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Synthesis of quartz crystals supporting Ag nanoparticle powder with enhanced antibacterial properties

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ABSTRACT

The commonly natural quartz stone was selected as the substrate materials for supporting Ag nanoparticles due to its high temperature resistance and low cost. The quartz crystals supporting Ag nanoparticles powder have been fabricated successfully through the silver nitrate loading on natural quartz precursors, which were obtained by a solvent evaporation process. After being calcinations, Ag nanoparticles with size of 30–50 nm were deposited on the surface of quartz matrix. Experimental studies revealed that the concentration of $AgNO_3$ plays a pivotal role in controlling the size and agglomeration of Ag nanoparticles in final products. The optimum temperature of $AgNO_3$ thermal-decomposing is ca. 500 °C. With increasing the concentration of Ag nanoparticles attached on quartz crystals, some Ag particles grow up, and the colors of the powder change from light yellow to brown. Antibacterial tests showed that the quartz crystals supporting Ag nanoparticle exhibit excellent antibacterial performance against *E. coli*, mainly attributed to the facts that the Ag nanoparticles can penetrate into the bacteria and cause the death of bacteria cells.

1. Introduction

As an important functional material, silver has attracted remarkable attention due to its stability, durable and broad spectrum antibacterial activity based on the unique chemical and physical properties [1–3]. Recently, it is reported that silver nano-particles show enhanced antibacterial performance than that of bulk silver materials because of their higher surface area and good dispersibility in sample. AgNPS can readily penetrate into the bacteria and interact with proteins in the cells and this process may cause the death of bacteria cells [4]. However, the antibacterial property of pure AgNPS was still be influenced by the aggregation of nano-particles and complex condition such as water, sunlight and air [5]. As a result, their antibacterial activity may be affected by the working environments. To solve these problems, the proper substrates can be used to support AgNPS, which is an efficient method for the dispersion of the small nano-particles. Recently, a wide range of materials, such as SiO_2, TiO_2, ZnO, carbon and graphene et al., have been selected as the supporting materials. Lin et al. [6] utilized hollow silica spheres synthesized by core-shell template method as silver-loading substrates and antibacterial activities of the silver loaded spheres were studied. Youssef et al. [7–9] prepared chitosan–silver nanocomposites films, chitosan (CS)/calcium silicate nanocomposites doped with Ag-nanoparticles, polyaniline (PANI/PS)/Ag-NPs nanocomposite via sol–gel method. Meanwhile, they also prepared TiO_2 nanoparticle doped silver and TiO_2 nanowire doped silver via photo-reducing Ag^+ ions to Ag metal on the TiO_2 nanoparticle or TiO_2 nanowire surfaces [10]. And these materials reduce aggregation of Ag nanoparticles and enhance their antibacterial activities. Panwar et al. [11] reported a facile method for the synthesis of silver-silica Janus particles with functionalities suitable for textile applications. Liu et al. [12] synthesized silver-modified TiO_2 nanorods via controlled hydrolysis of tetrabutyltitanate in ethanol and immersion method. Zhang et al. [13] found that the bacterial activity of Ag/ZnO heterostructure nano-particles against *Escherichia coli* was enhanced greatly in contrast with that of the simple mixture of Ag and ZnO nanoparticles. Jiang et al. [14] fabricated a novel Ag/C antibacterial agent using the corn crispy as the carbon substrate for supporting the Ag particles. Unfortunately, although the above works are very interesting, the preparation processes seem to be very tedious. First, multi-steps processes are needed for the synthesis of supporting materials, which would increase the cost of antibacterial agent [15,16]. Second, some antibacterial agent used in high temperature environment such as antibacterial ceramics, require substrate materials resistant to high temperature [17]. Therefore, the proper substrates materials selected to support AgNPS is critical to antibacterial activity and application of antibacterial agent.

