Talanta 79 (2009) 953–958

Contents lists available at ScienceDirect

Talanta

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

Mg^{2+}/Na^{+}-doped rutile TiO_2 nanofiber mats for high-speed and anti-fogged humidity sensors

Hongnan Zhang [a], Zhenyu Li [a], Li Liu [b], Ce Wang [a,*], Yen Wei [a,c,**], Alan G. MacDiarmid [a]

[a] The Alan G. MacDiarmid Institute, Jilin University, Changchun, 130012, PR China
[b] College of Physics, Jilin University, Changchun, 130012, PR China
[c] Department of Chemistry, Drexel University, Philadelphia, PA, 19104, USA

ARTICLE INFO

Article history:
Received 19 January 2009
Received in revised form 18 May 2009
Accepted 21 May 2009
Available online 27 May 2009

Keywords:
Electrospinning
Humidity sensor
Rutile TiO_2 nanofibers
High-speed
Anti-fogged

ABSTRACT

Mg^{2+} and Na^{+} doped rutile TiO_2 nanofibers have been prepared through in situ electrospinning technique and calcination with poly(vinyl pyrrolidone) (PVP) nanofibers as sacrificed template. The as-prepared composite nanofibers are spin-coated onto a ceramic substrate with three pairs of carbon interdigital electrodes to measure its humidity sensing behaviors. The product exhibits high-speed response (2 s) and recovery (1 s) for detecting moisture. Additionally, under UV irradiation, a water contact angle (θ) of nearly 0° has been observed based on the product, providing our humidity sensor with the anti-fogged properties.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

The past several decades have witnessed the huge progress on the fabrication of humidity sensors for their practical applications in air-quality control, environmental monitoring, healthcare, defense and security, etc. [1,2]. Recently, taking the advantages of large surface area, high surface to volume ratio, and special physical and chemical properties of one-dimensional (1D) metallic oxide nanostructures, the synthesis of sensitive humidity sensors based on 1D metallic oxide nanostructures is of current interest [3–7]. Hitherto, many sensitive and stable humidity sensors have been reported. For example, Fu and Wang reported the fast humidity sensors based on pure CeO_2 nanowires [3]. Zhang and Wang studied the humidity sensing performances based on Ba-doped CeO_2 nanowires [4]. Mathur and coworkers used the individual tin oxide nanowires to detect the water vapor in different gaseous environments [5]. Wang and co-workers investigated the humidity sensing properties based on a single SnO_2 nanowire [6]. Our group presented the highly sensitive and stable humidity nanosensors based on LiCl doped TiO_2 electrospun nanofibers [7]. Although huge and significant progresses on humidity sensors have been obtained, high-speed humidity sensor with both response time and recovery time less than 2 s, during the whole relative humidity measurement, has still not be obtained yet. Additionally, no papers on anti-fogged and high-speed humidity sensors have been reported.

TiO_2, as an important metallic oxide, has been widely investigated in the fields of environmental cleaning [8] and protection [9], sensors [10], anti-fogged mirror [11], and solar cells [12]. Recently, rutile TiO_2 (1 1 0) has also been proven to be active sites for water dissociation [13]. Those outstanding properties make rutile TiO_2 a good candidate in synthesizing humidity sensors. Mg^{2+} and Na^{+} are often used in humidity sensors to facilitate the ionic conduction during the humidity sensing measurement [14,15]. In this paper, 1D rutile TiO_2 nanofiber, Mg^{2+}, and Na^{+} are combined, for the first time, to form a novel type high-speed and anti-fogged humidity sensor via electrospinning and calcination. The response time and recovery time, during the whole relative humidity (RH: 11–95%), are 2 s and 1 s, respectively. Most importantly, under UV irradiation, a water contact angle (θ) of nearly 0° has been observed based on the product, endowing our humidity sensor with the anti-fogged properties.

