Materials Letters 213 (2018) 7–10

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/mlblue

Synthesis, characterization, and properties of porous silver spheres using rape pollen as novel bio-templates

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ARTICLE INFO

Article history:
Received 22 August 2017
Received in revised form 20 October 2017
Accepted 25 October 2017

Keywords:
Electronic materials
Microstructure
Silver
Nanoparticles
Template
Rape pollen

ABSTRACT

Porous silver spheres were successfully prepared by reducing silver-ammonia solution and using rape pollen as novel bio-templates. The synthesized porous silver spheres with diameter of 50 μm have nanoparticles of ca. 25 nm. The samples were characterized by X-ray diffraction, scanning electron microscope (SEM), and transmission electron microscope (TEM) techniques. The thermal and electrical properties were also studied. We find that the reaction temperature and $AgNO_3$ concentration have important influence on the morphology and electrical properties of the final products. TEM observations showed that the as-synthesized products are composed of nanoparticles with size around 25 nm. Volume resistivity results revealed that the volume resistivity was decreased with increasing the amount of $AgNO_3$ concentration. The volume resistivity of porous silver was decreased two orders of magnitude while the $AgNO_3$ increased twice.

1. Introduction

Silver powder is an important material in the electronics industry field because of its high electric conductivity and chemical stability under various conditions [1,2]. Porous silver powder, in particular, has important applications in fuel cells, chemical sensors, catalysis, single-molecule sensors, surface-enhanced Raman scattering, chemical sensors due to its unique properties [3,4]. Various methods including template method, electrochemical, ultrasonic spray pyrolysis, spray drying and calcining technology have been used for preparing porous silver [5,6].

The template synthesis is a simple and general chemical method for preparing porous metal. The templates used mainly include negatively charged spheres, functionalized hollow silica spheres, starch, silica colloidal, and other templates [7,8]. Recently, there are some reports about the production of porous silver using template methods. Zhang et al. have been synthesized monodisperse hollow Ag by a facile colloidal templating method. However, the silica colloidal templates were still hardly to remove completely [9]. Park et al. provide a strategy to prepare the hollow silver spheres by accumulating the silver nanoparticles on the surface of functionalized silica as templates [10]. Walsh et al. chose dextran as a soft template for the synthesis of metallic and metal oxide sponges, such as silver sponges [5]. Although some progresses has been made in these research areas, further investigations are still needed for better control the structure and morphology.

In our present work, we reported a facile method for the synthesis of porous silver spheres starting from silver nitrate and using rape pollen as a novel green bio-template. In this method, the rape pollens were beneficial to the formation of porous silver with dense structure. To the best of our knowledge, no previous studies have explored the fabrication of porous silver spheres using this bio-template method. The effects of the experimental parameters, such as the reaction temperatures, the relative amount of rape pollens and silver nitrate were investigated. At the same time, the thermal property and conductivity properties were also studied.

2. Experimental

All the chemicals were analytical grade and used in the present work without further purification. In a typical synthesis process, 0.6 g of $AgNO_3$ (>99%) was dissolved in distilled water at room temperature, and then $NH_3{\cdot}H_2O$ aqueous solution (25%, wt/wt) was added to above solution to form silver-ammonia solution (clear solution). Then, 0.2 g pure rape bee pollen was introduced under continuous stirring for 60 min by ultrasonic dispersing technology. In the third step, 35 mL HCHO aqueous solution (0.03 g/mL) was added by dropwise into above solution in 30 min at 60 °C. The mixed solution was then stirred for 60 min. A dark brown precipitate was formed during the stirring. The product was washed five times with distilled water and absolute ethanol and then dried at 60 °C for 24 h under vacuum environment.

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https://doi.org/10.1016/j.matlet.2017.10.108
0167-577X/

The final products were characterized using field emission scanning electron microscope (FESEM, Hitachi S3400N), transmission electron microscopy (TEM, Hitachi, HT7700, 100 kV), X-ray diffraction patterns (XRD, Bruker D8 Advance, Cu Kα radiation, λ = 1.5406 Å). TG analysis was carried out over the temperature range from 20 to 790 °C at 10 °C/min rate by mean of SDT Q600 instrument. The electrical properties of products were determined by using standard four probes techniques.

