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Morphology controllable preparation and infrared emissivity of vanadium pentoxide

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HIGHLIGHTS

- V_2O_5 was prepared by hydrothermal method followed by a post-annealing treatment.
- Different morphologies of V_2O_5 can be controlled by surfactants.
- Microstructure of products has great influence on infrared emissivity.

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ABSTRACT

Vanadium pentoxide (V_2O_5) with different morphologies including nanorods, nanoparticles and microparticles have successfully been synthesized by surfactants assisted hydrothermal method combined with a post-annealing process. Structure, morphology and emissivity of the obtained V_2O_5 have been investigated by X-ray powder diffraction (XRD), scanning electron microscopy (SEM), Fourier transform infrared (FTIR) and infrared emissivity (IR-2). The results show that the morphologies of V_2O_5 play a key role in affecting the infrared emissivity. V_2O_5 nanorods show more excellent infrared emissivity (0.908 in wavelength of 3–5 μm, 0.986 in wavelength of 8–14 μm and 0.965 in wavelength of 1–22 μm) than that of V_2O_5 nanoparticles and microparticles.

1. Introduction

Vanadium pentoxide(V_2O_5) as a kind of transition metal compounds, presents out-standing optical, magnetic, electronic and electrochemical properties, which make it suitable for several applications(such as Li ion batteries [1–3], chemical sensor [4], catalyst [5], electrochromic devices [6–7], and field emitters [8]). To date, considerable efforts have been devoted to synthesize V_2O_5 with different morphologies. Li et al. developed a facile, green, and low-cost synthesis of leaf-like V_2O_5 nanosheets with superior electrochemical performance [9]. V_2O_5 nanobelts using as highly selective and stable ethanol sensor materials were synthesized by a hydrothermal approach [10]. Cao et al. developed a mediated polyol process to self-assemble V_2O_5 nanorods into hollow microspheres which exhibited desirable electrochemical properties [11]. Nevertheless, it remains a challenge to realize the morphology-controlled synthesis of V_2O_5.

High infrared emissivity materials have widely been used in energy conservation equipment or thermal protective system [12–14]. In recent years, many attentions have been attracted to improve the infrared emissivity by changing the factors of component, crystalline size, heat treatment, doping [15,16]. However, the relationship between infrared emissivity and morphology of materials has rarely been investigated. In this paper, V_2O_5 nanorods, nanoparticles and microparticles can be controllably achieved. Furthermore, the relationship between the infrared emissivity and morphology was also investigated, and it is found that the emissivity can be tuned by controlling the morphologies of V_2O_5.

2. Experimental

The controlled synthesis of V_2O_5 with different morphologies was realized by using different surfactants through a hydrothermal method with post-annealing process. In a typical synthesis, 1.17 g ammonium metavanadate (NH_4VO_3) was dissolved in 100 ml of deionized water, allowing ammonium metavanadate to completely dissolve under magnetic stirring. Nitric acid was added dropwise to adjust the pH of the NH_4VO_3 solution to 2–3. Then,

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5 g of F127 was added to the solution. The obtained solution was transferred into a Teflon-lined stainless steel autoclave and heated for 24 h at 180 °C. The precipitates was collected by centrifugation and washed with deionized water and ethanol for several times, and then dried at 70 °C for 12 h. Finally, V_2O_5 nanorods were obtained by annealing the as-prepared precipitates at 400 °C in air for 1 h. V_2O_5 nanoparticles were synthesized under the same conditions expect CTAB instead of F127, and V_2O_5 microparticles were synthesized under the same conditions without using surfactants.

The crystalline structure was characterized by X-ray diffraction (XRD Rigaku D/max-2550) using Cu Kα radiation. The morphology was analyzed by scanning electron microscope (SEM JSM-6700F). Infrared emissivity value was investigated by IR-2 infrared emissometer (Shanghai institute of technological physics of the Chinese Academy of Sciences) by the following steps: the prepared V_2O_5 powder was put into a mold (∅60 mm, 1 mm depth) and pressed by a smooth plate to ensure the same surface roughness of products. After the black body stabilized, the infrared emissivity of the samples with different wavelengths (1–22 μm, 8–14 μm and 3–5 μm) were obtained when the instruments calibrated at different temperatures (200 °C, 250 °C, 350 °C). Infrared spectrum was measured with Fourier transfer infrared spectrometer (FTIR, AVATAR370) using KBr pellets.

3. Results and discussion

The morphological evolution of the prepared V_2O_5 is investigated by SEM. As shown in Fig. 1, morphology of the prepared V_2O_5 changed dramatically by using different surfactants. Fig. 1(a) and (d) displays that the V_2O_5 nanorods with 0.5–1.3 μm in length and 70–150 nm in diameter are prepared by using F127. The sample prepared by using CTAB represents a spherical-like shapes with particle size of 70–220 nm (Fig. 1(b) and (e)). However, V_2O_5 microparticles with an average size of 1 μm are obtained without any surfactants in the hydrothermal process (Fig. 1(c) and (f)). Based on the SEM images, it is found that the morphologies of V_2O_5 can be tuned by the surfactants.

