Surfaces and Interfaces 13 (2018) 11–21

Contents lists available at ScienceDirect

Surfaces and Interfaces

journal homepage: www.elsevier.com/locate/surfin

UV-blue spectral down-shifting of titanium dioxide nano-structures doped with nitrogen on the glass substrate to study its anti-bacterial properties on the *E. Coli* bacteria

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ARTICLE INFO

Keywords:
TCVD
Titanium dioxide
Doping of nitrogen
Down shifting

ABSTRACT

In this study, titanium dioxide (TiO_2) nano-structures including nanoparticles and nano-wires are synthesized on the glass substrate at temperatures of 300, 400 and 500 °C using thermal chemical vapor deposition technique. Doping with nitrogen are done in three different temperatures including 300, 400, 500 °C to obtain optimum nitrogen doping content. To investigate the optical properties, crystalline structure, morphology, thickness and chemical components of the nano-structures, UV–Visible spectrometer, X-Ray diffraction, field emission scanning electron microscopy and energy dispersive X-ray spectroscopy are used, respectively. Results show that the temperature and location of substrate play a significant impact on the morphology and structure of as-grown TiO_2 nano-structures. The crystal structure of the obtained layers including TiO_2 nano-structures on the glass are consisted anatase and rutile crystalline phases. The atomic percentage of nitrogen in TiO_2 nano-structures at a doping temperature of 400 °C increase in comparison to the other two doping temperatures. In addition, observing the peak of TiN and $Ti_{3.72}\ O_{8.00}\ N_{2.24}$ structures in the X-Ray pattern at doping temperature of 400 °C, refer to dope TiO_2 nano-structures with a significant amount of nitrogen. Moreover, the reduction of band gap at about 0.4 eV, for N-TiO_2 nano-structures grown at 400 °C, confirms the enhancement of photo-catalytic activity in the visible region. Antibacterial properties of pure titanium dioxide and doped with nitrogen were examined under dark, sunlight and UV light for *E. Coli* bacteria. The results show that growth of *E. Coli* bacteria significantly reduces in solution using N-TiO_2/glass system treated at 400 °C in NH_3/N_2 ambient under sunlight due to down shifting of TiO_2 band gap in compared with other samples.

1. Introduction

Nowadays, titanium dioxide (TiO_2) is well known as biologically and chemically inert, mechanically robust, nontoxic, cheap, biocompatible, antifogging and super-hydrophobic [1–8]. These properties have been applied to removing bacteria and harmful organic materials from water and air as well as in self-cleaning or self-sterilizing of surfaces for places such as medical centers [1]. TiO_2 nano-structures (NS) have attracted significant attention as one of the appropriate photo catalysts for the degradation of organic pollutants, self-cleaning, self-disinfecting material and environmental purification [2]. For the first time, photo-catalytic behavior of TiO_2 is discovered about four decades ago by Honda and Fujishima [2]. In fact, photo-catalytic activity depends on the band gap energy of materials, particularly the formation of free radicals [4]. The photo-catalytic activity of nanoparticle catalysts is affected their physic-chemical properties such as the specific surface area, acid-base sites, and crystalline structure, nano-scale size as well as the reaction conditions such as temperature, pH and light intensity [6,7]. All the above-mentioned parameters are responsible for the generation rate of the electron-hole pairs as well as their recombination rate [6].

TiO_2 exists in three crystalline phase rutile, anatase and brookite. Among these phases, the rutile phase is more stable and the other two phases are converted to rutile using temperatures processing [9]. One of disadvantages of TiO_2 despite significant photo-catalytic properties is large band gap, so absorbs a small part of the solar spectrum approximately 4% of the energy of sunlight in the ultraviolet region [10,11]. It has a large band gap at intervals of 3.0 to 3.2 eV which is inactive under visible light illumination [12,13]. Pure TiO_2 has been modified by various ways such as impurity doping [5,14–19] and dye sensitization [20] to obtain activity in visible light. To reduce the absorption threshold energy, many researcher have studied doping TiO_2 with

