles which involves thermal evaporation of target material in electron beam evaporation devices or Joule heated refractory crucibles at 1-50 m bar pressure (Fig.1). Ultra-fine nanoparticles are formed due to gas phase collision and nucleation (condensation) at high residual pressure. The problem associated with these techniques is non-uniform heating resulting inhomogeneous nanoparticles[1].
2. **Microwave/ Gamma irradiation**:-In this technique microwave radiations are used for heating and evaporation the target material. The microwave/ gamma radiations provide uniform heating without heating the environment and produces homogeneous nanoparticles. Hasanpoor et al. studied synthesis zinc oxide (ZnO) using microwave irradiation. They investigated effect of microwave irradiation power, time and type precursor on structure of ZnO and correlated these parameters. The change in structure of nanoparticles by replacing zinc nitrate with zinc acetate was also studied[2].

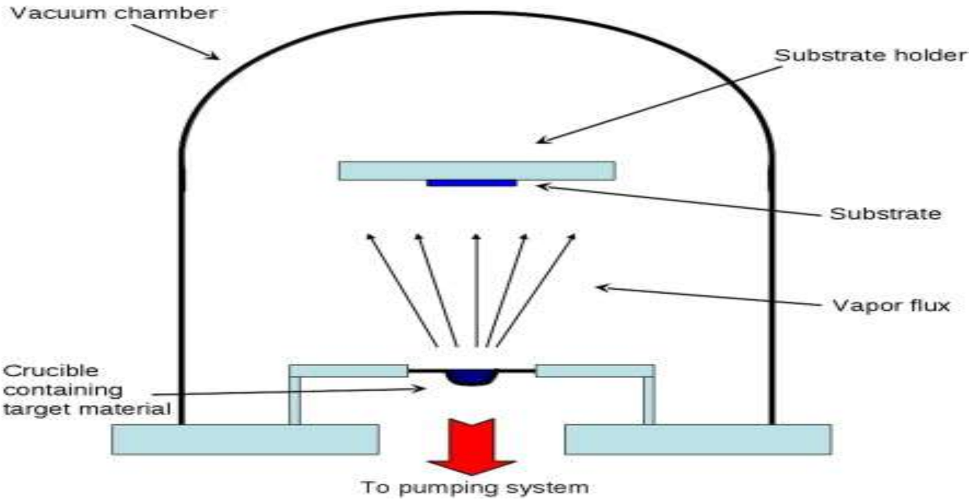

Fig. 1 Schematic diagram of Thermal evaporation - condensation for the synthesis of nanoparticles[3]

3. Sputtering:- This is a top-down process of nanoparticles synthesis in which a solid surface is bombarded with high energy particles (Argon ions) resulting in surface erosion of the solid surface with formation of atoms due to collision of energetic particles and the solid surface (Fig. 2).

Mechanism of Sputtering:-
It Can be well understood by two theoretical models:
(i) According to thermal vaporization theory it is the heat of bombardment of high energy particles that cause vaporization of the solid surface.
(ii) The momentum-transfer theory believes in transferring of the kinetic energy/ momentum of high energy particles to the atoms of solid surface.

Factors influencing sputtering:-
(i) Energy of the bombarded ions or particles.
(ii) Type of the target surface.
(iii) Angle of reflection of particles incident.
(iv) Crystal structure of solid surface.

Types of sputtering:- Its mainly of three types:

(i) DC diode sputtering.
(ii) RF radio sputtering.
(iii) Magnetron sputtering

P.Ayyub et al. studied synthesis metal and metal oxide nanoparticles of TiO2, ZnO, γ -Al_2O_3, Cu_2O, Ag and Cu. They investigated that mean particle size and crystallographic orientation are influenced mainly by the sputtering power, the substrate temperature and the nature, pressure and flow rate of the sputtering gas[4].

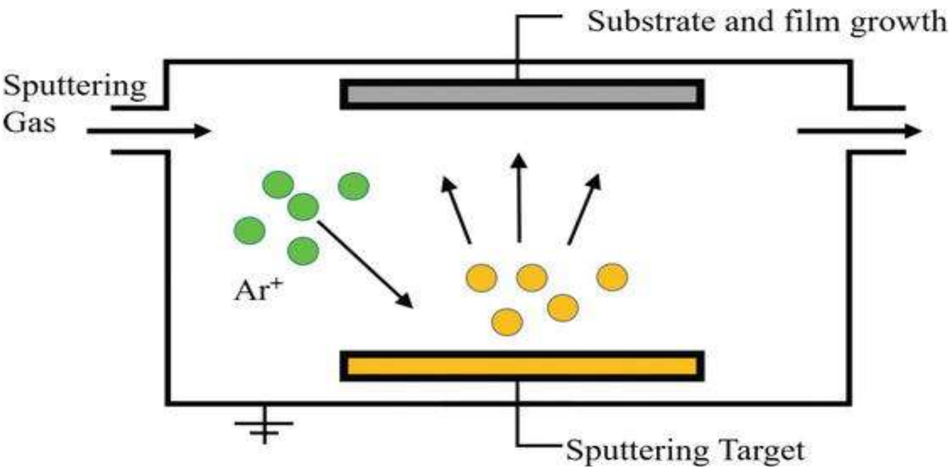

Fig. 2 Schematic diagram magnetron sputtering used for the synthesis of nanoparticles[5]

