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Short communication

Synthesis of titanium nanorods with LPG as fuel and oxygen as oxidant in diffusion flame reactor

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ABSTRACT

Nanophase titanium dioxide (TiO_2) and titanium nanorods (TNRs) are synthesized by flame synthesis using LPG as fuel and oxygen (O_2) as oxidant. Titanium tetraisopropoxide is used as precursor. TNRs and titanium nanoparticle (TNP) is characterized by SEM and XRD. In this paper, process parameters are investigated to synthesize the TNRs and TNPs. TNRs are formed at 1.2 slpm of O_2; its average diameter is 200–600 nm. Average diameter of TNPs formed at 0.8 slpm of O_2 is 90–120 nm. The results conclude at a constant flowrate of 0.4 slpm of LPG, and increasing of O_2 flowrate from 0.8 to 1.2 slpm leads to formation of TNRs.

1. Introduction

Gas phase combustion synthesis of inorganic particles is used routinely today to make a variety of commodities like including SiO_2, TiO_2, Al2O3 etc. Titanium dioxide (TiO_2) is a wide-band gap (3.2 eV) semiconductor; it is one of many metal oxides currently under investigation. It is readily converted into different nanostructured forms, including nanotubes. TiO_2 has attracted considerable attention because it has great potential applications such as catalysis [1], photocatalysis [2] and dye-sensitized solar cells [3]. Extensive research has been conducted on TiO_2 nanoparticles [4], thin film [5] and mesoporous TiO_2 [6,7]. Recently much research has been done to obtain TiO_2 nanotubes with a large surface area and high photocatalytic activity. Hoyer synthesized TiO_2 nanotubes with diameter of 70–100 nm with sol–gel method [8]. Imai et al. in 1996 reported anatase phase TiO_2 nanotubes with diameter of 8 nm [9]. Anatase and rutiles phase TiO_2 nanotubes have been synthesized by Zhang et al. [10]. Kranthi et al. [11] synthesized TiO_2 nanoparticles by flame aerosol method using methane, and oxygen as fuel and oxidant, respectively with titanium tetraisopropoxide as precursor. Bhanwala et al. [12] synthesized pure and carbon doped TiO_2 nanoparticles in flame aerosol reactor using inexpensive fuel gas LPG (liquid petroleum gas) as fuel and air/oxygen as oxidant with titanium tetrachloride ($TiCl_4$) as precursor, and using of oxygen instead of air increases the production of spherical particles with average diameter of particle size is 104 nm. Jitputti et al. [13] proved that TiO_2 nanotubes synthesized by hydrothermal treatment of Degussa P-25 showed higher photocatalytic activity than Degussa P-25 commercially available. Formenti et al. [20] and Rulison et al. [21] produced titania by oxidation of $TiCl_4$ in H_2/O_2 diffusion flame reactor and found strong bearing of precursor concentration and residence on particle size (~15–140 nm) and morphology. Pratsinis et al. [19] investigated the effect of gas mixing, precursor concentration, particle residence time and flame temperature on product titania nanoparticles size and phase composition with different configurations of diffusion flame reactor and reported that fine anatase titania powder was obtained at low precursor concentration. Hafez et al. [22] synthesized anatase TiO_2 nanorods by hydrothermal method and that the efficiency could increase from 5.8% to 7.1% if the dye-sensitized nanocrystalline solar cells (DSSC) electrodes change from nanoparticles to nanorods. Chen et al. [23] successfully synthesized pure rutile phase TiO_2 nanorods under hydrothermal conditions, showing an increase of photocatalytic activity for the time ranging from 1 to 15 h because of the increase of crystal domain. The two mainstream methods to synthesize nano-particles are wet methods (sol–gel) and aerosol methods such as flame synthesis. Wet methods offer fine control over particle size and particle size distributions. However, in wet-process the final product often includes a mixture of amorphous and crystalline particles, resulting in costly and time consuming

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post process steps. Flame aerosol methods can be operated continuously allowing for greater output with minimal post processing. These methods produce fewer byproducts, usually making them more economically viable than wet methods [14,15].

Till now to our best knowledge, no author has reported about synthesis of TiO_2 nanorods, synthesized by diffusion flame reactor using LPG as fuel and oxygen as oxidant, though TiO_2 nanorods were successfully synthesized by wet chemical methods (sol–gel). Hence, in this current paper TiO_2 nano-rods and nanoparticles synthesis method is reported using inexpensive gas (LPG) as fuel and oxygen as oxidant.

2. Materials and methods

2.1. Materials

Titanium tetraisopropoxide (TTIP) was purchased from SRL Chemicals India, LPG (domestic, Bharat Gas), and oxygen and nitrogen gas were purchased from Industrial gas Agency of Pvt. Ltd. India. All experiments were carried out in a flame reactor indigenously by JNTUH Hyderabad as shown in Fig. 1

2.2. Methodology

The flame reactor has been indigenously designed to produce nanomaterials. The detailed setup of the reactor has been discussed in our previous paper on synthesis of nanocarbon materials. [16] The reactor operates under atmospheric pressure. The measured quantity of the LPG and the oxidant reaches the ignition chamber. During the process we have observed the dark orange flame color which is perfect in a spindle form. Along the entire length of the flame, its temperature was recorded using a K-type thermocouple.

