Research Article

Application of Polymer Nanocolloid Preparation in Stability Analysis of Motion Mechanics

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Nanomaterials are widely used in various fields because of their own advantages. When the particle size of the material is reduced to the nanometer level, it will lead to new characteristics of acoustic, optical, electrical, magnetic, and thermal properties. This will greatly enrich the research content of the material and is expected to get new uses. Therefore, the preparation technology of nanomaterials is one of the current research hotspots and has broad application prospects. At present, the most commonly used preparation techniques are hydrothermal method and sol-gel method, but not all crystals grow in a hydrothermal environment, so this paper adopts the sol-gel method for preparation. However, in the preparation of nanocolloids, agglomeration often occurs between colloidal nanoparticles. In order to avoid the agglomeration between particles, this paper adopts an appropriate method to disperse the particles. In order to further explore the stability of nanocolloids, the colloidal film material prepared by the cadmium sulfide (CdS) sol method was used as the research sample. It also proposes a sol preparation method incorporating ultrasonic waves and further discusses the kinetic characteristics. The research results show that the sedimentation velocity of 1 nm cadmium sulfide nanocolloids in water is $1.3 \times 10^{-12}$ (m/s) prepared by colloid of cadmium sulfide.

1. Introduction

Nanomaterials are used in various fields due to their superior material properties. For example, due to their small size and light weight, it is possible to manufacture small and lightweight storage components with a capacity of 1000 GB. Nanomaterials also have potential applications in the field of fire protection. Scientists have discovered that certain nanomaterials have the ability to stop burning. For example, they can be added to combustible materials as flame retardants to alter their flammability and make them fire-resistant. On the basis of further research on nanomaterials, the colloidal field of their dispersion system is being explored. In this paper, cadmium sulfide, a II–VI compound, was used as a sample to study its properties. It is one of the most popular optoelectronic functional materials and the first choice of many researchers. As a wet chemical synthesis method, it has the advantages of simple equipment, easy process control, high powder purity and uniformity, low cost, and others. It has great advantages in the preparation of coatings and coating complex shape parts. In this paper, the agglomeration phenomenon between particles is treated by ultrasonic wave. The nanocolloids were then prepared using a sol-gel method, and further film deposition was performed. Various influencing factors and the dynamic stability of colloids under ultrasonic frequency were discussed. The research results will help people to understand the stability of nanocolloids from qualitative and quantitative levels. They help to artificially control the stability of nanocolloids to a certain extent.

Nanomaterials are not only new materials but also important raw materials for new materials. At present, the preparation technology and application of nanomaterials are examples of the hotspots in nanomaterials research. The development of nanomaterials is very important for people to further understand the properties and structures of solid
materials. Cadmium sulfide is widely used as an optoelectronic information material. The research on cadmium sulfide is of great significance to the development of optoelectronic applications.

The main point of this paper is that, on the basis of the sol-gel method to prepare nanocolloids, the ultrasonic frequency method is proposed to further solve the agglomeration of nanoparticles during the preparation of colloids. In this paper, cadmium sulfide is used as the research sample to illustrate the stability of its prepared colloid. It also applies and details the unique cavitation effects of ultrasonic irradiation.

