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Study on Initiation Ability of Nano-AgN_3 Synthesized by In-Situ Strategy

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Abstract. Silver azide (AgN_3) is one of the environmentally primary explosives with excellent initiation performances, and it can meet the demand for the miniaturization of modern weapon equipment. In this paper, nano-silver oxide (Ag_2O) of 70 nm-90 nm was prepared by wet chemical method using polyvinylpyrrolidone (PVP) as a surfactant to synthesize nanoscale AgN_3 by in-situ synthetic strategy. The analysis results demonstrated that the nano-AgN_3 had a spherical distribution, and great initiation performance. The average velocity of the titanium (Ti) sheet impacted by AgN_3 can reach more than 2600 m/s. In addition, the CL-20 explosive can be initiated stably and reliably by the AgN_3 chip assembled in the micro-initiator. It provides a new technical route for the application of MEMS micro-initiator.

Keywords. Silver azide, in-situ synthesis, nanoscale explosives, nano-Ag_2O, primary explosive

1. Introduction

With the development of modern warfare and the progress of science and technology, the requirements of intelligence, miniaturization and reliability of fuze are becoming higher and higher. Micro-initiators developed on the basis of MEMS (micro-electro-mechanical system) technology, with small mass and volume, play an important role in improving the performance of MEMS fuze and meet the requirements of modern weapons and equipment for miniaturization and intellectualization of fuze [1]. Therefore, in recent years, the research and application of micro-initiator has attracted great attention. In terms of structure design, the micro-initiator can separate the energy exchange element, the primer and the secondary explosives such as HNS-IV and CL-20 through the security mechanism. This special structure greatly improves the safety and reliability of weapon equipment.

Traditional primary explosives represented by heavy metal azides, such as lead azide (LA) and lead styphnate (LS) have been widely used [2-4]. However, lead does great harm to people and the environment during its use [5], and the most widely used primary explosive LA/LS can not be applied to micro-initiators due to its poor initiation ability [6, 7]. In recent years, researchers have considered utilizing various primary explosives to optimize the initiation ability of micro-initiators. Nevertheless, it is difficult for primary explosives synthesized by the liquid-phase method to meet the filling and using

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requirements of micro-initiators. In this paper, researchers directly fabricated the primary explosives chips by the gas-solid phase or liquid-solid phase azide reaction with nanoscale metal particles, which have become one of the hotspots in the field of energetic materials.

As a typical high energy initiator, AgN_3 has also attracted the attention of some researchers. Its electrostatic safety is far better than pure $Cu(N_3)_2$ (18 mJ compared to 0.05 mJ) [8-10]. Moreover, AgN_3 has better thermal stability, while it decomposes and releases nitrogen at about 250°C, and explodes when heated to about 300°C [11, 12]. And the explosive products are Ag and N_2, which are environmentally friendly. In this paper, the in-situ synthetic method effectively improved the sensitivity of AgN_3, avoiding the potential harm during its loading, transporting and using [13]. Furthermore, the AgN_3 chip assembled into a micro-initiator can successfully initiate 3.2 mg CL-20 explosive with a density of 1.48 g/cm^3 prepared by spray drying method [14], which makes it possible for AgN_3 to be widely used. In order to further study the application prospect of AgN_3, the initiation properties were studied in detail in this paper.

2. Experimental Section

2.1. Materials

AR Silver nitrate and anhydrous ethanol was obtained from Beijing Chemical Works, AR sodium hydroxide was obtained from Shanghai Saen Chemical Technology Co., Ltd., polyvinylpyrrolidone K30 was obtained from Xilong Science Co., Ltd., 85 wt% phosphoric acid was obtained from Shanghai Saen Chemical Technology Co., Ltd., AR sodium azide was obtained from MYM Biotechnology Co., Ltd., AR anhydrous calcium chloride was obtained from Tianjin Fuchen Chemical Reagent Factory, All chemicals were used without any further purification.

