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Synthesis of flower-like and dendritic platinum nanostructures with excellent catalytic activities on thermal decomposition of ammonium perchlorate

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ABSTRACT

A simple and effective method is developed to synthesize flower-like platinum (Pt) nanostructures through galvanic replacement reaction between aluminum (Al) nanoparticles and $PtCl_2$ aqueous solution at room temperature. Pt flowers exhibit an average size of approximately 1 μm, and many thin nanosheets comprise such flower-like structure. Dendritic Pt nanostructures can be obtained by simply adding an amount of polyvinyl pyrrolidone (PVP) into the reaction solution. Nanodendrites, which are 30–100 nm in size, are rich in interconnected nanoparticles. The catalytic activity on the thermal decomposition of ammonium perchlorate (AP) was characterized by DSC/TGA. Results showed that the addition of flower-like and dendritic Pt nanostructures decrease the high decomposition temperature of AP by 96 °C and 114 °C, and increases the total DSC heat release by 1.28 and 1.36 kJ g^{-1}, correspondingly. The obtained Pt nanostructures demonstrate excellent catalytic activity for thermal decomposition of AP.

1. Introduction

In recent years, nanosized noble metal materials gained considerable attention because of their unique physical and chemical properties [1–3]. In particular, platinum (Pt) nanostructure plays an important role in many industrial applications [4]. For example, Pt catalyzes the reduction of pollutant gases from automobiles, nitric acid synthesis, oil cracking, and proton-exchange membrane fuel cells [4–6]. All these applications require the use of Pt as fine particles. In addition, both reactivity and selectivity of Pt nanostructures in a catalytic reaction highly depend on their morphology and consequently on their crystallographic planes, which are exposed on the nanoparticle surfaces [6,7].

As such, controlling the size and shape of Pt nanostructures gained significant interest over the past few years. Considerable work is focused to manipulate the morphology and size of Pt nanostructures by finely adjusting the experimental conditions during their synthesis. To date, numerous Pt nanostructures have been prepared, such as wires [8], hollow spheres [9], corals [10], wheels [11], tubes [12], and frames [13]. Several recent reports were published regarding the synthesis of flower-like and dendritic nanostructures [14–20], because of their special structures, large surface areas, and unique properties. However, their synthesis involves complicated procedures and expensive raw materials. Therefore, a controllable, economic, and effective approach to synthesize flower-like and dendritic nanostructures should be developed.

Herein, we firstly present a facile strategy to synthesize flower-like and dendritic nanostructures via a simple replacement reaction between Al and $PdCl_2$ aqueous solution. The reaction was performed under room temperature and normal pressure. Furthermore, the flower-like and dendritic nanostructures showed excellent catalytic activity for thermal decomposition of ammonium perchlorate (AP), a key oxidizer in composite solid propellants.

2. Experimental procedure

The Al nanoparticles are commercial grade, and were obtained from Beijing Nachen S&T Ltd. Other reagents were of analytical grade purity and were used directly without further purification. In a typical synthetic procedure, 0.027 g of Al nanoparticles was added to a stirred 3×10^{-3} mol L^{-1} $PtCl_2$ solution with or without 0.005 g L^{-1} PVP (M_w = 55000) at room temperature. The pH value was adjusted to 2.0 by adding 0.5 mol L^{-1} HCl. After 50 min of replacement reaction, the residue was separated and washed for several times with distilled water and absolute ethanol, respectively. It was then dried in a vacuum for 5 h at room temperature.

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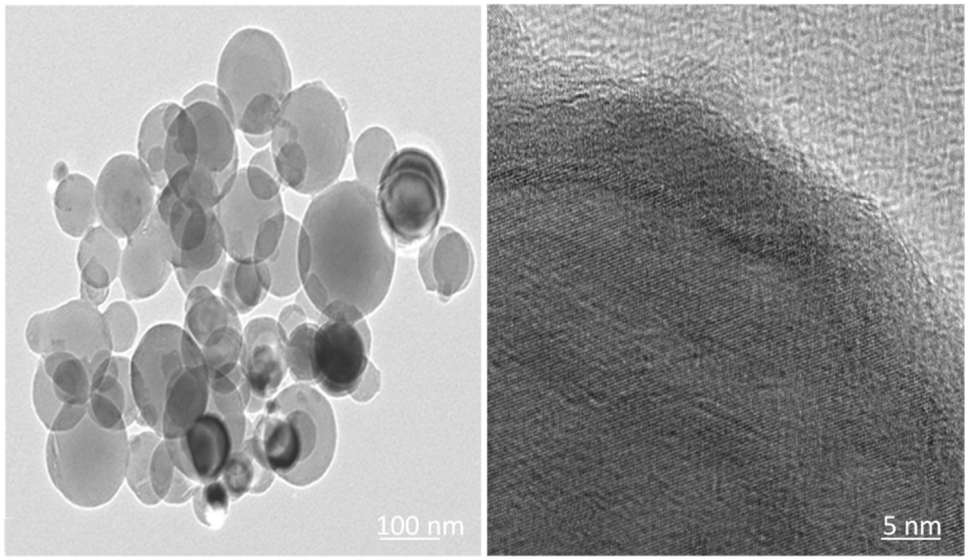

