PRODUCTION AND CHARACTERIZATION OF NANO COPPER POWDER USING ELECTRIC EXPLOSION PROCESS IN LIQUID MEDIA

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Abstract

Nanoscience and Nanotechnology are the growing fields of scientific research and commercial development. Nanosize powders are solid particles with typical size in the range of 1 to 100 nm. Nanosize powders have very large specific surface area giving rise to many special physical and chemical properties. The important objective of the present research is to produce high purity Nanopowder using pulse power technique. The advantage of the pulse power generation is that particle size could be controlled by varying the injected power and the method has high energy efficiency and high product purity. In the present study charging voltage, dielectric strength of operating medium, length and size of operating wire on the production of Nanoparticle were analysed. We exploded Cu wires of 25 mm in length and 0.08 mm in diameter in distilled water with same discharge energy /mol. The capacitance of the energy storage capacitor was 50000pF, and the charging voltage was varied from 30 kV to 40 kV. The mechanism of generation of Nanoparticles using pulsed power technique is explained in detail. Also the relationship between different control parameters on the particles were explained in detail.

Keywords: *Nanopowder Production, Wire Explosion Method, Copper Nano Powder, Trigatron Switch*

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1. INTRODUCTION

Nanopowders, also known as ultrafine powders , may be defined as powders or particles that have dimensions under 100 nm. The uniqueness of nanoparticle arise from their high ratio of surface area to volume. For this reason, nanosize powders are of many interesting application in material processing for electronics, magnetics, and optics. They are also applicable as catalysts and pigments.

The production of nanosized powder is one of the main application of wire explosion, and it is a simple method for producing various kinds of nanosized powders with particle diameters of less than 100 nm.

In the present work, wire explosion technique is adopted, which is a top down approach to produce nanopowders. This is basically an evaporation technique, where the particles are produced by passing a high pulsed current over a thin metallic conductor. This deposited energy melts, evaporates and ionizes the wire material resulting in a plasma that expands into the liquid medium. This high temperature plasma gradually cools due to the interaction with liquid resulting in a vapour of the wire material that condense uniformly in liquid media to form nanoparticles.

The main objective of the present work is to produce Nanocopper powder by using the wire explosion technique and to characterize them to confirm the formation of nanosized powders. By providing proper energy to the conductor to evaporate, it is possible to control the size and shape of particle. When the method of wire explosion in liquid is used in metal powder production, we can expect several advantages compared to conventional wire explosion in air. One of the advantages is that we can produce a non-oxide metal powder without a vacuum process, and we can safely keep the non oxide phase to the final stage of applications. In this study we produced copper nanopowders by wire electrical explosion in liquid media.

2. THEORY

2.1 Voltage to be applied to Evaporate the Wire

For a copper wire of length 2.5 cm and diameter 0.08 mm, total energy required for evaporation is 6.627J.

Total energy required for evaporation = Energy required to melt the wire + Latent heat of fusion + Energy required to evaporate the wire + Latent heat of evaporation.

$E = mcs(tm – tr) + mlf + mcs(tb – tm) + mle$

Specific Heat capacity of copper (cs)=385 J/kg/degree Celsius at 25 degree Celsius.

Melting point of copper (m.p)=1357.77 K
Boiling point of copper (b.p) =2835 K
Latent Heat of fusion of copper (lf) =209000 J/kg
Density of copper = 8920 kg/m³
E= 5915745 m.
Mass (m)=density*volume.
Volume =1.256*10-10 m³.
Mass = 1.120*10-6 kg.
So Total energy = 6.627 J.
Energy stored in capacitor = 0.5 CV^2.
Available capacitor is of 50000pF.
0.5 CV^2 = 6.627 J.
So V= 16.281 kV.

In order to convert the wire into plasma state, we applied 6 times the vaporization energy of the wire. Thus the voltage applied was 40 kV.

3. EXPERIMENTAL DETAILS

The schematic diagram of the EWE system designed for liquid media explosion is shown in fig.1. The cylinder is of 200 mm diameter and 150 mm in height and is made up of PVC material. We filled half of the chamber with distilled water. The electrodes are fixed on a top cover made with insulating wood. The wooden top can be removed and reconnect the wire after every explosion. The wire of explosion is located at the ends of the electrodes, and the gap distance is 25 mm. We use the wire diameter of 0.08 mm.

After connecting the wire, we close the chamber cover, at the same time the wire is sunk in the distilled water.

Fig.1 Experimental set up

A capacitor of 50000pF was charged to 40kV and the stored electrical energy was transferred to the copper wire in the form of impulse. The wire was connected to the capacitor through a trigatron switch. When the triggering occurs the stored energy is passed through the wire. It takes under 0.5s for the triggering action normally.

After 21 shots of the explosion, where each shot was carried out within 4 minutes, the colour of distilled water was gradually changed to brick red colour. This shows the presence of Nanoparticles in the distilled water.