2. Related Work

In recent years, scientists from all over the world have regarded the development and research of nanomaterials as a new material field that focuses on development. They conducted research on related application fields of nanomaterials. Among them, Tseng et al. prepared copper nanocolloids (CuNCs) by electrical spark discharge in deionized water at room temperature and pressure using a discharge machine. The zeta potential of CuNCs was 12.3 mV, indicating poor suspension stability. The PVA-containing CuNCs PVA/CuNCs were formed by adding polyvinyl alcohol (PVA), which effectively improved the suspension stability (zeta potential of 32.5 mV). When $T_{on}$: $T_{off}$ is set to 30:30 s, the preparation efficiency is the best, and the suspension stability is also the best [1]. Loan et al. investigated the cellular effects of platinum nanoparticles (PtNP) and platinum nanocolloids (PtNC) on mouse leukemia Raw 264.7 cells. PtNP produced a strong cytotoxic effect on Raw 264.7 cells, while PtNC showed only mild cytotoxicity. The data suggest that the preparation method of platinum nanoparticles may have different cellular effects on cell growth and signaling [2]. Kato et al. demonstrated significant stability in electrolytically generated hydrogen (dissolved hydrogen: 0.575 mg/L) water by HPLC-coulometric ECD analysis. However, there was almost no hydrogen in sparkling water, magnesium rod-derived hydrogen water, or tap water. This suggests that hydrogen-rich water inhibits the oxidative decomposition of Asc [3]. In the case of Ceokar-2, BAU-A activated carbon, alumina, and NaX zeolite supported nickel nanoparticles; Popov et al. performed gas phase hydrogenation of cyclic olefins. It is carried out at 140–240°C and hydrogen atmosphere. Conversion and selectivity are dependent on the type of support and hydrogen excess [4]. Tseng et al. used electrical discharge machining (EDM), submerged arc discharge method (SADM), and arc concentrated energy to ionize deionized water media. It prepares nanosilver colloid (Nh$_3$-Ag) which is different from the former. The process produces no chemical by-products. It has the characteristics of simple process and fast and green preparation. Comparing the nano-Ag colloids derived from Nh$_3$-Ag with the nano-Ag colloids derived from Ag, the Nh$_3$-Ag particles have good stability, and the concentration and zeta potential are both improved [5]. Haque et al. used sodium borohydride to chemically reduce silver nitrate in water and organic solvents to obtain colloidal silver nanoparticles. The effects of oxidizing agents, reducing agents, stabilizers, and temperature on the growth of silver nanoparticles are discussed. In water and organic solvents, the rate of change of Ag$^+$ ions to Ag0 is strongly temperature-dependent, although reduction can occur at room temperature. Silver nanocolloids with negative zeta potential have also been shown to be more stable [6]. The atomic stick-slip mode is easily observed in experiments. The traditional description of atomic-scale friction in terms of mechanical stick-slip instability (Prandtl-Tomlinson model) seems to be so successful that it masks the actual mechanism of energy dissipation. Krylov et al. showed that the traditional model fails completely. Because it can only explain the atomic resolution of the surface force map, the dissipative force is much higher than expected for sliding nanocontacts [7]. The research of the above scholars covers a wide range. Although they are all the results of the exploration of nanomaterials, due to the wide application of nanomaterials and the different selection of materials, they are less instructive to this paper.

3. Preparation Method of Nanocolloids

3.1. Stability Issues. For the preparation and application of nanomaterials, the stability of nanocolloids has a great influence on them. Unstable nanoparticles will affect the application and fabrication of materials [8]:

1. In the preparation of nanomaterials by chemical precipitation, powered nanoparticles are obtained by precipitating insoluble substances produced by chemical reactions and removing the solvent [9]. During this process, nanoscale insoluble materials are suspended in the solvent and precipitated. In particular, the sedimentation rate of nanoparticles has a great influence on the production efficiency [10].

2. The preparation of nanoparticles by the sol-gel method requires the preparation of stable nanosols. The unstable nanocolloids have a great influence on the uniformity of nanoparticles [11].

3. In the field of nanofilm electrodeposition and nanomicrocomposite electroplating, colloidal stability is more important to process stability [12].

4. Nanoparticles in the electric field are affected by both gravitational and electrostatic forces. The diversity of components in the dispersion system affects the stability of colloids [13].

3.2. Overview of the Advantages and Disadvantages of the Sol-Gel Method

1. The sol-gel method, which has developed rapidly in recent years, has many unique advantages compared with other methods:

1. In the sol-gel method, the carcass material is dispersed in a solvent before the reaction to form a low viscosity solution. This enables the reactants to be homogeneously mixed with each
other at the molecular level, obtaining a homogeneous state in a very short time [14].

(2) The sol-gel method should allow easy addition of trace elements, because the ratios in the reactants are easy to adjust, and doping should be done at the molecular level, because the reaction is reflected in solution [15].

(3) Most of the ceramic powders produced by the solid phase method are micron. The sol-gel method does not require high sintering temperature when producing nanopowders, so it is possible to obtain nanoscale powders [16].

