Scholar Publishing Group
Academic Journal of Energy
https://doi.org/10.38007/RE.2020.010402
ISSN 2790-2714 Vol. 1, Issue 4: 13-25

Properties of Nano-Aluminum Powder Composite Phase Change Energy Storage Materials

Imran A. Khan*

Institute of Materials Research and Engineering, Singapore 138634, Singapore

**corresponding author*

Keywords: Nano-Aluminum Powder, Phase Change Energy Storage Material, Composite Material, Process Parameter, Activation Energy

Abstract: Nano-aluminum powder has the advantages of fast burning rate, high combustion efficiency, complete combustion and no agglomeration and agglomeration during the combustion process. As a metal additive for solid propellants, it can significantly increase its specific impulse, reduce pressure index and characteristic signals. However, due to its large specific surface area and high specific surface energy, nano-aluminum powder is prone to oxidation and even spontaneous combustion. Phase change energy storage materials can absorb or release a large amount of heat during the phase change process, can solve the problem of energy supply and demand mismatch in time or space, and achieve the effect of temperature control and energy storage. Based on the above background, the research content of this article is the performance research of nano-aluminum powder composite phase change energy storage materials. In order to be able to prepare nano-aluminum powder with appropriate particle size by DC arc hydrogen plasma method, the cathode current and inert gas pressure are explored. The effects of other process parameters on the yield and particle size of nano-aluminum powder were analyzed, and the effect mechanism was analyzed. Finally, through experimental simulation, the results show that the nano-aluminum powder begins to oxidize at about 520 °C, which is 500 °C lower than the micro-aluminum powder's oxidation temperature at 1000 °C, which indicates that the nano-aluminum powder has a low oxidation activation energy, which may be related to Nano-aluminum powder is related to the release of additional energy storage.

1. Introduction

Energy has brought tremendous improvements to human activities today, and it is closely related to the progress of society. At present, energy shortage has become a problem faced by most countries, and human beings are constantly demanding non-renewable energy sources, causing most non-renewable energy sources to face exhaustion. Increasing the utilization of energy has attracted a large number of hobby workers, and the preparation and development of new energy is equally attractive. Due to the certain intermittent nature of energy, it is often impossible to achieve a consistent effect on energy coordination, which leads to a reduction in energy utilization.

Nano-aluminum powder has special surface and interface effects. Its surface atoms are more, and surface atoms will increase as the particle size of nano-aluminum powder decreases; and the specific surface area and specific surface energy of nano-aluminum powder are very large [1-2]. Both of the above factors cause the nano aluminum powder to be highly reactive and very sensitive to the environment. Especially when exposed to air, its surface atoms are easily oxidized to form dense and hard Al2O3, which forms an oxide shell. Coating the surface of nano-aluminum powder [3-4]. This will seriously affect the activity of nano-aluminum powder, and the oxides produced will not contribute to the combustion reaction, but will reduce the combustion effect of nano-aluminum powder [5-6]. Therefore, how to maintain the activity of nano-aluminum powder, prevent the formation of oxides, and be able to control the release of nano-aluminum powder activity, has become a research hotspot in this field [7-8]. Among them, carbon coating refers to coating a layer of carbon shell on the surface of nano-aluminum particles to form a core-shell structure of carbon-coated aluminum. The most direct role of the carbon shell on the surface of nano-aluminum powder is to isolate the contact between core aluminum and outside air to maintain Activity of nano-aluminum powder [9-10]. In addition, the carbon layer can burn quickly under high heat conditions, and the core aluminum is exposed to the high heat environment for combustion. The combustion of the carbon layer provides additional energy, which indirectly increases the enthalpy of combustion of nano-aluminum powder [11-12]. However, the preparation of carbon-coated nano-aluminum particles is difficult. Although many related studies have been done at home and abroad, they have not obtained ideal results [13-14].

Committed to the development of high-performance electrochemical energy storage materials and device technology, conventional electrochemical energy storage systems face great challenges in achieving high energy density, long cycle life, excellent biocompatibility and environmental friendliness. Bioenergy metabolism and storage systems have attractive advantages such as high efficiency, precise regulation, cleanliness and reproducibility. Recently, the rational design and manufacture of advanced electrochemical energy storage materials and smart devices have been inspired by nature. Wang summarizes the latest developments in the field of electrochemical energy storage materials and devices inspired by nature. Wang introduced nature-inspired methods for exploring, preparing and modifying electrochemical materials related to energy storage, including active materials, adhesives and separators. In addition, Wang also discussed the design and manufacturing of smart energy storage devices inspired by nature, such as self-healing supercapacitors, ultracapacitors with ultra-high operating voltages, and rechargeable batteries. Wang aims to provide in-depth insights and extended research perspectives for further research [15-16]. In the post-LIB era, it is important to find the next generation of energy storage technology with large energy density, long cycle life, high safety and low cost. As a result, lithium-sulfur and lithium-air batteries with high energy density and safe, low-cost room-temperature sodium-ion batteries have drawn increasing attention. Yang briefly outlined the latest advances in next-generation rechargeable batteries and their key electrode materials, with a particular focus on Li-S, Li-air, and Na-ion batteries. Yang also discussed the future development prospects of these new energy storage technologies [17-18]. Zhao deals with the heat transfer behavior of thermal energy storage components based on composite phase change materials (CPCM). Zhao designed and researched two types of components, namely single tube components and concentric tube components. CPCM consists of phase change material (PCM) based on molten salt, thermal conductivity enhancement material (TCEM), and ceramic framework material (CSM). Zhao built a mathematical model to simulate heat transfer behavior. First, the modeling results are compared with the experiments, and a good agreement with the experimental data is obtained, which proves the reliability of the model. Extensive modeling studies were then performed under different conditions. The effects of thermal properties, surface roughness and size of the CPCM, and the speed of the heat transfer fluid (HTF) were investigated. The results show that the thermal contact resistance between CPCMs should be considered. Increasing the mass fraction of TCEM and the thickness of CPCM and increasing the HTF speed will enhance the heat transfer performance of the module. Compared to single tube-based components, concentric tube-based components provide better heat transfer performance. Under given conditions, the total heat storage and release time is reduced by about 10% and 15%, respectively [19-20].

