# Review on synthesis Techniques of Nanocrystalline materials

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**Abstract: In this review paper I have discussed about the preparation techniques of nanocrystalline materials using single source precursor method, sonochemical method, solid state reaction method, solvothermal method, microwave irradiation method techniques. With the help of these techniques we will study the characteristics of the material.**

**Keywords: Nanocrystalline, single source, sonochemical, solvothermal**

## I. INTRODUCTION

Nanocrystalline semiconductors materials have been synthesized by different techniques such as thermolysis of single source precursor [1], sonochemical [2], solid state reactions [3], solvothermal [4] microwave irradiation method [5] and having lot of attention from inventors in different streams. Nanowires and nanorods are also one dimensional nanostructures and have been studied because they have their unique properties and strong potential applications, some of them are used in optoelectronic devices [6], sensors [7], solar cells [8], photocatalysis [9]. Nanocrystalline semiconductors structures are compounds of elements in II-VI, II-V and IV-VI. By the help of rapid solidification[10], chemical vapour deposition [11], chemical precipitation [12] and high energy ball milling 13[] and many other synthesis methods of nanocrystalline materials is discussed.

**Single source precursor method for synthesis of nanocrystalline semiconductors materials:** Single source precursor method is best approach for synthesizing nanocrystalline semiconductors materials and offers several advantages. In this method the synthesis process generally involves following steps:

**1. Precursor design:** It contains the required semiconductor elements in a single molecule and it is deposited onto substrate**.**

**2. Deposition:** For the deposition of precursor onto substrate, are some techniques such as atomic layer deposition, chemical vapour deposition and solution method.

**3. Thermal Method:** Thermal decomposition or annealing of the deposited precursor to induce crystallization and phase transformation, resulting in the formation of nanocrystalline semiconductor materials.

**Sonochemical method for synthesis of nanocrystalline semiconductors materials:** The sonochemical method for synthesizing nanocrystalline semiconductor materials typically involves the following steps:

**1. Preparation of Precursor solution:** Dissolve the precursor compounds (metals, salts or organometallic compounds) in a suitable solvent. The choice of solvent depends on the properties of the precursors and the desired properties of the final nanoparticles.

**2. Introduction of sonication:** Place the precursor solution in a reaction vessel equipped with an ultrasonic probe or bath. Apply high frequency sound waves to the solution using the sonication equipment.

**3. Cavitation:** The ultrasonic waves cause cavitation, where small bubbles form and rapidly collapse in the solution. During collapse, localized hotspots of high temperature and pressure are generated.

**4. Nucleation and Growth:** The extreme conditions created by cavitation promote nucleation, where atoms of molecules aggregate to form tiny nanocrystals. These nanocrystals then grow through the addition of precursor species onto their surfaces.

**5. Control of Reaction Parameters:** Adjust the reaction parameters such as temperature, pressure, sonication intensity and reaction time to control the size, shape and properties of the nanoparticles. Fine tuning these parameters allows for precise control over the synthesis process.

**6. Product separation and Purification:** After the synthesis is complete, separate the nanocrystalline semiconductor nanomaterials from the solvent. Purification steps such as washing and centrifugation may be necessary to remove any residual impurities or unreacted precursors.

The sonochemical method involves the use of high intensity ultrasound waves to induce chemical reactions in a solution. In the synthesis of nanocrystalline semiconductor materials, this method is used when the precursor of desired semiconductor material is with solution containing

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precursors. When ultrasound waves are applied to the solution, they create cavitation bubbles due to the rapid changes in the pressure and temperature. This phenomenon leads to the formation of highly reactive species such as free radicals, ions and electrons.

The reactive species facilitate the nucleation and growth of semiconductor nanocrystals from the precursor solution. The size, shape and properties of the resulting nanocrystals can be controlled by adjusting parameters such as ultrasound intensity, frequency, duration and precursor concentration.