(4) The equipment is simple, the cost is low, and the impact on the environment is small.

(2) Of course, the sol-gel method itself has its shortcomings, which hinder its development:

(1) In the preparation cycle of sol-gel, a long aging time of several days to several weeks is required [17].

(2) During the drying process, a large number of micropores are formed in the gel, allowing a large amount of gas and organic matter to escape and shrink [18].

(3) Many solvents added are toxic and may be harmful to human health and the environment [19].

(4) Metal alkoxides are difficult to prepare. They are expensive and have a high impact on the environment, which does not lead to a reduction in production costs [20].

3.3. Application of Sol-Gel Method. Figure 1 shows a schematic diagram of the whole process of the sol-gel method. The sol-gel method is widely used, and its application fields are sorted as follows:

(1) Bulk Material. The bulk material produced by the sol-gel method is a crack-free product. There are various shapes at every size scale above 1 nm. Bulk materials made in this way form a variety of complex shapes and feature densification at lower temperatures. At present, they are mainly used in the manufacture of optical lenses, refractive index graded glass, and transparent foamed glass [21].

(2) In fiber materials, molecular precursors chemically react to form linear inorganic polymers. During the linear joining process, the gel fibers can be pulled from the gel by means of pick-up or leakage as the viscosity of the system increases [22].

(3) The preparation of coatings and film materials is the most promising application direction of the sol-gel method. The preparation process is based on the dipping method or the rotating disk method. A liquid film is formed on a substrate, which is then converted into an amorphous film or coating by heat treatment. This method is currently being used to obtain various materials with special properties that the substrate does not have originally, such as antireflection films, waveguide films, color films, and photosensitive films [23].

(4) Ultrafine Powder. When the precursors of the desired components are prepared in a mixed solution by the sol-gel method and gelation and heat treatment are performed, powders with good performance indices are generally obtained [24].

(5) The composite material was prepared by sol-gel method. The functional organic substances such as additives are uniformly dispersed in the gel matrix. This uniform dispersion can be maintained even after heat-treatment densification, thereby better exhibiting their properties as composites. Since the
dopants can be varied, reinforced composites can be
prepared [25].

4. Preparation Experiment of Nanocolloids

Cadmium sulfide (CdS) was the experimental target of this
study. Because its transmittance to visible light is very high,
nanofilms using cadmium sulfide by sol-gel method are the
research object of this paper, in order to further solve a
common problem in the preparation of nanocolloids, that is,
the phenomenon of interparticle aggregation. In this paper,
nanocolloids were prepared by applying their unique cav-
itation dispersion and ultrasonic irradiation to a sol-gel
process. The process flow of the nanofilm is shown in
Figure 2.

4.1. Experimental Materials. The raw materials used in the
experiment are shown in Table 1.

| Material          | Cadmium nitrate | Sodium sulfide |
|-------------------|-----------------|----------------|
| Molecular formula | CdNO₃           | Na₂S₉H₂O       |
| Specification     | Analytically pure | Analytically pure |
| Dosage            | 3.2             | 4.8            |

\[ T_{\text{max}} = T_{\text{min}} \left( \frac{Y_p (a-1)}{V_p} \right), \quad P_{\text{max}} = V_p \left[ \frac{Y_p (a-1)}{V_p} \right]^{a/(a+1)} \]  

(1)

Here, \( T_{\text{min}} \) represents the ambient temperature, \( Y_p \) is the force outside the bubble, \( V_p \) is the vapor pressure in the
cavitation bubble, and \( a \) is the specific heat ratio of the
steam. The maximum temperature and maximum pressure
during the collapse time of the transient cavitation bubble
can be estimated by the above two formulas.

4.2. Theoretical Basis of Ultrasound in the Preparation of
Nanocolloids. Cavitation is the effect of high temperature,
high pressure, discharge, luminescence, shock wave, and so
forth, which are caused by the collapse of holes formed in the
liquid.