No matter what kind of phase change materials are used to distinguish, generally available, good phase change materials should contain the following characteristics: Thermodynamic standards: high heat storage density, less quality phase change energy storage materials can have higher heat storage Value, so that the storage volume is small and easy to place; high thermal conductivity makes the absorption and release of heat more obvious, and the temperature gradient is small; high heat capacity, through the heat capacity to achieve its own sensible heat effect; the liquid phase and The solid phase dissolution changes are consistent so as not to change the chemical properties of the solid phase and the liquid phase; the range of volume change during the phase change of the phase change energy storage material should be small, so that the amount of packaging materials will be lower; Kinetic standard: After the phase change process occurs, when the solid-phase condensation process occurs, its supercooling degree should be as small as possible, usually adding a nucleating agent, or some physical methods to solve; Chemical standard: Corrosive effect of materials Small, non-toxic, harmless, not easy to decompose, good chemical stability, etc .; Economic standards: low cost, easy to mass production, simple preparation process, easy to operate, so that it can be used in popularization and application.

2. Proposed Method

2.1. Nano Aluminum Powder

The reactivity of nano-aluminum powder is much higher than that of micro-aluminum powder.It is easy to undergo oxidation and hydrolysis with the surrounding environment during the preparation and storage process. As a result, the activity of nano-aluminum powder will be reduced or even completely lost, so it is suitable for the preparation of nano-aluminum powder. The methods are extremely limited, and it is necessary to further study the method of preparing highly active nano-aluminum powder [21-22]. The nano-aluminum powder prepared at the same time requires subsequent further characterization and research. In practical applications, the solid propellant made by adding nano-aluminum powder as a metal burner will not be used immediately, which makes how to store nano-aluminum powder reasonably important. [23-24].

The heating evaporation condensation method is to melt and evaporate the bulk metal by the rapid heating of the evaporation source in an inert atmosphere. The evaporated metal smoke atoms and the inert gas are rapidly cooled due to collision and lose energy, and grow by adsorption in the process of approaching the cooling device. And aggregates grow and aggregate to form nanoparticles [25-26]. Available heating sources are resistance wires, high frequency induction and lasers. Resistance wire has a limited heating limit temperature, which is not suitable for the preparation of high melting point metals. At the same time, it has the disadvantages of slow heating rate and low energy utilization [27-28]. High-frequency induction and laser are widely used in heat treatment processes such as surface hardening of steel.It has the characteristics of energy concentration, fast heating, high heating limit temperature, clean and pollution-free heat sources, and the heat source heating power can be controlled externally, which can meet the vacuum heating. The requirements are ideal heat sources for heating and evaporation in a vacuum environment [29-30].

The induction heating evaporation condensation method uses the principle of electromagnetic induction to place bulk metal raw materials in an induction coil with cooling water circulating in it. When an induction coil passes a certain frequency of alternating current, an alternating current with the same frequency as the current is generated inside and outside the induction coil. Magnetic field. Under the action of an alternating magnetic field, metal raw materials will generate an induced current in the same direction as the frequency of the induction coil. Because the induced current forms a closed loop along the surface of the metal material, that is, eddy current, this eddy current turns electrical energy into thermal energy, which heats the metal material to melt. When the temperature reaches a certain level, the molten liquid metal atoms will escape the liquid metal surface under the appropriate pressure in the furnace, and eventually form nano metal powder.

2.2. Preparation of Nano Aluminum Powder

The principle of the device for preparing nano-aluminum powder by heating evaporation condensation method. The main equipment includes HGL81 cross-current electrically excited continuous wave CO2 laser with rated power of 2kW, SP-25 (A) 5kW high-frequency induction heater, evaporation chamber, cooling collection chamber, Circulating water cooling system, gas flow control device, mechanical vacuum pump and various pressure reading systems. A composite crucible is placed in the center of the induction coil in the evaporation chamber to hold the metal aluminum block. In order to heat and melt the metal aluminum block, it is necessary to ensure that the composite crucible can be quickly heated and has a certain thermal insulation ability to reduce heat loss.Therefore, a cylindrical three-layer composite crucible was used in the experiment. Inside and outside are: high purity alumina crucible, graphite crucible and refractory lined crucible. High-purity alumina crucibles are used to hold aluminum blocks to prevent the molten aluminum liquid from chemically reacting with graphite crucibles. Graphite is used to interact with the induction coil to produce the required high temperature. Refractory crucibles are used to separate the graphite layer from the induction. Coil, and play a role in thermal insulation.

