Electrical Explosion of Wires Applying in Nanometer Materials Preparation

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Abstract – Many kinds of nanometer powders were produced by electrical explosion of wires (EEW). Further research on synthesis of Al_2O_3 and TiO_2 nanometer powders was carried out. The results of particles' size measurement showed that the average powder size of Al_2O_3 was 65 nm and that of TiO_2 was 44 nm. As the results of x-ray diffraction (XRD) and electron diffraction (ED), the particles of Al_2O_3 powder were γ-Al_2O_3 and the particles of TiO_2 powders were anatase and rutile. The effects of the experiment conditions on the powders' size were studied and the rule was concluded in brief. Moreover, the application of electrical explosion of wires in the chemical catalyzers has been investigated. The nanometer TiO_2 catalyzer was produced by EEW, and its catalyzing capability was studied simply.

1. Introduction

Electrical explosion of wires for preparation of nanopowders was developed in 1990. In Russia and Japan researchers produced many kinds of metal and metal compound nanopowders [1, 2, 3]. In China JiLin University synthesized Cu-Zn alloy nanopowders, whose particle size was between 30–180 nm, average particle size was about 85 nm [4]. In this paper, Al_2O_3 and TiO_2 nanopowders were successfully synthesized. The law was concluded for production of nanometer metal oxide powders by EEW.

Some researches show that nanometer catalyst will make chemical reaction faster 10–15 times than usual catalyst. In industry, composite catalyst is often used, because composite catalyst can improve catalysis, make separating catalyst from products easy and save materials. Electrical explosion of wires can finish preparation of nanopowders and spraying powders on the substrate in one step, then nanometer composite catalyst is gained. Application of EEW for nanometer composite catalyst has following advantages:

1. Particle size of catalyst coat is uniform.
2. The purity of the catalyst coat is very high.
3. The bonding between the coat and substrate is good.
4. The period of producing process is short.

In this paper, experiments on producing nanometer composite catalyst by EEW were carried out. Nanometer TiO_2 composite catalyst has been successfully produced.

2. Preparation of nanometer powders

Figure 1 schematically shows the arrangement of the experiment. When the capacitors are charged to the engaged value by high voltage source, the switch S1 is opened, the switch S_2 is triggered to be close. The pulse current passes the electrodes and the wire between them. When a high density (10^4–10^6 A/mm^2) current pulse, which is usually produced by the discharge of a capacitor, passes through a metal wire, the electrical energy can be deposited in the wire due to its resistance. The energy in the wire may considerably exceed the energy to evaporate the wire. The wire is molten, then evaporated into melt vapor or further produces plasma expanding into the ambient gas. The high temperature vapor or plasma cools rapidly because of collision with the ambient gas, then condense uniformly into powders. If the metal vapor or plasma reacts with the ambient gas, metal compounds would be synthesized. After a shot, the gas in the chamber was drawn out through the filter by a pump. The powders were gathered on the filter.

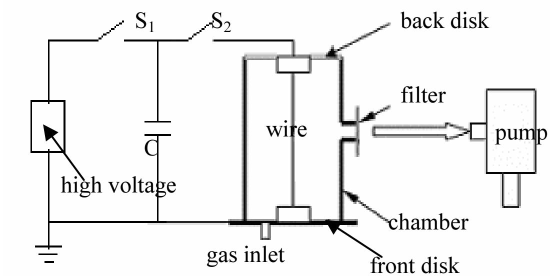

Fig. 1. Experimental setup for producing nanometer powders

Table I. Experiment conditions for producing powders

Wire			Gas pressure (Air)	Charging voltage (4 μF)
Material	Diameter	Length		
Al	0.25 mm	210 mm	0.02 MPa	36.5 kV
Ti				25 kV

The powders obtained in experiments were analyzed by using X-ray diffraction (XRD) and electron diffraction (ED) for evaluation of the crystalline component. The results of XRD and ED showed that the powders synthesized by exploding Al wire were γ-Al_2O_3 and that the powders produced by exploding Ti wire were composed of Anatase and Rutile.

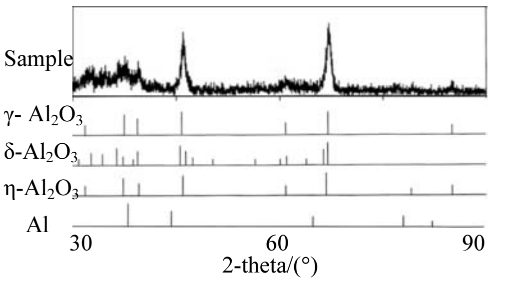

Fig. 2. XRD pattern of powders synthesized by exploding Al wire. There were 7 peaks identified as those of γ-Al_2O_3, close to those of δ-Al_2O_3 and η-Al_2O_3, there were no peaks of Al

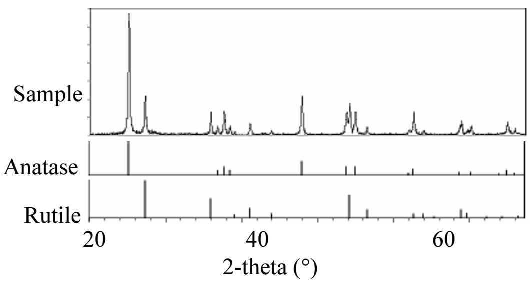

Fig. 3. XRD pattern of powders synthesized by exploding Ti wire. The peaks of the sample were composed of Anatase and Rutile