4.2.1. Cavitation Formation Process. The cavitation process
in liquids can be roughly divided into three stages: nucle-
ation, bubble growth, and detonation under appropriate
conditions. In the case of high-intensity ultrasound, small
cavitation bubbles can grow rapidly due to the inertial effect
of vibration. When the sound wave reaches positive pres-
sure, the bubbles remain inflated and have no time to
contract. When the pressure is negative again, they expand
further. But a strong collapse occurred during the final
positive pressure stage, causing them to collapse into a
cluster of very small bubbles. This condition is called
transient cavitation.

The maximum temperature \( (T_{\text{max}}) \) and the maximum
pressure \( (P_{\text{max}}) \) at which the bubble collapses are as follows:

\[ P_b = V_p + G_p. \]  

(2)

Here, \( P_b \) represents the pressure in the bubble, \( V_p \) is the
vapor pressure in the bubble, and \( G_p \) is the gas pressure in
the bubble. When the internal and external pressures are in
equilibrium,

\[ L_p = J_p + \frac{2\chi}{K_r}. \]  

(3)

Here, \( L_p \) represents the external pressure of the cavita-
tion bubble, the pressure when the fluid is at rest is \( J_p \), and
\( 2\chi/K_r \) is the surface tension of the cavitation bubble. If the
pressure of the fluid becomes \( J' p \), the radius of the cavitation
bubble becomes $K$. Assuming that the bubble is an ideal gas, the gas pressure is $G' p = Gp(Kr/K)$, and the bubble pressure $P'b$ at this time is

$$P'b = Vp + G' p = Vp + Gp\left(\frac{Kr}{K}\right)^3. \quad (4)$$

When $K > Kr$, the pressure outside the bubble becomes smaller due to the influence of surface tension, which is $L' p$.

$$L' p = f p + \frac{2\chi}{K}. \quad (5)$$

If the cavitation bubble is in equilibrium, then $P'b = Lp$.

### 4.2.3. Collapse Time of Ultrasonic Cavitation Bubbles

The focus of the discussion here is the time it takes for a cavitation bubble to shrink and collapse from its maximum radius. The radius $Kr$ of the cavitation is reduced to $K$ under the action of the external force $fp$ (i.e., the static pressure of the solution). In the absence of cavitation surface tension, the external force is equal to the product of the force and the volume change.

$$\int_{Kr}^{K} fp4\pi K^2 dK = fp \cdot \frac{4\pi}{3}(Kr^3 - K^3). \quad (6)$$

The kinetic energy of the liquid moving towards the shrinking space of the air bubble is equal; namely,

$$\frac{1}{2} mV^2 = 2\varphi \pi K^2 \frac{dK}{dS}. \quad (7)$$

$\varphi$ is the density of the fluid, and $dK/dS$ is the moving speed of the liquid; therefore,

$$fp \cdot \frac{3}{4}(Kr^3 - K^3) = 2\varphi \pi \int_{Kr}^{K} K^2 dK \left(\frac{dK}{dS}\right)^2. \quad (8)$$

If the volume cannot be compressed, the volume of the cavitation bubble is equal to the filling volume of the liquid. Arrange the formula to get

$$dS = dK\left(\frac{2fp}{3\varphi} \left(\frac{Kr^3}{K^3} - 1\right)\right)^{1/2}. \quad (9)$$

The integral of the above formula is taken from the right side to 0, and the time $S$ for the collapse of the cavitation bubble is obtained:

$$S \approx 0.92 Kr \varphi / fp^{1/2}. \quad (10)$$

### 4.3. Results of Preparing Nanocolloids

#### 4.3.1. XRD Experiment

XRD refers to X-ray diffraction. XRD can effectively explore the crystal structure and is especially suitable for the phase analysis of crystalline substances. If the constituent elements or groups of crystalline substances are not the same or their structures are different, their diffraction patterns are in the number of diffraction peaks and angular positions. The relative intensity order shows differences as far as the shape of the diffraction peaks is concerned. The XRD used in the experiment was DMAX/1200 X-ray diffractometer produced in Japan. It is a high-performance and multifunctional powder crystal X-ray diffractometer. It adopts Rigaku’s original CBO cross optical system and can perform various tests through different combinations of each unit.