4. Plasma Method:- It is very effective bottom-up approach to prepare nanoparticles. This involves heating of metal in evacuated chamber above its evaporation temperature using high high-temperature plasma. The high-temperature plasma is produced by heating of Helium (He) gas using heating coils operated at radio frequency (RF). The vapor of the metal nucleates on to the helium atoms and gets collected on the cold collector rod and passivated by oxygen (Fig. 3). Shuaib et al. prepared silver nanoparticles by using argon gas (Ar) at atmospheric pressure with DC microplasma technique. They investigated role of fructose molar concentration in the size of nanoparticles and found 2 mM as optimum concentration for silver nanoparticles in the range '50 ± 10 nm'[6].

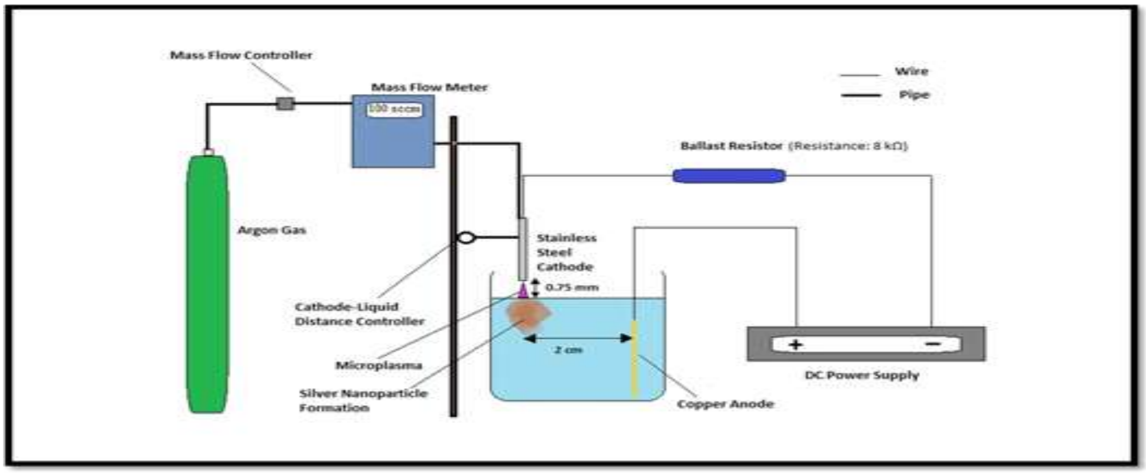

Fig. 3 Schematic diagram (not to scale) of a microplasma setup for silver nanoparticles synthesis[6].

5. Pulsed Laser Ablation (PLA) Method:- In this bottom-up method a pulsed laser beam is focused on the target material to ablate nanoparticles (Fif. 4). The properties of nanoparticles dependant on laser parameters like wavelength, pulse duration, flounce, and repetition rate and material properties etc. The rate of ablation Increases with increase in laser energy. The advantages of PLA over the other methods are: simple and safe techniques, wide range of target materials, can be carried out at room temperature, no chemical solution required, nanoparticles with complicated stoichiometry, high purity and narrower particle can be produced. The only disadvantage of PLA is its high cost. M. Ganjali et al. synthesized Ni nanoparticles by Pulsed Laser Ablation (PLA) Method in liquid phase. They usedA simple fiber pulsed laser setup to reduce the micron Ni particles to nano-si

6. zed by the PLA method with free additive in liquid and without oxidation at room temperature[7]

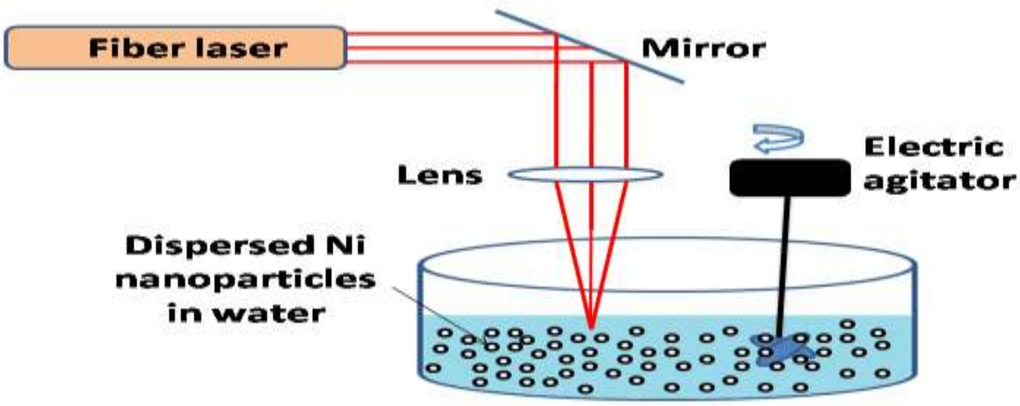

Fig. 4 Schematic diagram of synthesis of Ni Nanoparticles by Pulsed Laser Ablation Method in Liquid Phase[7].

