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Fabrication of Nanocomposite Powders by Sonochemical Method

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Abstract Nano particles have recently been a major research interest, motivated by their unusual physical and chemical properties. Such particles can be synthesized using physical and chemical methods. The physical methods need expensive installation like vacuum induction furnace. whereas in chemical methods the process is generally very simple and low cost. In this study, simple and new fabrication process by using ultrasound was investigated to prepare the nano-sized metal particles on various powders at room temperature.

Keywords : Nanocomposite powders, Sonochemisty, Ag-coated ZnO, Microstructure

1. Introduction

The chemical applications of ultrasound have become an exciting new field of research during the past decade.[1-3] It has been known that the chemical effects of ultrasound are diverse and include substantial improvements in both stoichiometric and catalytic chemical reactions. In some cases, ultrasonic irradiation can increase reactivity by nearly a millionfold. The chemical effects of ultrasound do not come from a direct interaction with molecular species but principally from acoustic cavitation.

Cavitation in a liquid occurs due to the stresses induced in the liquid by the passing of a sound wave through the liquid. A sound wave consists of compression and decompression/rarefaction cycles. If the pressure during the decompression cycle is low enough, the liquid can be torn apart to leave small bubbles. These cavitation bubbles (similar to those seen arising from the action of a boat propeller on water) are at the heart of sonochemistry systems. These bubbles are now subjected to the stresses induced by the sound waves. This causes the bubbles to grow during a decompression phase, and contract or even implode during a compression phase. Each one of these imploding bubbles can therefore be seen as a microreactor, with high temperature, and pressures of several hundreds of atmospheres.[4,5] In these processes, the use of ultrasonic irradiation facilitates the reduction. Organic liquid can generate free radicals upon ultrasonic irradiation, and it is easy to reduce metal ions.[6-7] The reduction of metal oxide particles based on this approach therefore can offer a unique route for synthesis of nano-sized metal and metal composite powders. In this study, the preparation of nano-sized Ag powders by sonochemistry technique is described.

2. Experimental Procedure

Sonication was performed with a ultrasonic generator (45 kHz) equipped with a transducer set at the tip of a horn which was immersed in a water. The output power of the generator is 150 W. Ag_2O powders with average particle size of about 3 μm were used as starting material. The powders were immersed in ethanol, which was contained in the beaker. The beaker was partly submerged in water in an ultrasonic generator. Powders were irradiated with ultrasound at room temperature. The dried powders were characterized by X-ray diffraction (RU-200B, Rigaku Co., Tokyo, Japan), in which a scan rate of 5°/min was used to record the patterns in the 2θ range of 20-100°. In order to examine the morphology and particle sizes of the products, transmission electron microscopy (TEM) images were taken on Hitachi Model H-8100, using an accelerating voltage of 200 kV.

3. Results and Discussion

The XRD patterns of the starting and product

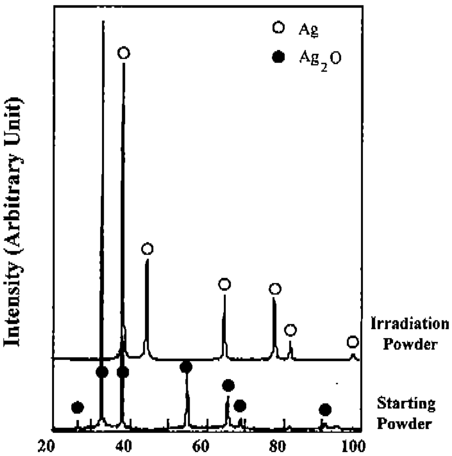

Fig. 1. XRD pattern of Ag_2O powders before and after ultrasonic irradiation.

Fig. 2. Ag-coated glass substrates in a function of ultrasonic irradiation.

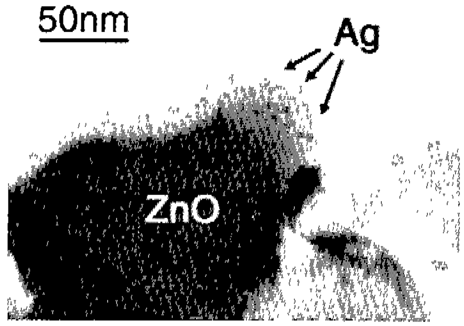

Fig. 3. TEM image of ZnO based Ag nanocomposite powders, synthesized by ultrasonic irradiation.

powder prepared by the sonochemical method are shown Fig. 1. The XRD pattern before ultrasonic irradiation contains the characteristic peaks for Ag_2O. After irradiation, Ag_2O peaks are not observed anymore, whereas the lines for Ag are found. This result indicated that Ag_2O powder was reduced into metallic Ag by ultrasonic irradiation at room temperature.

Figure 2 shows the Ag-coated glass substrates prepared by the ultrasonic irradiation. The color of glass substrates gradually changed from yellow to translucent metallic color due to the irradiation. These results suggest the formation of Ag particles on the surface of glass substrates. Fig. 3 shows TEM image of the products and the size distribution of the formed Ag particles on zinc oxide. It was indicated that the Ag particles were of nanometer size as an average size of less than 5 nm and homogeneously dispersed on the surface of powders.

In case of liquid-powder slurries subjected to ultrasonic irradiation, the turbulent flow and shock waves produced by intense ultrasound can drive metal particles together at sufficiently high speeds to cause effective melting at the point of collision. Such collisions are capable of inducing striking changes in surface texture, composition, and reactivity. Thus, it produces a newly exposed and highly heated surface, which makes the reduction of Ag_2O easily and rapidly.[8-9] Based on this process, therefore, it is interpreted that the nucleation of metallic Ag from Ag_2O occurred in solution, and then the growth and immobilization of the Ag particles would proceed on glass substrates.

4. Summary

Fabrication of nanocomposite powders by sonochemistry was reported in this study. It was able to deposit the Ag nanoparticles on zinc oxide powders and glass substrates at room temperature by the sonochemical reduction. It can be explained that the most important parameter in sonochemical effects observed in reduction of Ag_2O is the cavitation induced by ultrasonic irradiation. Considering that this method is very simple, safety and clean, it is reasonable to expect that the sonochemistry route can be extended to obtain various nanocomposite powders.

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