The experimental process for preparing nano-aluminum powder by induction heating evaporation condensation method is as follows: the evaporation chamber and the collection chamber are cleaned with absolute ethanol and further dried. The industrial pure aluminum block (99.9wt%) is cut into small pieces, cleaned, decontaminated and dried, and then placed in a composite crucible. Close the gas supply system valve, open the mechanical vacuum pump, and evacuate the system to less than 30Pa. Use high-purity Ar gas. (99.995%) Clean the entire system 2 or 3 times, exhaust the residual gas in the system as much as possible, pass high-purity Ar gas through the gas flow device and maintain the pressure at about 2kPa. Turn on the circulating water cooling system and the high-frequency induction heater, increase the induction current of the high-frequency induction heater, melt the aluminum block in the crucible, and continue to heat up the aluminum liquid to boil and evaporate. According to the particle size of the nano-aluminum powder to be prepared Adjust the size of the Ar gas flow, the pressure in the furnace and the magnitude of the induced current. When no aluminum vapor evaporates in the crucible, the aluminum block evaporates, close the vacuum pump and vacuum valve, and pass in a mixed gas (about 20: 1) of 0.5 atmAr gas and air to seal the entire system and passivate the nano aluminum powder. After about 10 hours, the passivated nano-aluminum powder was collected and packaged.

2.3. Composite Phase Change Energy Storage Material

There are three main types of heat storage: sensible heat storage, latent heat storage, and chemical reaction heat storage. Sensible heat energy storage simply stores energy by increasing the temperature of the material. This heat storage method is the simplest and most mature of all types of heat storage methods, and it is also the most widely used, but its disadvantage is that it stores energy. The heat density is low and the heat storage device is large; the latent heat energy storage is through the process of solidification, melting, condensation, gasification, sublimation, sublimation, and other forms of phase change. The principle is to store energy. It has a large heat storage density, and the heat storage and exothermic process is approximately isothermal, which is easy to control. The chemical reaction thermal energy storage uses the combined heat of reversible chemical reactions to store energy. The system is relatively complicated. It has not been widely used.

Before theoretically solving the phase change heat transfer problem, we must first establish a mathematical model of phase change heat transfer. A mathematical model of a phase change heat transfer problem is given. Equations (1) to (4) are the governing equations of the model.

$$\rho_s c_s \frac{\partial T_s}{\partial \tau} = \nabla \cdot (k_s \nabla T_s) + \dot{q}_s \tag{1}$$

$$\rho_l c_l (\frac{\partial T_l}{\partial \tau} + v \cdot \nabla T_l =) \nabla \cdot (k_s \nabla T_s) + \dot{q}_l \tag{2}$$

$$(\rho_s h_s - \rho_l h_l) v_\Sigma + \rho_l h_l v_l = (k \frac{\partial T}{\partial n})_t - (k \frac{\partial T}{\partial n})_s \tag{3}$$

$$(\rho_s - \rho_l) v_\Sigma + \rho_l v_l = 0 \tag{4}$$

Where T is the temperature, P is the density, c is the specific heat, k is the thermal conductivity, q is the volumetric heat source or heat sink, v is the liquid phase velocity vector, and t is the time; the subscript s indicates the solid phase, and the subscript l indicates the liquid. phase.

At the boundary, one of three types of boundary conditions can be applied:

$$T = T_\theta \tag{5}$$

$$-\left(k \frac{\partial T}{\partial n} \right) = q_0 \tag{6}$$

$$-\left(k \frac{\partial T}{\partial n} \right) = A_0 (T - T_a) \tag{7}$$

Where is the temperature of the PCM perimeter, q0 is the heat flow applied to the PCM perimeter, A0 is the equivalent heat transfer coefficient on the perimeter, and Ta is the external reference temperature.

In situ polymerization is an encapsulation technique closely related to interfacial polymerization. In the in-situ polymerization encapsulation process, the non-reactive monomer is added to the core material droplets and the suspension medium, but the monomer and the initiator are all added to the dispersed or continuous phase, that is, the monomer The body composition and catalyst are all located outside the core material droplets. In a miniemulsion system, the monomer is soluble in a single phase, and the polymer is insoluble in the entire system, so the polymerization reaction occurs on the surface of the core material droplets, and the polymerized monomer generates a relatively low molecular weight Polymer, when the size of the prepolymer is gradually increased, it is deposited on the surface of the core material. Due to the continuous cross-linking and polymerization reaction, a solid capsule shell is finally formed. The resulting polymer film can cover the core material droplets. Full surface. In-situ polymerization can use water-soluble or oil-soluble monomer mixtures, and can also use low molecular weight polymers or prepolymers instead of monomers. The technical characteristics of this method can be summarized as follows: all monomers and initiators are placed on the outside of the capsule core and the monomer is required to be soluble, while the polymer produced is insoluble, and the polymer is deposited on the surface of the capsule core and coated to form microcapsules.