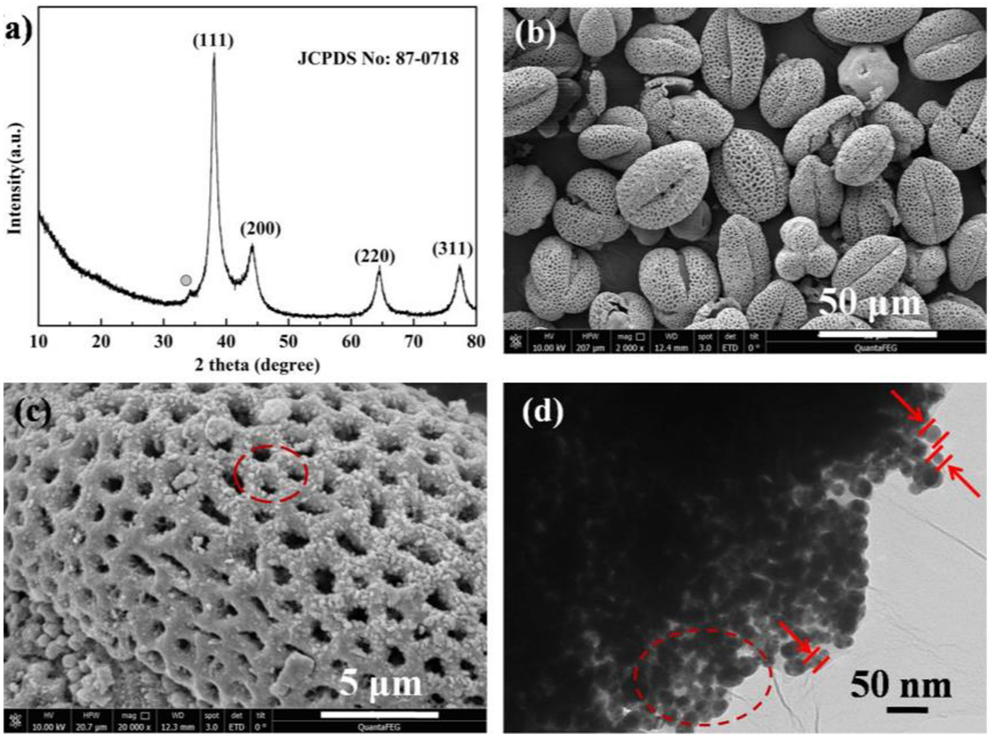

Fig. 1. XRD pattern (a), Low-magnification SEM image (b), high-magnification SEM image (c), and TEM image of as-prepared porous silver.

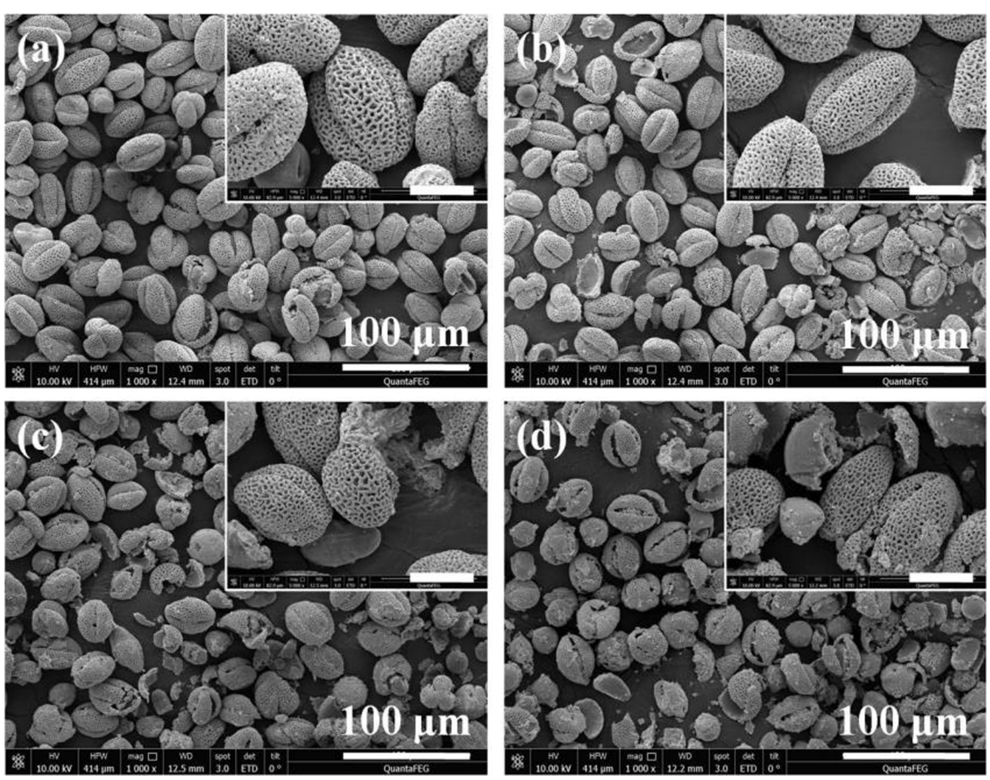

Fig. 2. SEM images of the samples prepared with different reaction temperature of (a) 40, (b) 50, (c) 60, and (d) 80 °C with loading 0.6 g $AgNO_3$. The insets are the corresponding higher magnification SEM images. All scale bars are 20 μm.