Fig. 1. TEM and HR-TEM images of aluminum reducing agent.

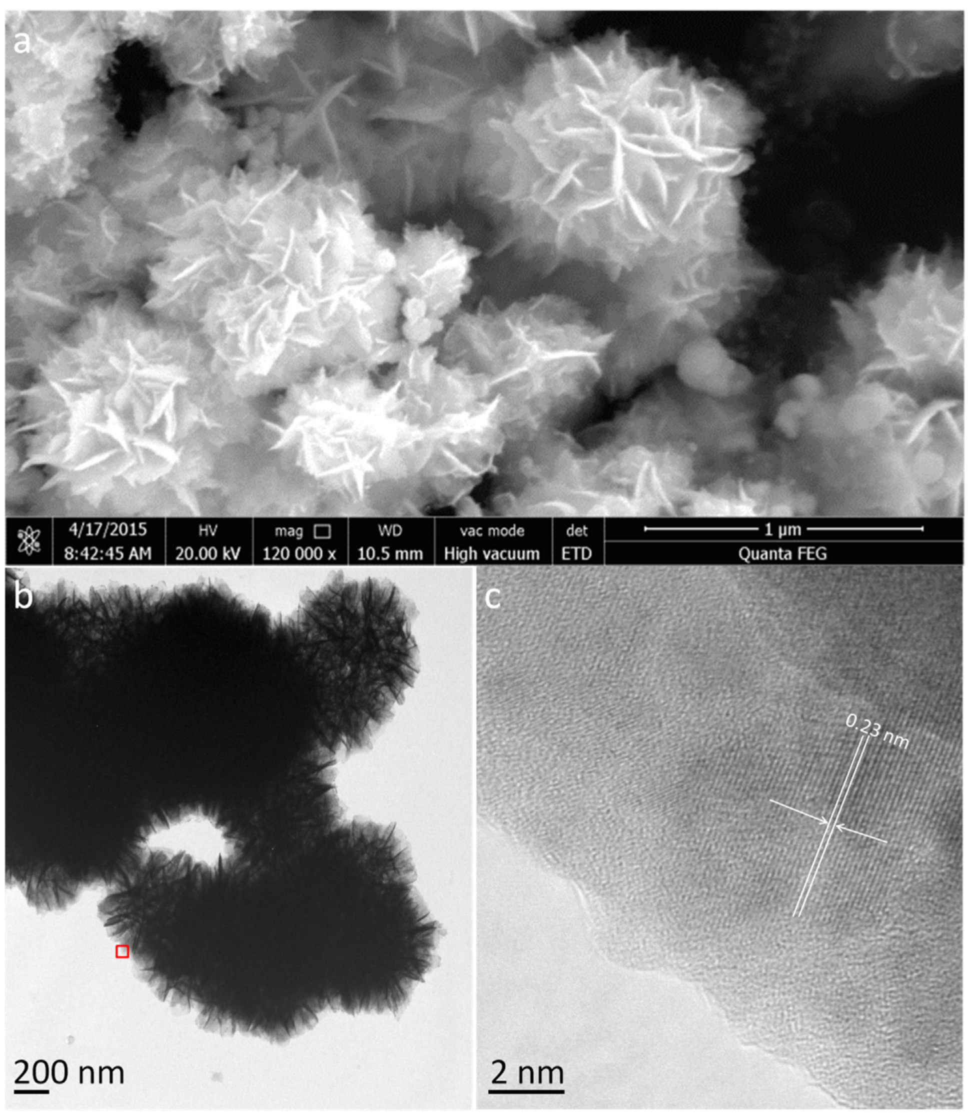

Fig. 2. FE-SEM (a) and TEM (b and c) images of flower-like Pt nanostructures prepared without PVP.