3. Experiments

3.1. Experimental Device

The main equipment of the device for preparing nano-aluminum powder by heating evaporation condensation method includes HGL81 type cross-current electrically excited continuous wave CO2 laser with rated power of 2kW, SP-25 (A) type 5kW high-frequency induction heater, evaporation chamber, cooling collection chamber, circulation Water cooling system, gas flow control device, mechanical vacuum pump and various pressure reading systems. A composite crucible is placed in the center of the induction coil in the evaporation chamber to hold the metal aluminum block. In order to heat and melt the metal aluminum block, it is necessary to ensure that the composite crucible can be quickly heated and has a certain thermal insulation ability to reduce heat loss.Therefore, a cylindrical three-layer composite crucible was used in the experiment. Inside and outside are: high purity alumina crucible, graphite crucible and refractory lined crucible. High-purity alumina crucibles are used to hold aluminum blocks to prevent the molten aluminum liquid from chemically reacting with graphite crucibles. Graphite is used to interact with the induction coil to produce the required high temperature. Refractory crucibles are used to separate the graphite layer from the induction. Coil, and play a role in thermal insulation. It is made by one-time pouring. After 48 hours of curing and demoulding, it is heated to about 600 °C in an air furnace for 10 hours and then cooled with the furnace to discharge the crucible as far as possible Moisture and other impurities and give it a certain strength.

3.2. Experimental Steps

The evaporation chamber and the collection chamber were cleaned with absolute ethanol and further dried. The industrial pure aluminum block (99.9wt%) is cut into small pieces, cleaned, decontaminated and dried, and then placed in a composite crucible. After installing the device, close the gas supply system valve, open the mechanical vacuum pump, and evacuate the system to less than 30Pa. High-purity Ar gas (99.995%) is used to clean the entire system 2 or 3 times, and the residual gas in the system is exhausted as much as possible. High-purity Ar gas is passed through the gas flow device and the pressure is maintained at about 2kPa. Turn on the circulating water cooling system and the high-frequency induction heater, increase the induction current of the high-frequency induction heater, melt the aluminum block in the crucible, and continue to heat up the aluminum liquid to boil and evaporate. According to the particle size of the nano-aluminum powder to be prepared Adjust the size of the Ar gas flow, the pressure in the furnace and the magnitude of the induced current. When no aluminum vapor evaporates in the crucible, the aluminum block evaporates, close the vacuum pump and vacuum valve, and pass in a mixed gas (about 20: 1) of 0.5 atmAr gas and air to seal the entire system and passivate the nano aluminum powder. After about 10 hours, the passivated nano-aluminum powder was collected and packaged.

4. Discussion

4.1. Analysis of the Method for Maintaining the Activity of Nano-Aluminum Powder

The average particle size of the nano-aluminum powder calculated between different diffraction peaks has a large difference. Therefore, in order to minimize the error, it is necessary to participate in the calculation of all diffraction peaks, and then use the principle of the least square solution to obtain the average particle size. The calculation process can be realized by XRD analysis software Jade5.0, and its calculation value is shown in Table 1.

Table 1. Physical parameters of the nanopowders

Aluminum powder	Preparation	Particle shape	Average particle size (nm)	Shell thickness (nm)
Al-E	Electric explosion wire	Irregular sphere	52.2	2~3
Al-P	Plasma	Spherical, rarely rod-shaped	54.2	3~5
Al-L	Laser heating	Spherical, few rods	51.8	2~5
Al-I	Induction heating	Spherical, rarely rod-shaped	47.3	4~5

The Scherrer formula provides a formula for calculating the size of nanoparticles:

$$D_c = \frac{K\lambda}{B \cdot \cos\theta} \tag{8}$$

In the formula, for the copper target, the Xie Le constant is K = 0.89, λ = 0.15406nm, B is the FWHM of the diffraction peak, and θ is the Bragg diffraction angle. The Xie Le formula is a more accurate method for calculating the size of nanoparticles, but this formula can only be calculated by using a certain diffraction peak. The physical property analysis results of nano aluminum powder are shown in Figure 1.

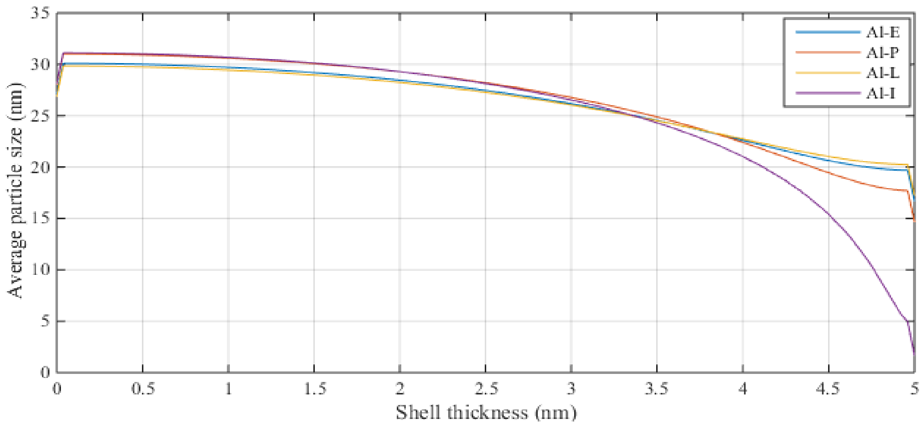

Figure 1. Physical property analysis results of nano aluminum powder

Once prepared, nano-aluminum powder cannot be used or tested immediately.It must be stored for the convenience of subsequent research work. Therefore, it is necessary to study its activity protection method, which must be simple and convenient, and its activity retention rate High, or preferably without loss. Based on the influence of storage atmosphere (inert, non-inert), humidity, and temperature on the activity of nano-aluminum powder, this article uses a simple method to protect the activity of nano-aluminum powder and analyzes the effect of maintaining the activity. Since the activity change of a certain nano-aluminum powder is examined here, in order to simplify the problem, the content of elemental aluminum is temporarily used as the evaluation index of nano-aluminum powder activity. The TG-DTA curve of nano-aluminum powder by electro-explosion method before and after linearization of heating temperature at high heating rate is shown in Figure 2.