The sulfide separator colloid was air-dried at low temperature, and the results of the XRD diffraction experiment are shown in Figure 3. Comparing the experimental results with the XRD patterns of $\beta$-CdS, the intergranular spacing and diffraction peak intensities of the two are relatively consistent. It is indicated that the obtained colloid is CdS.

#### 4.3.2. Kinetics of Liquid-Phase Chemical Synthesis of Monodisperse Powders

The Lamer model of a single particle in a dispersed state is shown in Figures 3 and 4. When the concentration of solute reaches the saturation concentration $C1$ through continuous accumulation, it begins to enter the nucleation stage, and the nucleation process will inevitably occur. When the solute concentration develops with time and returns to $C1$ again, it means that its nucleation stage is over, and it begins to enter the next stage of nuclear growth. The growth process continues until the solute concentration approaches $Z$.

### 5. Stability of Nanocolloids

#### 5.1. Effects of Buffers and Solution Ph on CdS Deposition

Figure 5(a) shows the curves of the effect of pH on the thickness of CdS films when deposition with and without buffer is used, respectively. The deposition thickness of CdS films increased with increasing pH in the absence of buffer. However, the thickness of CdS films decreased with the
increase of pH when buffer was used. But the change is relatively gentle between 9 and 11. The changes were more pronounced at higher pH values. This phenomenon may be that the same concentration of buffer cannot meet the needs of different pH. Buffers may have lost their buffering effect as pH rises. Figure 5(b) shows the influence curve of deposition time, and the overall trend is increasing. However, the deposition rate without the buffer saturates relatively quickly and is far less fast than the deposition rate with the buffer added. It can be seen that the buffer can effectively prolong the deposition time.

5.2. The Effect of Ultrasound on the Preparation of Nanomaterials. The particle size distribution and particle-particle interfaces are difficult to observe in TEM. From the observation of sedimentation, it can be seen that the particles grow significantly. The particles grow gradually with the increase of sonication time. The nanoparticles produced by sonication gradually grew, and once the reaction had progressed to a certain extent, the sonicated particles did not grow. This is due to two effects of ultrasonication: particle formation-growth effect and particle dissolution-dispersion effect. The initial stage of ultrasonic irradiation is a solution system. This results in a uniform ultrasonic chemical reaction. The original chemical bonds are broken in a small area by the high-energy effect of the ultrasound, providing thermodynamic and kinetic energy for the new reaction. In particular, the high-energy sputtering of ultrasonic waves makes the particles extremely active. Cavitation results also contribute to the formation of crystals. In the liquid phase, ultrasonic waves aid in the formation of nanoparticles. When the sonication reaches a certain stage, the formation of nanoparticles leads to a heterogeneous superbiochemical reaction in the solution. It creates a microjet impact effect, which is the dissolution of the particles. Because this shock wave produces a fixed area of corrosion on the particle surface, when the particles no longer grow, the growth and dispersion effects reach an equilibrium.

During ultrasonic cavitation, many related physical parameters, such as liquid, sound field, and environment, will affect the process of cavitation. It elaborates on two important influencing parameters, namely, the effect of temperature change and the effect of ultrasonic frequency. The change statistics of the influencing parameters are shown in Figure 6.

Figure 6(a) shows the effect of temperature change: in general, as the vapor pressure increases with temperature, not only the surface tension coefficient but also the viscosity coefficient decreases. Overall, the surface tension of water shows a decreasing trend with increasing temperature, as shown in Figure 6(a). However, the vapor pressure increases with increasing temperature, resulting in a decrease in cavitation strength and cavitation effect. As the vapor pressure in the bubble increases, the maximum temperature $T_{\text{max}}$ and the maximum pressure $P_{\text{max}}$ must decrease. But the sound pressure (Pa) required for cavitation decreases with increasing temperature, further reducing $T_{\text{max}}$ and $P_{\text{max}}$. Therefore, working at cryogenic conditions and selecting liquids with the lowest vapor pressure are necessary to maximize the acoustic chemistry. Figure 6(b) shows the effect of ultrasonic frequency changes. At higher frequencies, the cavitation effect becomes weaker. To generate cavitation at higher ultrasonic frequencies, the sound intensity can be increased. This is, the threshold sound intensity of ultrasonic cavitation increases with increasing frequency. A combination of the above factors is a commonly used approach in sonochemistry. The frequency of ultrasound is 20 kHz–50 kHz.