2. Experimental

2.1. Chemical

$MgCl_2$ (>95%), tetrabutyl titanate (>95%), ethanol (>95%) and acetic acid (>95%) were of analytical grade and purchased

* Corresponding author. Tel.: +86 431 85618292; fax: +86 431 85198292.
** Corresponding author at: The Alan G. MacDiarmid Institute, Jilin University, Changchun, 130012, PR China. Tel.: +86 431 85618292/+1 215 895 2650; fax: +86 431 85198292/+1 215 895 1265.
E-mail addresses: cwang@jlu.edu.cn (C. Wang), weiyen@drexel.edu (Y. Wei).

0039-9140/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.talanta.2009.05.035

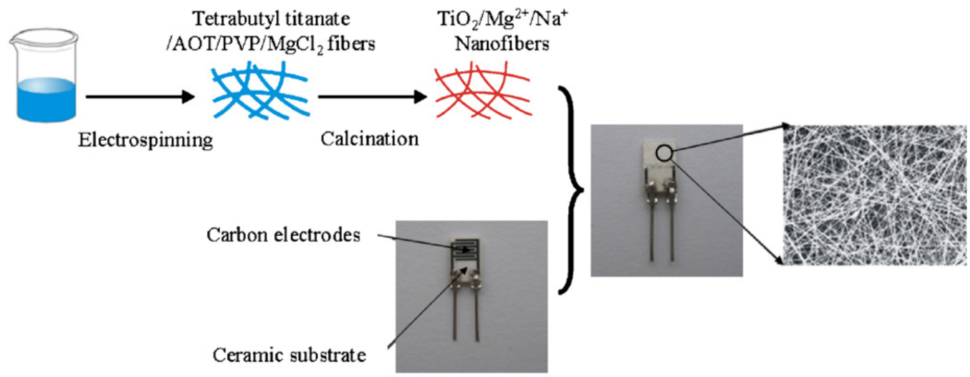

Fig. 1. Schematic diagrams of the steps to fabricate Mg^{2+}/Na^{+}-doped TiO_2 nanofiber mats for humidity measurement via electrospinning and calcination.

from Tianjin Chemical Company. Poly(vinyl pyrrolidone) (Mw: 1,300,000) and dioctyl sulfosuccinate sodium (AOT: $C_{20}H_{37}OSNa$) were purchased from Aldrich.

2.2. The whole procedures for humidity sensor

In a typical procedure, 1.5 g of tetrabutyl titanate was mixed with 3 mL of acetic and 3 mL of ethanol in glovebox under vigorous stirring for 10 min. Subsequently, this solution was added to 7.5 mL of ethanol containing 0.45 g of poly(vinyl pyrrolidone) (PVP), 0.02 g of dioctyl sulfosuccinate sodium (AOT: $C_{20}H_{37}OSNa$) and a suitable amount of $MgCl_2$ under vigorous stirring for 30 min. The mixture was loaded into a glass syringe and connected to high-voltage power supply for electrospinning, 12 kV was provided between the cathode (a flat aluminum foil) and anode (syringe) at a distance of 20 cm. Then, calcination (600 °C in air for 3 h) has been used to remove PVP and to convert both tetrabutyl titanate into rutile TiO_2 nanofibers and AOT into Na^+ according to previous reported method [16].

Consequently, the as-prepared Mg^{2+}/Na^+ doped TiO_2 nanofibers were mixed in a weight ratio of 100:5 and were ground with deionized water to form a dilute paste. The paste was screen-printed onto a ceramic substrate (7 mm × 5 mm, 0.5 mm in thick) with three pairs of carbon interdigital electrodes (electrodes width and distance: 0.15 mm) to form a film with the thickness about 10 μm, and then the film was dried at 60 °C in air for 5 h. Finally, the humidity sensor was fabricated after aging at 95% RH with a voltage of 1 V, 100 Hz for 24 h. The characteristic curves of humidity sensitivity were measured on a ZL5 intelligent LCR test meter (Made in Shanghai, China) at room temperature. The voltage applied in our studies was AC 1 V. The controlled humidity environments were achieved using supersaturating aqueous solutions of different salts of LiCl, $MgCl_2$, $Mg(NO_3)_2$, NaCl, KCl and KNO_3 in a closed glass vessel at room temperature, which yielded 11%, 33%, 54%, 75%, 85% and 95% RH, respectively. This method was established by Wang [17,18]. The procedures for the preparation of the new sensors are illustrated in Fig. 1.