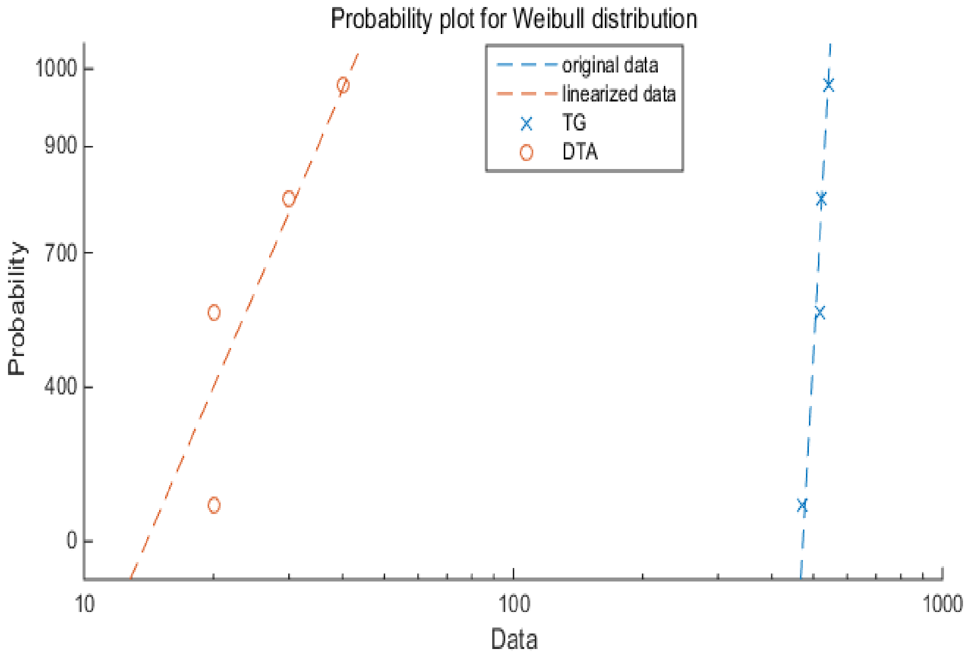

Figure 2. TG-DTA curves of Pre- and post-linearized heating temperature under high heating rate for Al-E

It can be seen from the figure that both the DTA and TG curves have a “twisting” phenomenon. In this case, the oxidative exothermic enthalpy and mass changes may not reflect the true situation of the sample, and the extraction of parameters such as ΔH and Δm will become more difficult. For this reason, in this paper, the heating temperature is linearized at a high heating rate. The curves before and after the treatment are greatly different, so that the DTG curve also changes a lot, which brings great difficulties to the accurate extraction of the thermal parameter vox. The nano-aluminum powder in the propellant has the characteristics of high combustion temperature and instantaneous concentrated energy release during actual use. The high heating rate may be closer to the actual operating conditions, but the existing thermal analysis instruments have limited heating rates. There is a large deviation in the measurement after the instrument is high, and there may also be extreme drift at high heating rates. Therefore, it is more suitable to select a low heating rate for judging the activity of nano-aluminum powder.

4.2. Thermal Analysis of Nano-Aluminum Powder in an Inert Atmosphere

The exothermic phenomenon of P1 and P2 is mainly caused by the extra energy stored in a large number of defects inside the nano-aluminum powder released during heating. At the same time, different types of defects have different exothermic temperature intervals, which causes exothermicity at different temperatures. phenomenon. The thermal parameters of the DSC curve of the nano-aluminum powder are shown in Table 2.

Table 2. DSC parameters of Al nanopowders under Ar atmosphere

Methods		Al-E	Al-P	Al-L
P_1	T_{O1}	350.15	351.67	347.79
	T_{P1}	363.82	362.43	365.19
	ΔH_1	18.3143	5.7912	13.3757
P_2	T_{O2}	473.32	434.52	472.89
	T_{P2}	483.23	441.83	480.87
	ΔH_2	7.9508	7.5731	5.1883
P_3	T_{O3}	395.27	403.48	404.02
	T_{P3}	404.19	413.57	410.14
	ΔH_3	-6.1031	-3.7099	-3.5124

The DSC results of the nano-aluminum powder in an argon atmosphere are shown in Figure 3.