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7. Mechanical (Ball milling) Method:- It is a top-down approach for preparation of nanoparticles by applying mechanical energy. This involves crushing of solid materials using hardened steel, silicon carbide (SiC) or tungsten carbide (WC) balls in stainless steel container (Fig. 5). The crushing is carried out for 100 to 150 hours to get uniform powder. This method is easy, inexpensive and produces nanoparticles of 2-20 nm range but at the same time problems like control on shape and purity is lacking[8].

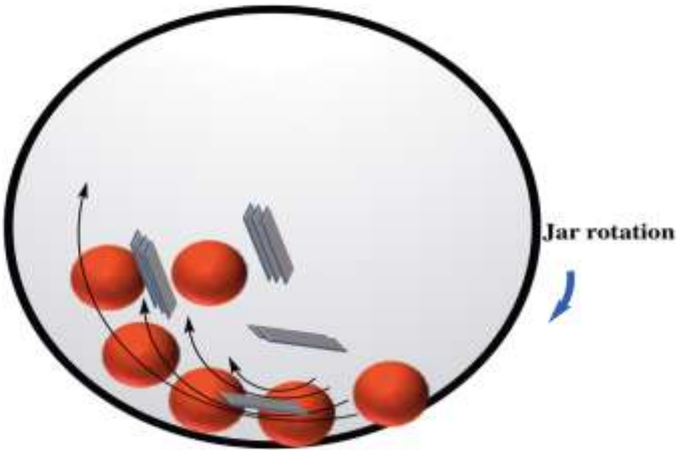

Fig. 5 Schematic diagram of synthesis of grapheme Nanoparticles by Ball Milling Method inLiquid Phase[8].

8. Nanolithographic Method:- Nanolithography is a top-down nanoparticles preparatory technique supplemented with thin film deposition, self-assembly and self-organization techniques (Fig. 6). In this process a tightly focused beam (ions, electron and light) is focused on the target surface to produce nanoparticles[9]. There any many types of nanolithographic techniques depending on the type of beam used:

(i) Electron beam lithography
(ii) Ion beam lithography
(iii) Ion track lithography
(iv) x-ray lithography
(v) Nanoimprint lithography
(vi) Extreme ultraviolet lithography

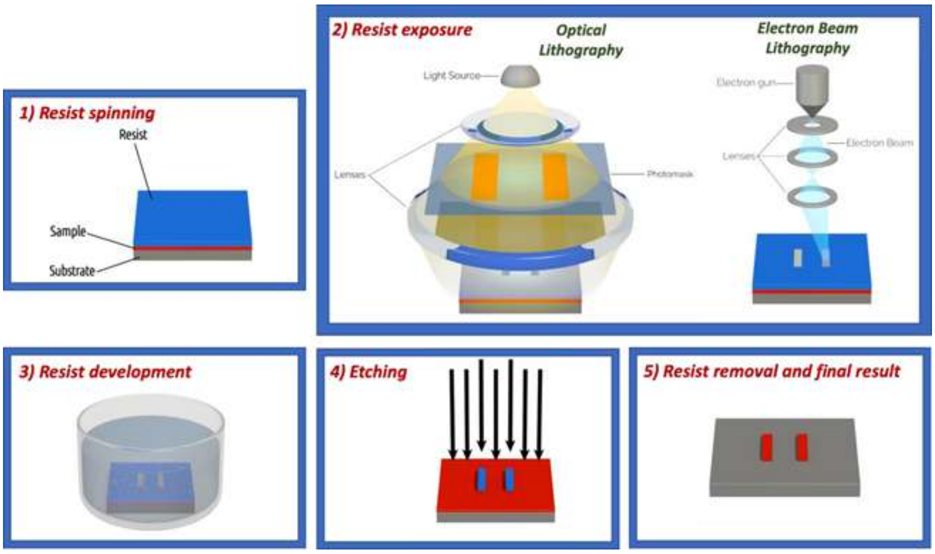

Fig. 6 Various steps commonly performed in optical and electron beam lithography techniques: resist coating (1), resist exposure (2), resist development (3), sample etching (4) and resist removal with the final result (5)[9].

9. Wire explosion Method:- It is a top-down nanoparticles preparatory technique based on Joule's heating effect. A high power current is passed through the metallic wire which in turn disintegrates the wire and generates nanoparticles[10]. Sindu et al. prepared aluminium nanopowder in nitrogen, argon and helium atmosphere using wire explosion method[11].

III. CONCLUSION

The nanoparticles have attracted researchers due to their unique physical, chemical properties and diverse applications. Many physical methods for preparation of nanoparticles in different sizes and shape have been developed so far. The methods such as Thermal, Microwave/ gamma irradiation, sputtering, plasma, pulsed laser ablation, mechanical, lithographic and wire explosion techniques are very common physical techniques for preparation of nanoparticles. The advantage with physical methods is low cost but at the same time lack of control over particle size in the problem.

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