5.3. Coagulation and Separation of Particles under the Action of Ultrasonic Waves. In the ultrasonic standing wave field, the motion of particles in the suspension is mainly affected by the acoustic radiation force, the Stokes drag force, and the effective buoyancy force. Stokes resistance is the resistance that a spherical object overcomes in viscous laminar flow. When an object moves at a uniform speed in a viscous fluid, a layer of liquid adheres to the surface of the object, and there is internal friction between this liquid layer and its adjacent liquid layer, so the object must overcome this blocking force during the movement.

In the coordinate system of Figure 7, the motion of a single particle can be expressed as
(Pm Pv + Z) r2d \over rs = H1 + H2 + H3. \quad (11)

Here, Pm and Pv are the density and volume of the particle, respectively, Z is the additional mass, and d is the distance between the particle and the sound pressure node or abdomen. The time is denoted by S, the sound radiation force is denoted by H1, the effective lift is denoted by H2, and H3 is the Stokes drag force. The expression formulas of all these items are given as follows:

Z = Y1Pv/2. \quad (12)

Here, Y1 is the density of the liquid.

H3 = −3\pi y1P d r d \over rs. \quad (13)

Here, y1 represents the viscosity of the liquid, and P d is the particle diameter.

H2 = g \left( Y1 - P_m \right) P_v, \quad H1 = -3 \rho v BKU \sin 2 Bd, \quad (14)

U = \frac{1}{3} \left[ 5Pm - 2Y1 \frac{Y1C_1^2}{Y1 - 2Y1} - \frac{Y1C_1^2}{Y1 - 2Y1} \right].

Ds is the distance between the particle in equilibrium and the sound pressure node or abdomen. It can be seen from the analysis that when the particles reach the equilibrium state, the agglomeration position has nothing to do with its initial position and does not specify the specific sound pressure node or abdomen.

If it is necessary to discuss the influence of parameters in the coagulation process; the following formula is generally used:

s = \frac{3y1C_1^2}{(2\pi HP d)^2KU} \tan \frac{\tan Br0}{\tan Br1}. \quad (16)

The relationship between time-average acoustic energy density, ultrasonic frequency, and coagulation time can be obtained through the formula.

In order to visualize the relationship between parameter changes in the equilibrium state, with a certain sound energy density, namely, K = 10 J m⁻³, and a certain ultrasonic frequency, namely, f = 24.1 KHz, the statistics of the relationship between the time-averaged acoustic energy density, ultrasonic frequency, and coagulation time in these two cases are shown in Figure 8.

Figure 8(a) shows the relationship between ultrasonic frequency and particle agglomeration at a certain time-averaged acoustic energy density. This indicates that, at a certain time-averaged acoustic energy density, the agglomeration time required for the particles to reach equilibrium decreases as the ultrasonic frequency increases. Figure 8(b) shows the relationship between the time-averaged acoustic energy density and particle agglomeration at a
certain ultrasonic frequency. This shows that, at a certain ultrasonic frequency, with the increase of the time-averaged acoustic energy density, the required particle agglomeration time is significantly reduced. But, in practice, when the average sound energy density exceeds a certain limit, cavitation will occur. Therefore, the time-averaged sound energy density must be controlled within a certain limit.

5.4. Dynamic Stability of Colloids. It performs force analysis on heterogeneous particles in viscous fluids. It assumes the heterogeneous particle as a sphere with a diameter of \( L \) and explores the effect of its force:

(1) When the sphere is downward, the gravity \( Z \) of the particle is expressed as

\[
Z = P_m S = \beta m T_m S = \frac{1}{6} \pi L^3 \beta m S. \tag{17}
\]

Here, \( P_m, T_m, \) and \( \beta m \) represent the mass, volume, and density of the particle, respectively, and \( S \) is the acceleration of gravity.

(2) Relative buoyancy of the fluid

According to the principle of Archimedes’ law, the magnitude of the upward buoyant force \( F \) received is equal to the gravity of the displaced fluid of the same volume, which is

\[
F = \alpha_1 T_m S = \frac{1}{6} \pi L^3 \alpha_1 S. \tag{18}
\]

Here, \( \alpha_1 \) is the density of the fluid.