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https://doi.org/10.1016/j.surfin.2018.07.003
Received 13 January 2018; Received in revised form 3 July 2018; Accepted 16 July 2018
Available online 17 July 2018
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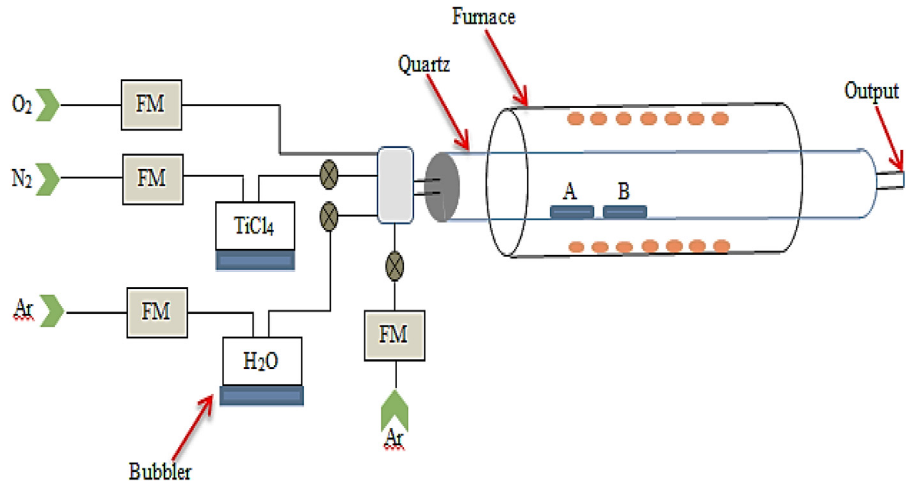

Fig. 1. TCVD systems to grow NSs of TiO_2 at various tempratures.

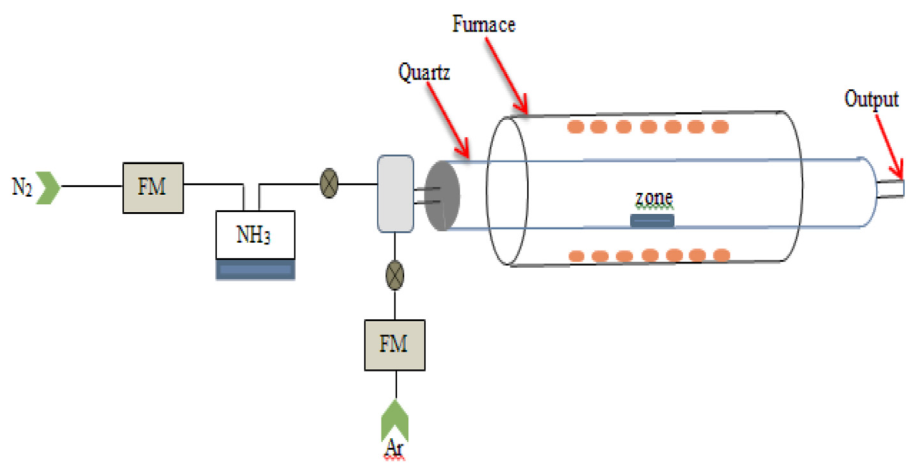

Fig. 2. TCVD systems to dope NSs of TiO_2 with nitrogen.

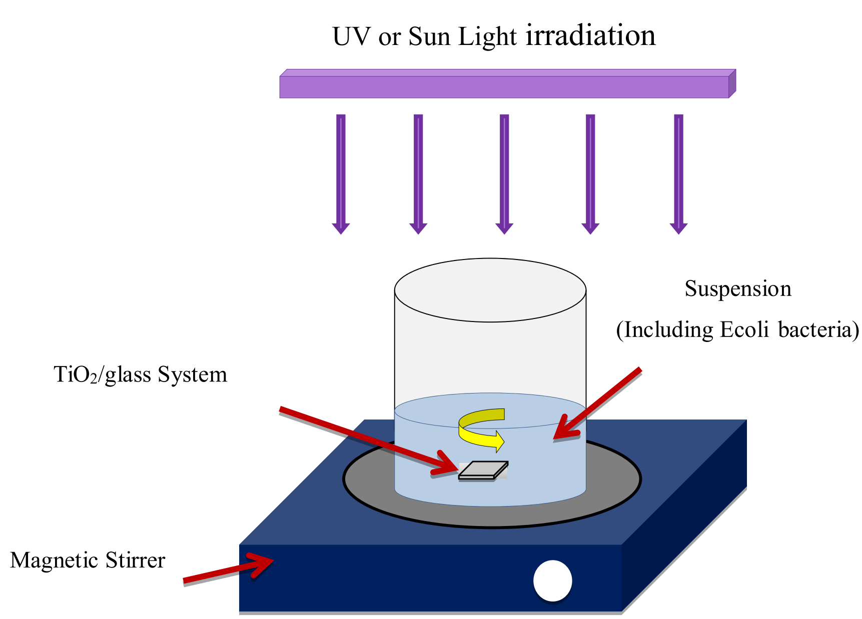

Fig. 3. Schematic of the antibacterial setup.