2.2. Synthesis of Nano-Ag_2O

Taking 400 mL 0.147 mol/L $AgNO_3$ solution which was dissolved with PVP as the base solution. 100 mL 0.025 mol/L NaOH solution was added dropwise to it. Then the reaction was carried out under ultrasonic (KQ-300E, China) and dark conditions for 2 h to make sure the reaction is complete. After that, the Ag_2O nanoparticle(NP) precipitate was separated by a high-speed centrifuge (XiangYi H1850, China), washed, and dried in an oven at 60°C for 24 h to obtain Ag_2O NP.

2.3. In-situ Synthesis of Nano-AgN_3

The in-situ synthesis system for AgN_3 includes a gas-solid in-situ reaction device, an anti-suction device and an exhaust gas treatment device. The Ag_2O NP was filled into the chip with a certain pressure before the reaction, whose size was 1 mm in inner diameter, 3 mm in outer diameter, and 0.5 mm in thickness. The chips were placed in the fixed splint. Then the splint was placed in the azide reaction vessel. In a typical reaction, 2.5 g sodium azide was contained in a three-mouth flask, and 5 mL phosphoric acid was filled in the constant liquid funnel, which was added dropwise to the flask and heated to 50°C to generate HN_3 gas. A wet test paper of Fe^{3+} solution was used to check the air

tightness of the device. Reaction time lasted 24 h, and it was lowed to room temperature after the reaction. Residual HN_3 gas in the container was purged by inert gas. The whole reaction device was removed and disassembled to obtain AgN_3 chips.

3. Results and Discussion

3.1. Analysis of Nano-Ag_2O

The morphology, composition and structure of nano-Ag_2O were studied by TEM (Figure 1). It can be seen that Ag_2O clusters with a relatively uniform particle size ranged from 70 nm to 90 nm. The morphology was almost sphere. Moreover, the Ag_2O clusters exhibited good dispersion and independence. We analyzed that the PVP dissolved in solution was adsorbed on the surface of nano-Ag_2O crystal during the synthetic process, which inhibited the Ag_2O agglomeration effect through the interaction between electrostatic repulsion, van der Waals force and steric hindrance effect [15], so as to regulate the size and dispersion of nano-Ag_2O.

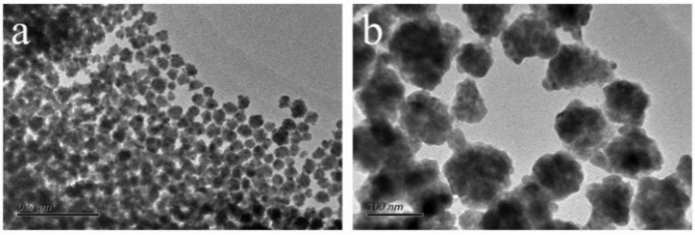

Figure 1. TEM figure of nano-Ag_2O.

3.2. Analysis of Nano-AgN_3

The microstructure of AgN_3 was analyzed by SEM. SEM test results of AgN_3 products with an azide reaction time of 0, 10 min, 30 min, 1 h, 2 h, 6 h, 12 h and 24 h are shown in Figure 2. It can be seen that with the extension of the reaction time, nano-Ag_2O particles were gradually converted to AgN_3, and the particle volume kept expanding. At the same time, the generated AgN_3 particles became larger and larger, which contacted each other and interweaved together to form the azide product with a denser structure. The independence of nano-Ag_2O particles disappeared and was transformed into AgN_3 particles with a larger particle size.

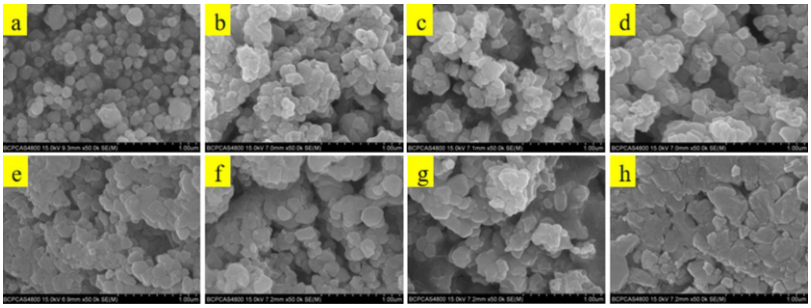

Figure 2. Reaction time. (a) 0; (b) 10 min; (c) 30 min; (d) 1 h; (e) 2 h; (f) 6 h; (g) 12 h; (h) 24h.