(3) The motion resistance of the fluid to the particle

From the principle of buoyancy, the viscosity of a viscous fluid hinders the motion of particles, and the resistance is in the opposite direction of the movement. It takes spherical particles as an example, and the resistance \( D \) of the fluid can be expressed as

\[
D = 3\pi rLR. \tag{19}
\]

Here, \( r \) is the dynamic viscosity of the fluid, and \( R \) is the dynamic velocity of the particle.

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![Figure 8: Relationship between acoustic energy density, ultrasonic frequency, and coagulation time under certain conditions.](image)

Figure 8: Relationship between acoustic energy density, ultrasonic frequency, and coagulation time under certain conditions.

![Figure 9: Schematic diagram of heterogeneous particles.](image)

Figure 9: Schematic diagram of heterogeneous particles.

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(4) The force of the heterogeneous point in the fluid

As shown in Figure 9, when the mass point is at rest, \( R = 0 \), and the resistance of the fluid is \( D = 0 \). When the gravity \( Z \) of the particle itself interacts with the relative buoyancy \( F \) of the fluid, the resultant force \( H1 \) can be expressed as
\[ H_1 = Z - F = \frac{1}{6} \pi L^3 (\beta m - \alpha 1)S. \]  \hspace{1cm} (20)

From the above formula, the direction of the resultant force is determined by the relative value of the density \( \beta m \) of the mass point and the density \( \alpha 1 \) of the fluid. Assuming that \( \beta m > \alpha 1 \), the force of the sphere accelerates downward, forming a resistance \( D \) to the particle; in this case, the resultant force \( H_2 \) of the particle is

\[ H_2 = Z - F - D = \frac{1}{6} \pi L^3 (\beta m - \alpha 1)S - 3\pi r LR. \]  \hspace{1cm} (21)

From the above formula, the moving speed of the particle increases, and the resultant force \( H_2 \) will decrease due to its influence. After \( H_2 = 0 \), the particle descends at a uniform speed, and the settling velocity can be expressed as

\[ H_2 = Z - F - D = \frac{1}{6} \pi L^3 (\beta m - \alpha 1)S - 3\pi r LR = 0. \]  \hspace{1cm} (22)

It can be derived that

\[ R = \frac{L^2}{18r} (\beta m - \alpha 1)S. \]  \hspace{1cm} (23)

The above analysis shows that when the density of the colloid is different from that of the fluid, the particles in the colloid will settle or float. That is, colloids are kinetically unstable.

In order to show the sedimentation velocity of nanoparticles in water more clearly, the viscosity power of water in this paper is \( r = 1.52 \times 10^{-3} \text{Pa} \cdot \text{s} \), and the density of water is \( \alpha 1 = 1000 \text{Kg/m}^3 \). When the acceleration of gravity is \( S = 9.81 \text{m/s}^2 \), the sedimentation velocity of cadmium sulfide and other metal nanoparticles is calculated and counted. The results are shown in Table 2.

As can be seen from the settling time of each particle at 10 mm in Table 3, the sedimentation rate is very small and the kinetic stability of the particles is quite high. It can be

### Table 2: Statistics of settling velocity of nanoparticles in water.

| Nanoparticles | Density | 1 nm | 10 nm | 100 nm | 1 um |
|---------------|---------|------|-------|--------|------|
| TiO₂          | 4260    | 1.3 × 10⁻¹² | 1.3 × 10⁻¹³ | 1.3 × 10⁻⁶ |
| ZnO₂          | 5606    | 1.7 × 10⁻¹² | 1.7 × 10⁻¹³ | 1.7 × 10⁻⁶ |
| SiO₂          | 2430    | 0.2 × 10⁻¹² | 0.2 × 10⁻¹³ | 0.2 × 10⁻⁶ |
| Al₂O₃         | 3950    | 1.1 × 10⁻¹² | 1.1 × 10⁻¹³ | 1.1 × 10⁻⁶ |
| ZrO₂          | 58900   | 1.8 × 10⁻¹² | 1.8 × 10⁻¹³ | 1.8 × 10⁻⁶ |
| CdS           | 4500    | 1.3 × 10⁻¹² | 1.3 × 10⁻¹³ | 1.3 × 10⁻⁶ |