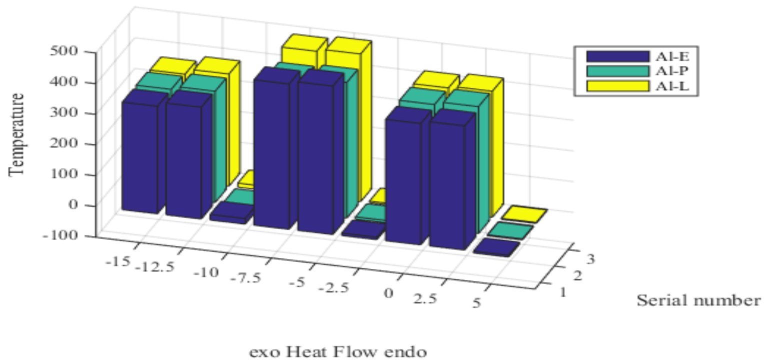

Figure 3. DSC results of nanopowders under Ar atmosphere

Studies have shown that nano-aluminum powder begins to oxidize at about 520 °C, which is 500 °C lower than the temperature at which micro-aluminum powder begins to oxidize at 1000 °C. This indicates that the oxidation activation energy of nano-aluminum powder is low, which may be similar to that of nano-aluminum powder. The release of additional energy storage is related, so it is necessary to study the thermal behavior of nano-aluminum powder before 500 °C in an inert environment. After 500 °C, the nano-aluminum powder will exotherm in the reaction with oxidants than in an inert environment. Much more, so the thermal behavior of nano-aluminum powder under inert environment before 500 ℃ will be more important than the research after 500 ℃. The comparison of the diffraction peak positions of nano-aluminum powder and micro-aluminum powder is shown in Figure 4.

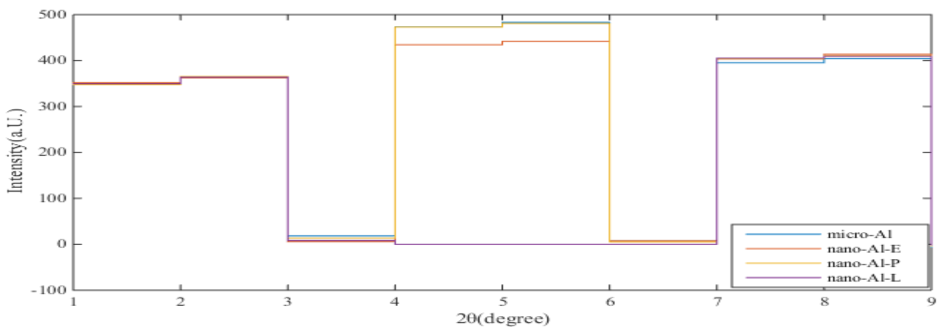

Figure 4. Comparison of the diffraction peaks of micro- and nano-powders

It can be seen that as the θ increases, the interplanar spacing d decreases and the lattice constant a decreases. Therefore, the nano-aluminum powder produced by the electric explosion wire method has a lattice shrinkage. The intra-particle pressure model can explain this phenomenon. The theory believes that the lattice shrinkage is caused by the pressure drop in the crystal grains. The relative shrinkage of the lattice constant and the change in the intra-grain pressure follow Hooke's law. Different from the aluminum powder prepared by other methods, the explosion of the metal aluminum wire causes the pressure in the original lattice of the metal wire to be released and reduced. As a result, lattice shrinkage occurs.

4.3. Thermal Conductivity Analysis of Nano-Aluminum Powder Composite Phase Change Material

In this paper, the thermal conductivity of nano-aluminum powder is tested to verify the reliability of the experimental system. The temperature test curve of nano-aluminum powder is shown in Figure 5.

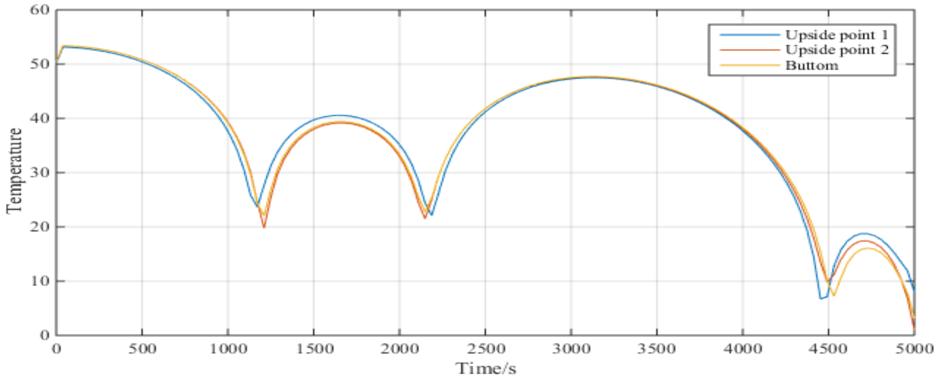

Figure 5. Temperature test curve of nano aluminum powder

When the lower surface is heated by the heating plate to heat the copper plate, the temperature of the lower surface of the sample changes with time until the temperature fluctuates up and down around 46.50C; this is because the heater surface temperature is set to be constant at 500C. After setting the upper temperature limit, the thermostat is automatically powered off. When the surface temperature of the heater is lowered to the set lower limit temperature, the thermostat is automatically energized due to temperature fluctuations. After 6000s, the heat transfer process enters the steady-state heat conduction stage. At this time, the temperature curves of the two thermocouples on the upper surface have completely overlapped, indicating that the upper surface temperature is uniform and in a constant state. At this time, the temperature gradient of the upper and lower surfaces of the sample can be used to calculate the thermal conductivity of the sample. After calculation, the thermal conductivity of nano-aluminum powder is 0.25W / (m-K), which is in good agreement with literature values.

4.4. Analysis of the Effect of Cathode Current on the Yield and Particle Size of Nano-Aluminum Powder

The effect of the arc current on the yield and average particle size of nano-aluminum powder is shown in Figure 6.