2.3. Measurements

The X-ray powder diffraction (XRD) data were collected on an X'Pert MPD Philips diffractometer (Cu Kα X-radiation at 40 kV and 50 mA). Scanning electron microscopy (SEM) images were recorded on a SHIMADZU SSX-550 (Japan) instrument. The humidity measured machine was ZL5 intelligent LCR test meter made in Shanghai China. Water CA was measured with an OCA20 (Dataphysics, Germany) at ambient temperature.

3. Results and discussion

3.1. Materials characterization

Fig. 2a shows the SEM image of the TiO_2 nanofibers containing 5.56 wt.% Mg^{2+} and 0.22 wt.% Na^+, indicating a large scale of composite nanofibers with the average diameter of 200 nm can be obtained via our method. In XRD pattern, as shown in Fig. 2b, (1 1 0), (1 0 1), (2 0 0), (1 1 1), (2 1 0), (2 1 1), (2 2 0), (0 0 2), (3 1 0), (3 0 1) and (1 1 2) peaks at 2θ = 27. 35°, 36.0°, 39.15°, 41.2°, 44°, 54.25°, 56.55°, 62.75°, 63.9°, 68.95°, and 69.8° can be clearly detected correspond-

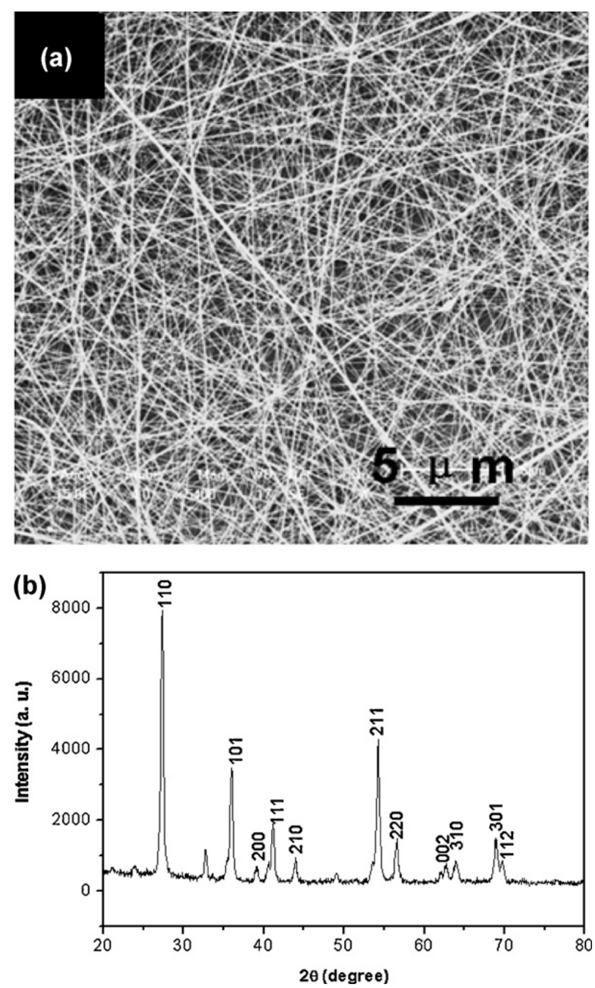

Fig. 2. (a) SEM image and (b) XRD pattern of the as-prepared product.

Download English Version:

https://daneshyari.com/en/article/10559658

Download Persian Version:

https://daneshyari.com/article/10559658

Daneshyari.com