After the experiment the distilled water was collected in a bottle. The submicron-sized particles naturally settle down. The speed of sedimentation can be accelerated by using centrifugal separator. Separated particles are collected and these are tested using SEM, TEM, and XRD analysis.

4. RESULT

The wire installed between the electrodes was turned into particles in every discharge. However, we cannot say that all the wire was turned into nanosized particles. Figure 3 shows that a large number of submicron-sized particles exist in the produced copper powders, even though discharge energy is 6 times larger than the vaporization energy of the wire (3.0 kJ). The existence of submicron sized particles has been attributed to the very high vapor pressure during the explosion. Under the high vapor pressure, the wire could not totally be vaporized even though the energy deposition exceeded the vaporization energy of the wires because additional energy would be required to vaporize the inner part of the wire. Thus, a little of the inner part of the wire still remained in a liquid state, finally the non-vaporized part was disintegrated into submicron-sized liquid droplets, resulting in the formation of submicron-sized particles [6].

The submicron-sized particles naturally settle down. The speed of sedimentation can be accelerated by using centrifugal separator. Figure 4 shows FE-SEM images of copper nanoparticles classified by using a centrifugal separator. Most micrometer-sized particles precipitated at the conditions of 500 rpm for 5 minutes, as shown in Fig. 2. The colloid, after a first separation at 500 rpm for 5 min, was precipitated again at 1000 rpm for 5 min. This process was repeated at the conditions of 1500, 2000, 2500, and finally 6000 rpm, respectively for 5 min. The particles precipitated at 2000 rpm and 6000 rpm are shown in Figs. 3 and 4.

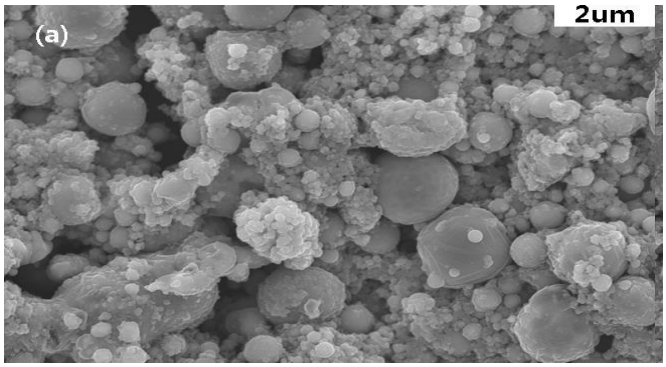

Fig.2 FE-SEM images of Copper powders size-classified with centrifugal separator: (a) 500 rpm, 5minutes;

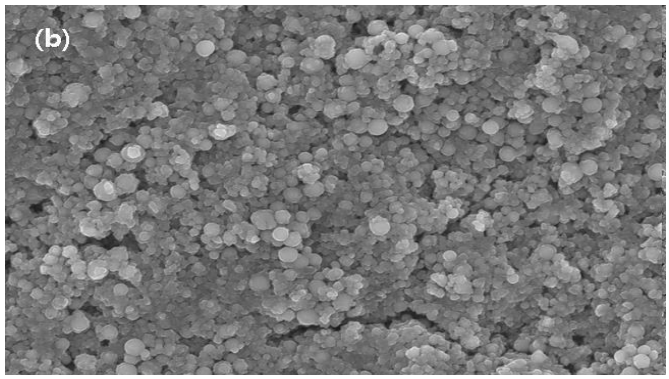

Fig.3 FE-SEM images of Copper powders size-classified with centrifugal separator: (a) 2000 rpm, 5minutes;500 nm

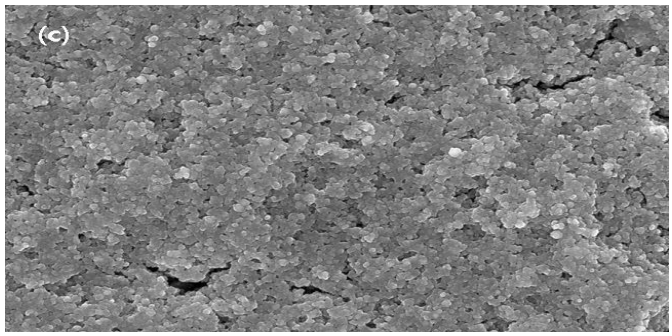

Fig.4 FE-SEM images of Copper powders size-classified with centrifugal separator: (a) 6000 rpm, 5minutes;200 nm.

5. CONCLUSIONS

We successfully exploded copper wires of 0.08 mm in diameter and 25 mm in length in distilled water at an energy of 40 J, which is 6 times larger than the vaporization energy, to produce copper powders. The copper powder showed a wide size distribution. The existences of large numbers of submicron-sized particles were attributed to unvaporized metal droplets. The powder was classified by diameter and was gathered by using a centrifugal separator. The size of Nanopowder observed was between 200 to 500 nm.

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