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Short communication

Rapid growth of vertically aligned tungsten oxide nanostructures by flame vapor deposition process

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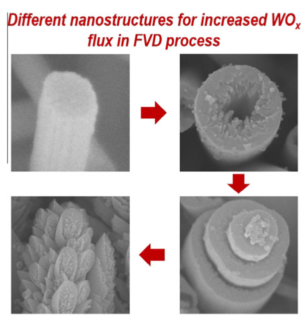
HIGHLIGHTS

- Flame vapor deposition system embedded with a wire feeder was developed firstly.
- The wire feed rate was found to determine the morphology of nanostructures.
- Various tungsten oxide nanostructures vertically grown on substrate were obtained.
- The feasible growth mechanisms of all nanostructures were proposed in this work.
- This work offers a method for rapid growth of nanostructured metal oxide thin films.

GRAPHICAL ABSTRACT



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ABSTRACT

Flame vapor deposition system embedded with a wire feeder was developed for the first time to guarantee the precise control of wire feed rate. Vertically aligned nanowire, nanotube, multi-tube and bush-like tungsten oxide nanostructures were successfully obtained in this system. The feasible growth mechanisms of these nanostructures were proposed. This research offers a robust and fast approach to prepare nanostructured metal oxide thin films with controlled morphologies.

1. Introduction

Tungsten oxide has been found to have great potential applications in photocatalyst [1,2], dye-sensitized solar cell [3] and photoelectrochemical water splitting [4–9] due to its unique photoelectrochemical properties. The morphology modification is one of the strategies to improve the performance of tungsten oxide-based electrode [6]. Many researchers have prepared vertically aligned tungsten oxide nanostructures such as nanowires [4,8,10,11], nanorods [5,9,12], nanotubes [4], nanoplates [13,14] and hyperbranched structures [15] on conductive glass substrate (commonly FTO-coated glass) to harvest solar energy. This is because the vertically aligned nanostructures increase the path-length of the light through material for efficient light absorption with scattering, while maintaining the path lengths reasonably short for the photo-generated charges to travel (for holes to reach the electrolyte solution and for electrons to reach the current collector) [16]. It also increases the interfacial contact area between electrode and electrolyte solution. There are several

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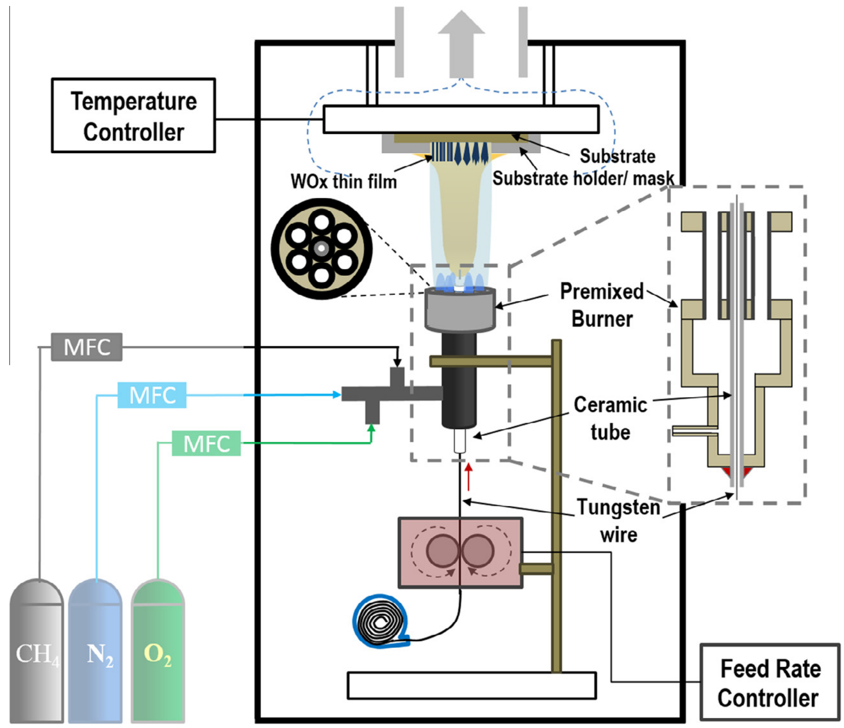

Fig. 1. Schematic of the experimental setup for flame vapor deposition of tungsten oxide nanostructured thin films.

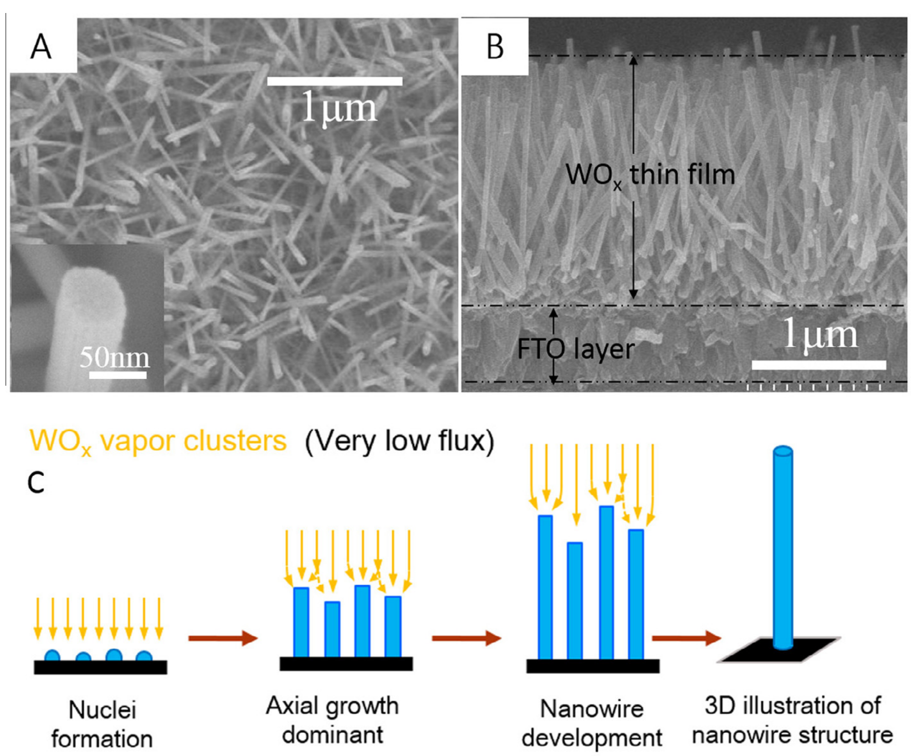

Fig. 2. (A) top view and (B) cross-sectional FESEM images of nanowire structured tungsten oxide thin films grown on FTO glass at tungsten feed rates of 2 μm/s, and (C) schematic to illustrate the growth mechanism of nanowire structure.

methods which have been explored to synthesize these tungsten oxide nanostructures on conductive glass, typically, chemical vapor deposition method (CVD) [9–11,17] and hydrothermal method [8,13,14]. However, the CVD process can be complex with the expensive vacuum systems [18] and is difficult to scale up [19]. Hydrothermal growth is relatively inexpensive, but its