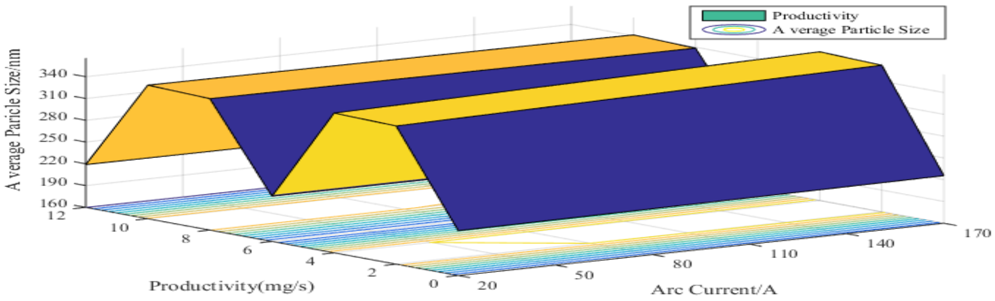

Figure 6. Effect of arc current on productivity and average particle size of ahaminum nanoparticles

It can be seen that with the increase of the cathode current, the yield of nano-aluminum powder increases linearly, and the average particle size of nano-aluminum powder first increases and then decreases, and the average particle size has a maximum value, which is related to The effect of arc current on zinc powder and nickel powder is different. When the current was increased from 30A to 150A, the yield of nano-aluminum powder increased from the original 2.079mg S-1 to 13.475mg S-1, an increase of 6.47 times; when the current was 90A, the average particle size of nano-aluminum powder the largest diameter. It can also be seen from the experimental data that the particle size of the smallest nano-aluminum powder is greater than 150 nm even at 150A. This is because the nano-aluminum powder is easy to agglomerate to form secondary particles, and its particle size will be larger than that of the original particles. When the particle size of the prepared nano-aluminum powder is measured by a laser particle size analyzer, the use of absolute ethanol as a dispersant can only improve the aggregation behavior of the nano-aluminum powder to a certain extent.

5. Conclusion

This article closely focuses on the topic of heat transfer characteristics of composite phase change energy storage materials, and establishes physical models for heat transfer of nanometer aluminum powder composite phase change materials at different scales through macro, mesoscopic and micro research methods, and applies the finite volume method And molecular dynamics methods were used to numerically simulate the subject. In addition, the thermophysical parameters of nano-aluminum powder composite phase change materials were also determined experimentally, and the macro-scale and pore-scale phase change heat transfer processes were studied by visual experimental methods.

This article first explored the preparation of carbon-coated nano-aluminum particles by DC arc hydrogen plasma method, and then chemically coated carbon nanoparticles with aluminum, and characterized the carbon-coated nanoparticles. Aluminum powder, the influence of experimental process conditions on the yield and particle size of nanometer aluminum powder. The results show that part of the nano-aluminum particles are coated with carbon, and part of the aluminum surface is coated with alumina. The exothermic peak of the nano-aluminum powder prepared on the DTA curve appeared at 494 ℃, and the corresponding TGA curve began to gain weight at 450 ℃, indicating that the oxidation temperature of the nano-aluminum powder decreased.

There are still some shortcomings in this article. For example, the device can be enlarged, the wire feed rate can be increased, and the "melt ball" temperature can be increased, thereby increasing the temperature of nano-aluminum powder entering high purity nitrogen. To achieve the atmosphere flow in the heating furnace; to find suitable additives and further study the impact of ammonium chloride. Moreover, the thermal conductivity of different inorganic packaging materials can be studied, and the heat transfer characteristics of this material after packaging, and the light absorption characteristics of the materials after packaging can be studied and discussed.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Hangai Y, Morita T, Koyama S, et al. Functionally Graded Aluminum Foam Fabricated by Friction Powder Sintering Process with Traversing Tool. Journal of Materials Engineering & Performance, 2016, 25(9):1-6. DOI: 10.1007/s11665-016-2218-x

[2] Su Y, Sun X, Zhang H. Effect of Viscosity of Slurry on Stability of Aluminum Powder Bubble. Jianzhu Cailiao Xuebao/Journal of Building Materials, 2017, 20(4):506-510.

[3] Shahien M, Yamada M, Fukumoto M. Splat Morphology and Influence of Feeding Rate during Reactive Plasma Spray of Aluminum Powder. Journal of Thermal Spray Technology, 2016, 25(8):1-12. DOI: 10.1007/s11666-016-0417-5

[4] Xiao-Ling X, Sheng-Xiang Z, Wen-Xiang L I, et al. The Reactivity between Aluminum Powder and Liquid Phase of Fuel-air Explosives. Chinese journal of explosives & propellants, 2016, 39(6):55-57. DOI: 10.14077/j.issn.1007-7812.2016.06.009

[5] Yuan-Yuan H, Jian-Feng G, Jun-Qin W, et al. Preparation and Characterization of High Activity Micron Porous Aluminum Powder. chinese journal of explosives & propellants, 2016, 23(6):673-677.

[6] Yoon B, Lee S H, Lee H S. Low-temperature densification of nano Si-C powder containing Al-C additives prepared by high-energy ball-milling. Ceramics International, 2017, 43(1):12-19.

[7] Sina H, Surreddi K B, Iyengar S. ChemInform Abstract: Phase Evolution During the Reactive Sintering of Ternary Al—Ni—Ti Powder Compacts.. Cheminform, 2016, 47(9):294-305.