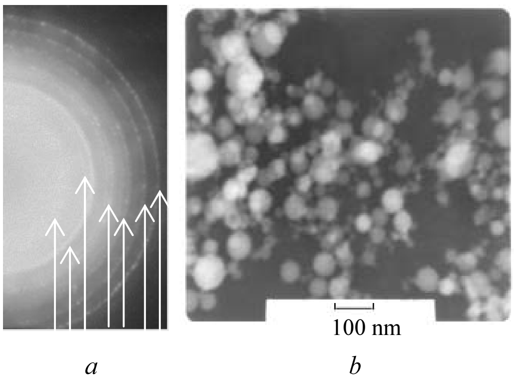

Fig. 4. ED pattern (*a*) and TEM photo of Al_2O_3 powders (*b*). The rings were identified as those of γ-Al_2O_3.The sizes of powders were less than 100 ns

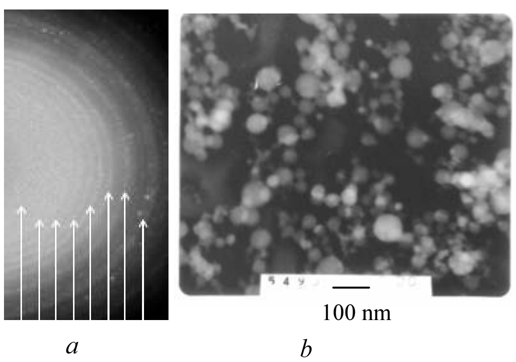

Fig. 5. ED pattern (*a*) and TEM photo of TiO_2 powders (*b*). The rings were identified as those of Anatase and Rutile. The sizes of powders were less than 100 ns

Malvern Zetasizer-Nano analyzer measured particle size of powders. The average size of Al_2O_3 powders was 65 nm (Fig. 4, *b*), and that of TiO_2 powders was 44 nm (Fig. 5, *b*).

3. Effects of experiment conditions on powders' size

The effects of the experiment conditions, including gas pressure in the chamber, the diameter of wire and energy stored in the capacitor, on powders' size were investigated.

The results show: (1) The lower gas pressure in the chamber, the smaller the particle size; (2) The smaller the wire's diameter, the smaller the particle size; (3) if $K < 3$, the average size of powders is the smallest when K is about 2.0; if $K > 3$, the average size of powders decreases as K increases. The reasons for these phenomena should be related to the concentration of the metal vapor. The heavier the concentration is, the bigger the particle size is. The results from experiments with Ti wires were similar to those of Al wires [6]. Therefore, the laws should be applied to synthesis of other nanometer metal oxides.

4. Application for nanometer catalyst

Some nanometer powders produced by EEW can be used as catalyst in the chemical reaction. But in industry, composite catalysts are often used, which is synthesized by spraying powders catalyst on the surface of the substrate. Nanometer composite catalyst can increase the catalyst-reactant interface and enhance reaction speed and production efficiency. Moreover, it is useful for separating the catalyst from the production.

Experiment conditions were following. The air pressure was 0.025 MPa, the diameter of wire was 0.25 mm, the length of wire was 210 mm, the distance between the wire and the substrate was 3 cm, and charging voltage of the capacitors was 40 kV. Powders were sprayed over the substrate twice in the same conditions. Microstructure of the coat on the substrate was observed by scanning electron microscope (SEM). From Fig. 7 it can be inferred that most of particles were below 100 nm in size. So nanometer composite catalyst was synthesized.

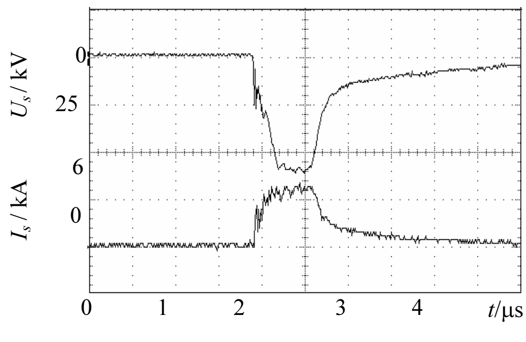

Fig. 6. Voltage and current on the metal Ti wire

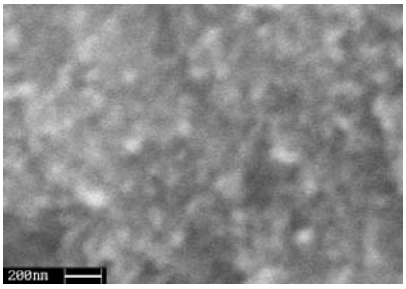

Fig. 7. SEM picture of the composite catalyst's coat

The chemical reaction experiment with catalyst gained was carried out many times. The experimental results showed that the catalyst enhanced the speed of reaction 50% and the selectivity of production 3%, compared with customary catalyst.

5. Conclusion

Nanometer TiO_2 and Al_2O_3 powders were produced by EEW, and their average sizes were 65nm and 44nm, respectively. Research results show that the conditions affect the size of powders very much. (1) The lower gas pressure in the chamber, the smaller the particle size. (2) The smaller the wire's diameter is, the smaller the particle size. (3) The particle size varies non-linearly with the initial energy stored in capacitors.

Investigation on application of electrical explosion of wires for chemical catalysts has been carried out. Nanometer TiO_2 composite catalyst was synthesized by EEW. The average size of particles in the coat was below 100 nm. Chemical experimental results show that the new type of catalyst has superiority in accelerating reaction and selecting production, compared with customary catalyst.

References

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