The sonochemical method offers advantages such as relatively low processing temperatures, shorter reaction times and ability to produce nanocrystalline semiconductor materials with well defined characteristics.

**Solid state reaction method for synthesis of nanocrystalline semiconductors materials:** Solid state reaction method is a common approach for synthesizing nanocrystalline semiconductors materials. It involves the direct reaction of solid precursor materials at elevated temperatures to form the desired product. Here is a detailed explanation of the process.

**1. Selection of Precursor Materials:** The first step involves selecting appropriate precursor materials typical metal or semiconductor oxides, salts or other compounds which react to form the desired semiconductor compound. The choice of precursor materials depends on the specific semiconductor being synthesized.

**2. Grinding or Mixing:** The precursor materials are usually ground or mixed together to ensure intimate contact homogeneity of the reactants. This step is crucial for promoting the reaction kinetics by increasing the surface area available for the reaction.

**3. Heating:** The mixed precursor powders are then subjected to high temperatures in a controlled atmosphere to initiate the solid state reaction. The temperature and duration of heating are critical parameters that influence the phase purity, crystallinity and size of the resulting nanocrystalline semiconductor.

**4. Reaction Mechanism:** During heating, the solid state diffusion of atoms or ions occurs between the precursor materials, leading to the formation of intermediate phases and eventually the desired nanocrystalline semiconductor compound. The reaction kinetics are influenced by factors such as temperature, pressure, particle size, and chemical composition.

**5. Annealing:** After the completion of the reaction, the resulting product is often subjected to an annealing step at a lower temperature to enhance crystallinity, remove defects, and optimize the physical properties of the nanocrystalline semiconductor.

**Solvothermal method for synthesis of nanocrystalline semiconductors materials:** The Solvothermal method for synthesizing nanocrystalline semiconductors materials typically involves the following steps:

**1. Preparation of Precursors:** Start with precursors which are usually metal salts or metal-organic compounds containing the elements required for the semiconductor material.

**2. Solvent Selection:** Choose a suitable solvent or solvent mixture that can dissolve both the precursors and any ligands attached to them. Common solvents include organic solvents like ethanol, methanol or water.

**3. Mixing:** Dissolve the precursors in the chosen solvent to form a homogeneous solution. The concentration of precursors and solvent plays a crucial role in controlling the size, shape and properties of the resulting nanocrystals.

**4. Reactor Setup:** Transfer the solution into a high pressure reactor, typically made of stainless steel of Teflon lined autoclaves, capable of withstanding elevated temperatures and pressures.

**5. Heating:** Heat the reactor to a specific temperature typically ranging from $100^0$C to $300^0$C, depending on the desired semiconductor material and its synthesis conditions. The elevated temperature accelerates the reaction kinetics.

**6. Pressurization:** Increase the pressure inside the reactor to supercritical or near supercritical conditions. The elevated pressure helps to dissolve the precursors more effectively and promotes the nucleation and growth of nanocrystals.

**7. Reaction Time:** Maintain the reaction conditions temperature, pressure for a certain period, allowing the nucleation and growth of nanocrystals to occur. The duration of the reaction can range from hours to days, depending on the desired size and properties of the nanocrystals.

**8. Cooling:** After the desired reaction time, cool the reactor gradually to room temperature to prevent rapid changes in pressure, which could lead to unwanted side reactions or phase transformations.

**9. Isolation:** Remove the nanocrystals from the solvent using techniques such as centrifugation, filteration or precipitation. Wash the nanocrystals with appropriate solvents to remove any residual impurities or ligands.

**10. Drying:** Dry the isolated nanocrystals under vaccum or in an inert atmosphere to remove any remaining solvent and ensure the stability of the nanocrystal product.

## II. CONCLUSION

In this paper I discussed about the different types of synthesis techniques for the preparation of nanocrystalline materials. Some of them, I have discussed thermolysis,

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sonochemical, solid state reactions, solvothermal microwave irradiation method. After this, researchers will study the growth of nanoparticles with size and shape.

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