### Table 3: Statistical table of time used to settle 10 mm in water.

| Nanoparticles | Density | 1 nm | 10 nm | 100 nm | 1 um |
|---------------|---------|------|-------|--------|------|
| TiO₂          | 4260    | 244 years | 2.4 years | 9 days | 2.1 hours |
| ZnO₂          | 5606    | 192 years | 2 years | 7 days | 1.7 hours |
| SiO₂          | 2430    | 618 years | 6.2 years | 23 days | 5.4 hours |
| Al₂O₃         | 3950    | 300 years | 3 years | 11 days | 2.6 hours |
| ZrO₂          | 58900   | 181 years | 1.8 years | 6.6 days | 1.6 hours |
| CdS           | 4500    | 253 years | 2.5 years | 9.2 days | 2.2 hours |

Figure 10: The effect of temperature on the deposition rate and the effect of adding ultrasonic waves on the deposition rate.
inferred that, kinetically, the nanoparticle colloid is in a relatively stable transferable state.

The kinetic stability of nanocolloids is mainly due to the small size of nanoparticles. Since the sedimentation velocity is proportional to the square of the particle size, the sedimentation velocity increases significantly with the particle size. But the thermodynamic instability of nanoparticles may lead to aggregation and induce kinetic instability. Thermodynamic instability of nanoparticles tends to increasing nanoparticle aggregation. This in turn induces kinetic instability. In general engineering terms, colloids are sufficiently stable if they are controlled in nanoscale (1–100 nanometers) particle size.

5.5. Results of Nanofilm Deposition. Figure 10(a) shows the effect of temperature change on the deposition rate. From the data trend in the figure, the overall trend is upward. In the three cases, the data line segment has a polyline point, which divides the data line into two parts. It can be clearly seen that the growth after the breaking point is slow until the growth stops. Through the comparison of different temperature curves, it can be concluded that the deposition rate has a direct relationship with the temperature change. The higher the temperature, the faster the deposition. Figure 10(b) is a comparison diagram of the deposition velocity with or without ultrasonic waves. Under the condition of constant temperature of 80°C, it can be seen that the difference between the two curves of adding ultrasonic waves and removing ultrasonic waves at the deposition time before 20 minutes is not large. After that, the difference between the two gradually increased. Ultrasonic oscillation avoids physical adsorption of colloidal particles.

6. Conclusions

In this paper, the process of preparing nano-CdS colloids by sol-gel method and its influencing factors, the growth model of nano-CdS colloids, the aggregation and separation of particles under the action of ultrasonic waves, and the stability of nanocolloid motion are systematically investigated, and the following conclusions are drawn by design.

This paper proposes the preparation of nanocolloids by adding ultrasonic irradiation on the basis of sol-gel method. The effects of ultrasonic frequency and time, pH, and other parameters are also discussed. The mixture was sonicated for 20 min and well stirred. Under ultrasonic irradiation, the water temperature was controlled at 20°C. The reaction of sodium sulfide stock solution with cadmium nitrate lasted for 120 min, and the pH of the colloid was controlled at 9–10; the ultrasonic cavitation process was described in detail. Then, a method of controlling colloidal agglomeration by ultrasonic waves is proposed. Then, an improved strategy to optimize the combination to solve the agglomeration problem in nanocolloid preparation is proposed in combination with the characteristics of the preparation process of cadmium sulfide colloids. Thus, the agglomeration problem in colloid preparation was avoided and the stability and homogeneity of nanocolloids were effectively improved; the causes and theoretical derivation of the agglomeration and separation of colloidal particles under the action of ultrasonic waves were studied. The agglomeration and separation phenomena of colloidal particles under the action of ultrasonic waves and their influencing factors were elucidated; the kinetic stability of nanocolloids was further investigated by taking the sedimentation rate of cadmium sulfide as an example.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare no conflicts of interest in this study.

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