An X-ray diffractometer was used to further analyze the composition of AgN_3. (Figure 3). It can be seen from the pattern that the synthesized AgN_3 was consistent with the orthorhombic AgN_3 (JCPDS No.89-8021). The small diffraction peak located at 2θ=37.312° corresponded to Ag_2O instead of AgN_3, which also demonstrated that the AgN_3 product was a mixture of AgN_3 and Ag_2O without other components.

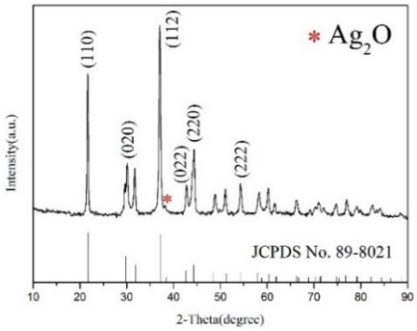

Figure 3. XRD pattern of AgN_3.

3.3. Investigation of Initiation Ability

The average velocity of the Ti sheet was measured by the electric probe method. In the actual measurement experiment, the size of the AgN_3 chip was 1 mm in diameter, 0.5 mm in thickness, and about 1.21 mg in mass. The average velocity of 20 um titanium sheet coordinated with 430 um, 580 um and 930 um acceleration chamber was 2182.74, 2660.55 and 2137.93 m/s respectively. Therefore, in the actual initiation experiment, the micro-initiation device was assembled by the 20 μm thickness Ti sheet and 580 μm acceleration chamber.

The AgN_3 chip was assembled into the micro-initiation device to detonate the CL-20 explosive prepared by the spray drying method. Besides, the AgN_3 chip was reacted for 24 h and the CL-20 explosive of 1.48 g/cm^3 was 1.5 mm in diameter, 1.2 mm in thickness and 3.2 mg in mass. Figure 4b showed that the dent depth of the aluminum plate was 0.70 mm. We can also see that the CL-20 explosive shell was blown up, and there was no explosive residue in the device, demonstrating that the CL-20 explosive was completely detonated. It showed that the SA chip synthesized by this method in this paper can detonate the CL-20 explosive in a micro-initiator, which meant it can replace the traditional primary explosives in some occasions.

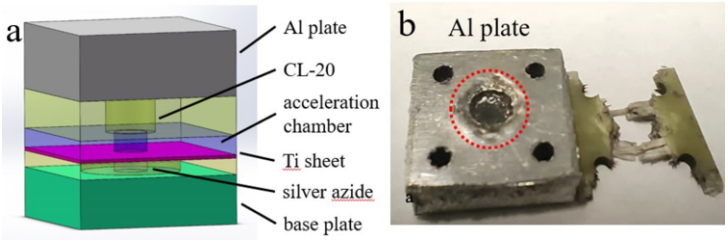

Figure 4. (a) Schematic illustration of micro-initiation device; (b) Al dent.

4. Conclusions

In summary, we synthesized nano-Ag_2O ranging from 70 nm-90 nm and took it as a precursor to fabricated AgN_3 chip by in-situ synthesis. Experimental results showed that the synthesized Ag_2O had high purity, uniform spherical particle size and good dispersibility. Furthermore, the chip containing 1.21 mg AgN_3 was assembled into a micro-initiator, which was assembled by the 20 μm thickness Ti sheet and 580 μm acceleration chamber, which can drive the Ti sheet to reach 2660.55 m/s. In addition, the AgN_3 chip can also detonate the CL-20 explosive successfully, which provides a new technical route for the application of MEMS micro-initiators.

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