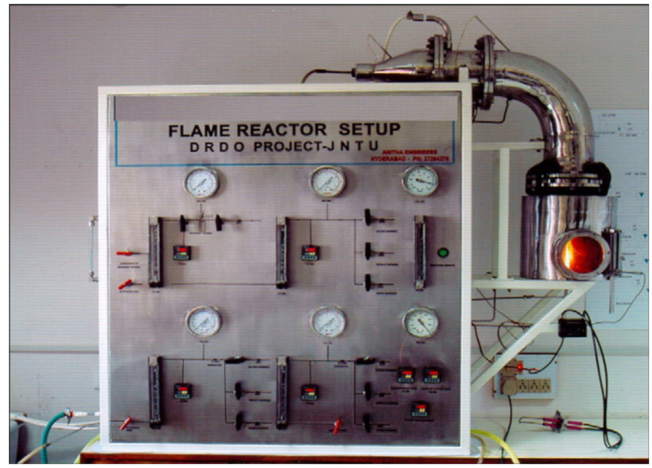

Fig. 1. Flame reactor setup, with flow meters front view (rotameters).

In this study, titania nanorods were synthesized in diffusion flame by using titanium tetraisoproxide (TTIP, 98% purity, spectrochem) as the titanium precursor. In this experiment, flame is ignited in the burner with LPG and oxygen, nitrogen gas is bubbled through a reagent vessel containing liquid TTIP to deliver the TTIP vapour to the burner, as shown in Fig. 2. In order to prevent any condensation of the precursor, all gas line downstream the TTIP reagent vessel and the burner were wrapped with heating tapes to maintain them at 125 °C. The TiO_2 produced is captured on a glass fiber filter (Axiva GF/A) Fig. 3, and is scrapped carefully and weighed. Later, it was heat treated at 350 °C in the presence of air for 60 min to remove any traces of amorphous carbon impurities and then the samples were characterized by SEM and XRD.

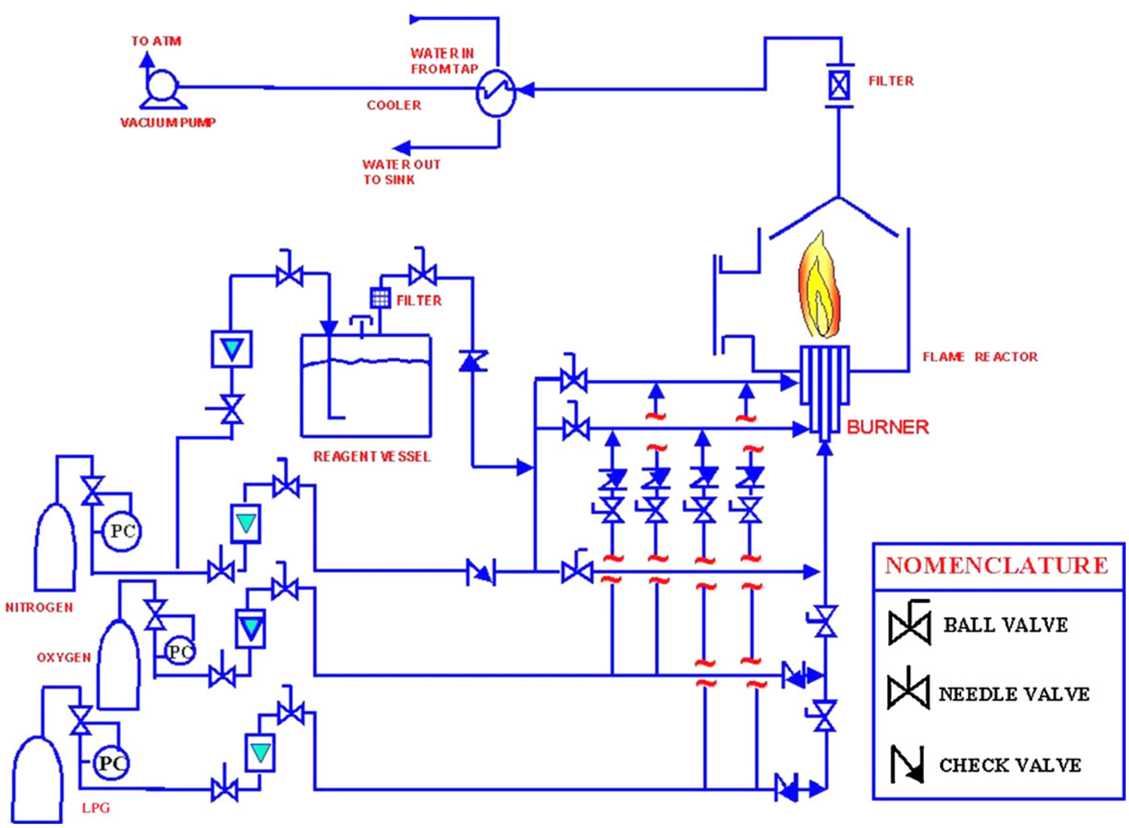

Fig. 2. Flow chart diagram of flame reactor unit.