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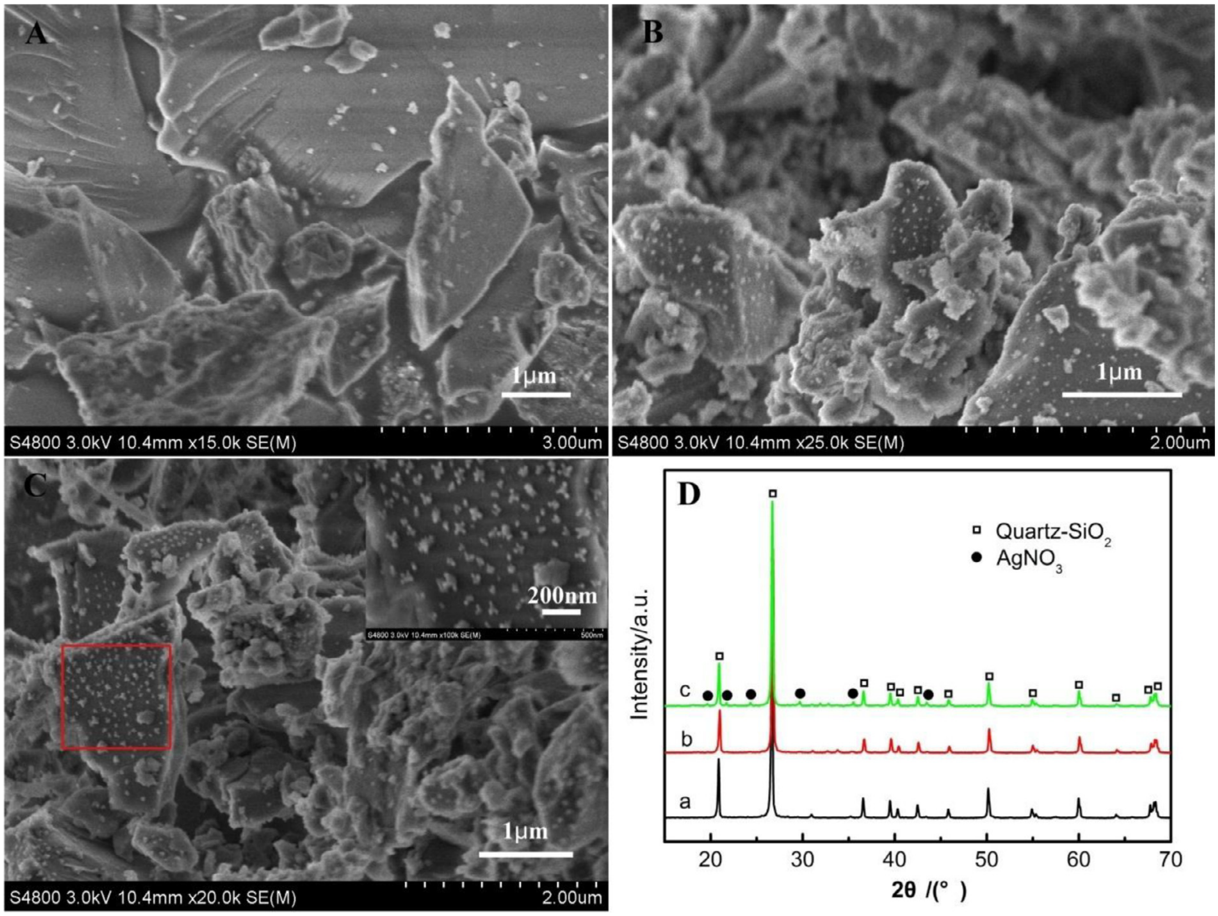

Fig. 1. SEM micrographs (A–C) and XRD patterns (D) of quartz crystals absorbing 1% (a), 5% (b), 10% (c) $AgNO_3$. The inset of C is the magnified SEM micrograph of red outline area in C. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

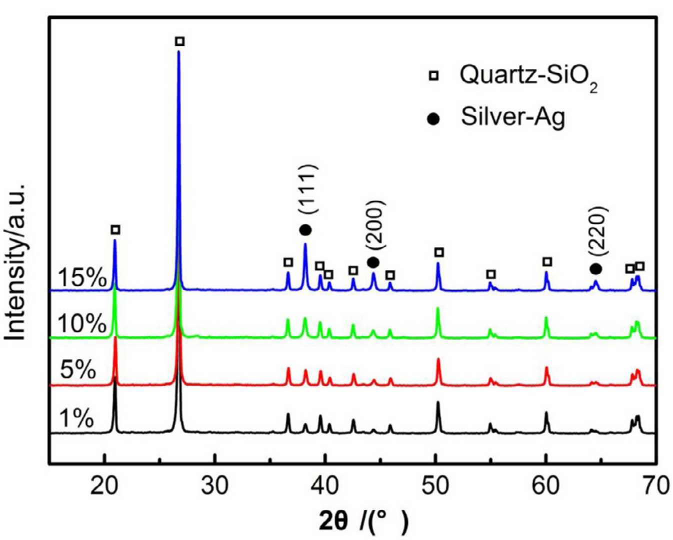

Fig. 2. XRD patterns of quartz crystals absorbing different $AgNO_3$ under calcinated at 500 °C for 4 h.

Quartz crystal, mainly components of natural sand stone, is one of the most used crystals in world. Based on its physical and chemical characteristics, quartz crystals are widely used in industrial manufactories [18–20]. Meanwhile, they are featured for low cost, resistant high temperature and non-toxic. In this paper, we report the fabrication of quartz crystals supporting AgNPS powder with antibacterial performance. The commonly natural quartz stone was selected as the substrate materials. AgNPS attached on quartz stone were synthesized by absorption and thermal decomposition of $AgNO_3$. The structure and dispersion of AgNPS attached on quartz crystals, the thermal behavior and the antibacterial performance of quartz crystals supporting AgNPS powder were discussed.

2. Experimental

2.1. Materials

White natural superfine quartz stone (SiO_2, ≥95%; fineness ≤20 μm) was obtained from Shaanxi Huagao Quartz Sand Co., Ltd., China. The other chemicals were analytical grade without further purification. $AgNO_3$ (silver nitrate, A.R.) was purchased from Sinopharm Chemical Reagent Co., Ltd., China.

2.2. Preparation of quartz crystals supporting AgNPS powder

The quartz crystals supporting AgNPS powder were synthesized by adsorption and metal salt thermal decomposition. To optimize the AgNPs deposition on the surface of quartz crystals, we prepared quartz crystals supporting AgNPS powder through changing reaction conditions. In a typical reaction, 2 g superfine quartz stone were dispersed into 50 ml distilled water and ethanol and sonicated for 30 min. Then a desired amount of $AgNO_3$ solution (the concentration of 1.0 g/100 ml) was added to the solution with continuous stirring and solvent was evaporated at 50 °C for designed