Fig. 2 shows the XRD patterns of V_2O_5 with different morphologies. All diffraction peaks are indexed to the orthorhombic structure of V_2O_5 (JCPDS No. 65-0131, space group Pmmn). As shown in Fig. 2, no other peaks are detected, indicating the products are pure orthorhombic V_2O_5. The peaks of V_2O_5 at $2\theta = 20.3$, 26.2, 31.0 are assigned to (001), (110), (400) diffraction peaks of orthorhombic V_2O_5.

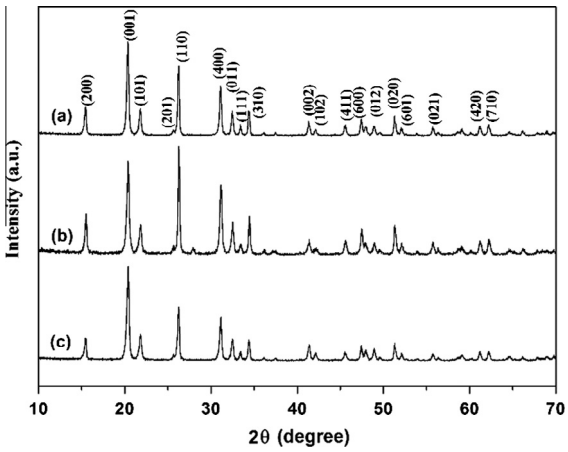

Fig. 2. XRD patterns of V_2O_5 with different morphology: (a) nanorods, (b) nanoparticles, (c) microparticles.

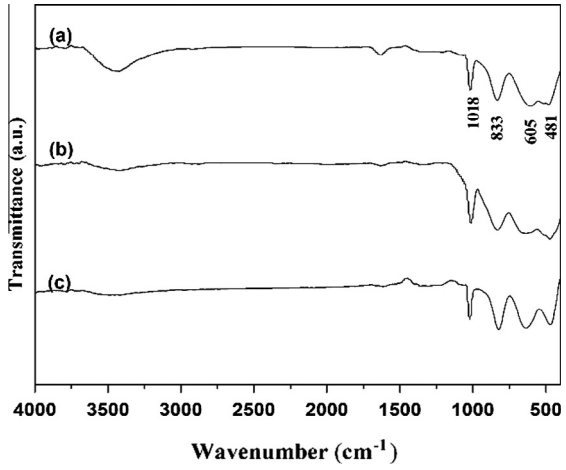

Fig. 3. FTIR spectra of V_2O_5: (a) nanorods, (b) nanoparticles, (c) microparticles.

FTIR spectra of V_2O_5 with different morphologies are shown in Fig. 3. Fig. 3(a) shows the spectrum of V_2O_5 nanorods and the peaks at 1018 cm^{-1} correspond to the V=O stretching vibration. The peaks around 833 cm^{-1} and 605 cm^{-1} are assigned to the symmetric and asymmetric stretching of V—O—V. The peak at 481 cm^{-1} is assigned to the V—O—V bending vibration [17,18]. As can be seen from Fig. 3b and c, the similar peaks are also found in the spectrum

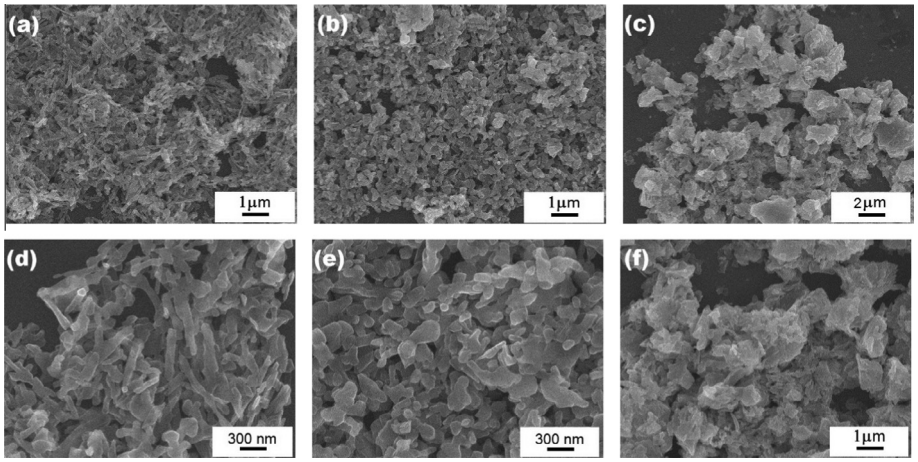

Fig. 1. SEM images of V_2O_5: (a) and (d) nanorods, (b) and (e) nanoparticles, (c) and (f) microparticles.