[8] Yoon B, Lee S H, Lee H S. Low-temperature densification of nano Si-C powder containing Al-C additives prepared by high-energy ball-milling. Ceramics International, 2017, 43(1):12-19.

[9] Shujing L I, Guijuan L I, Binwen D, et al. Effects of Extra Al powder Additions on Properties of ZrN-based Composites Prepared by Aluminothermic Reduction and Nitridation Process. Chinas Refractories, 2016, 25(3):31-35.

[10] Goudar D M, Srivastava V C, Rudrakshi G B. Effect of Atomization Parameters on Size and Morphology of Al-17Si Alloy Powder Produced by Free Fall Atomizer. Engineering Journal, 2017, 21(1):155-168.

[11] Jailani H S, Rajadurai A, Mohan B, et al. Sliding wear behaviour of Al-Si alloy–fly ash composites produced by powder metallurgy technique. Industrial Lubrication & Tribology, 2017, 69(2):241-247.

[12] Xie X, Wang Y, Qi J, et al. Ethanol-Water-Derived Sucrose-Coated-Al 2 O 3 for Submicrometer AlON Powder Synthesis. Journal of the American Ceramic Society, 2016,

99(8):2601-2606.
[13] Hao G L, Xian-Yu L I, Wang W G. Low frequency damping behavior associated with sintering process in Al powder compact. Transactions of Nonferrous Metals Society of China, 2016, 26(4):1176-1182. DOI: 10.1016/S1003-6326(16)64180-8
[14] Zhang L, Zhang X, Chu Z, et al. Thermoelastic analysis of Al2O3 powder in pulse electric current sintering. journal of chongqing university, 2017, 40(4):18-23.
[15] Wang H, Yang Y, Guo L. Nature-Inspired Electrochemical Energy-Storage Materials and Devices. Advanced Energy Materials, 2016, 7(5):1601709.
[16] Schon T B, Mcallister B T, Li P F, et al. The rise of organic electrode materials for energy storage. Chemical Society Reviews, 2016, 45(22):6345. DOI: 10.1039/c6cs00173d
[17] Yang Z, Zhang W, Shen Y, et al. Next-Generation Energy Storage Technologies and Their Key Electrode Materials. Acta Physico Chimica Sinica, 2016, 32(5):1062-1071.
[18] Yang Y, Li H, Sun Y, et al. Structure and properties of Al2O3/430L composite honeycombs fabricated by plasticizing powder extrusion. Cailiao Kexue yu Gongyi/Material Science and Technology, 2017, 25(3):19-25
[19] Zhao B, Li C, Jin Y, et al. Heat Transfer Performance of Thermal Energy Storage Components Containing Composite Phase Change Materials. Iet Renewable Power Generation, 2016, 10(10):1515-1522. DOI: 10.1049/iet-rpg.2016.0026
[20].Purohit R, Solanki N K, Bajpayee G, et al. Development of Cu-Al 2 O 3 -CBN Hybrid Composite through Powder Metallurgy Process and Analysis of Mechanical Properties. Materials today: proceedings, 2017, 4(2):3270-3279.
[21] Xu Z, Jiang D, Wu F, et al. Preparation and droplet impact dynamics of superhydrophobic nano-aluminum films on metal substrates. journal of materials science, 2018, 53(7):5364-5379.
[22] Tsukrenko V V, Ruban A K, V. P. Red'ko, et al. Effect of Coo Microadditive on the Properties of ZrO 2 –Y 2 O 3 –CeO 2 –Al 2 O 3, Nanocrystalline Powder. Powder Metallurgy & Metal Ceramics, 2016, 55(1-2):29-36.
[23] Paravan C, Maggi F, Dossi S, et al. Pre-burning Characterization of Nanosized Aluminum in Condensed Energetic Systems. energetic nanomaterials, 2016:341-368.
[24] Krainov A Y, Poryazov V A, Moiseeva K M, et al. Mathematical combustion model of nanoaluminum-air suspension. Combustion Theory & Modelling, 2019(2):1-17.
[25] Althomali Y M, Ebrahim M I. Microshear bond strength of Nano-Bond adhesive containing nanosized aluminum trioxide particles. journal of orthodontic science, 2017, 6(2):71-75.
[26] Batygina M V, Dobrynkin N M, Noskov A S. Synthesis of nano-sized boehmite by hydrolysis of aluminum chloride hexahydrate under hydrothermal conditions. Tsvetnye Metally, 2017(2):51-55.
[27] Eid E I, Khalaf-Allah R A, Taher S H, et al. An experimental investigation of the effect of the addition of nano Aluminum oxide on pool boiling of refrigerant 134A. Heat and mass transfer, 2017, 53(8):2597-2607.
[28] Xu F, Fang F, Zhu Y, et al. Study on Crystallographic Orientation Effect on Surface Generation of Aluminum in Nano-cutting. Nanoscale Research Letters, 2017, 12(1):1-13.
[29] Theodossiadis G D, Zaeh M F. In-situ investigation of the thermal reaction properties of multilayered aluminum–nickel nanofoils. production engineering, 2017, 11(29):1-9.
[30] Derakhshani M, Hashamzadeh A, Amini M M. High surface area mesoporous alumina nanosheets and nanorolls from an aluminum based metal organic framework. Ceramics International, 2016, 42(15):17742-17748.