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Colloids and Surfaces A: Physicochem. Eng. Aspects 313–314 (2008) 355–358
COLLOIDS AND SURFACES A
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Fabrication of gas ionization sensors using well-aligned MWCNT arrays grown in porous AAO templates

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Received 19 November 2006; accepted 28 April 2007
Available online 2 June 2007

Abstract

Gas ionization sensors based on the field ionization from well-aligned MWCNT arrays grown in porous AAO templates were fabricated. The breakdown voltages were measured in different gases of different concentrations. The changes of the breakdown voltage were related to the type of detected gases and its concentration. At the same time, the pre-discharge processes had also been studied to test the responses of the gases sensors to several gases. It was found that the as-prepared gas ionization sensors using well-aligned MWCNT arrays grown in porous AAO templates have shown good sensitivity to acetic acid with short response or recovery time.

Keywords: Field ionization; MWCNT array; Acetic acid

1. Introduction

Ionization sensors work by fingerprinting the ionization characteristics of distinct gases, but they have not been well used because of their huge, bulky architecture and high power consumption. The rapid development of nanomaterials has provided an opportunity for the application of gas ionization sensors. The sharp tips of nanomaterials generate very high electric fields at relatively low voltages [1,2]. Modi et al. had fabricated gas ionization sensors using MWCNT film grown on SiO_2 substrate and measured their response to some inorganic gases [3]. Zhang and Zhu have designed field ionization sensors based on membranes of CNTs as the cathode material; the changes of the breakdown voltage of the gas sensors in the mixture gases were studied to detect several gases [4]. MacLaren and co-workers developed field ionization sensors based on the MWCNTs grown on the stainless steel tip as the anode, the nanotips of the CNTs produced high electrical field to ionize the gases around the nanotips then the gases of high ionization energy, even noble gases could be detected [5]. In this paper, gas ionization sensors have been fabricated using MWCNT arrays grown in porous AAO templates. At the same time, the changes of breakdown voltage and pre-discharge current have been used to characterise several organic gases in ambient air.

2. Experiment

2.1. Fabrication of gas ionization sensors

The MWCNTs arrays were grown in AAO templates via CVD method [6]. Then two sides of the templates were etched partly using 10%NaOH solution and milled to remove the amorphous carbon. The one side was coated with a gold layer to keep ohmic contact between the MWCNTs arrays and the electrode. Fig. 1 shows the as-prepared MWCNTs arrays. The MWCNTs array was used as anode and the tungsten needle as the cathode. The distance between the two electrodes could be adjusted.

2.2. Test of the as-prepared sensors

The tests of the as-prepared sensors were carried out in the test set-up as shown in Fig. 2. A Picoammeter/voltage source (Keithley 6487) was adopted to measure the current in the test circuitry; the dc current sensitivity of the equipment is in the range 10^{-14} A. The as-prepared gas ionization sensors were put

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0927-7757/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.colsurfa.2007.04.118

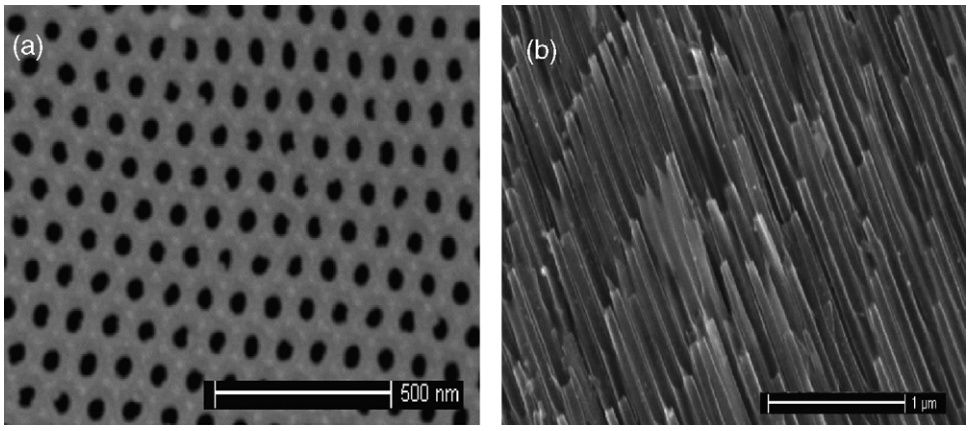

Fig. 1. Scanning electron micrograph of MWCNT arrays grown in porous AAO templates: (a) AAO templates; (b) MWCNT arrays.

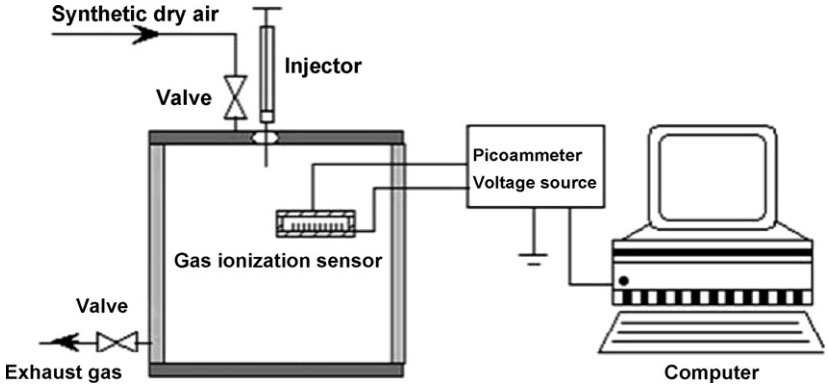

Fig. 2. Diagram of actual test set-up.

into the gas container and exhaust gases were removed using synthetic dry gases.

The breakdown voltages were measured to test the response of the as-prepared gas sensors to ethanol and acetic acid of different concentrations. The inter-electrode gap was 50 μm then.

The repeatability of the gas sensors and pre-discharge current responses were tested as the inter-electrode gap was 20 μm. To test the repeatability, the breakdown process was repeated eight times. The pre-discharge currents were measured at the voltage of 100 V, which was much lower than the average breakdown voltage of 235.4 V. We tested the dynamic response of the gas ionization sensors to acetic acid of 50 μg/l. At the same time, the pre-discharge current responses to several gases of different concentrations were also tested.

3. Results and discussion

The diameter of MWCNTs grown in the AAO templates was 80 nm on average with open-end, and the density of the MWCNTs was about 10^{12} cm^{-2}. The charged MWCNTs could ionize the molecules surrounding the nanotips to positive ions. The ionized positive ions and the photoelectric effect of external

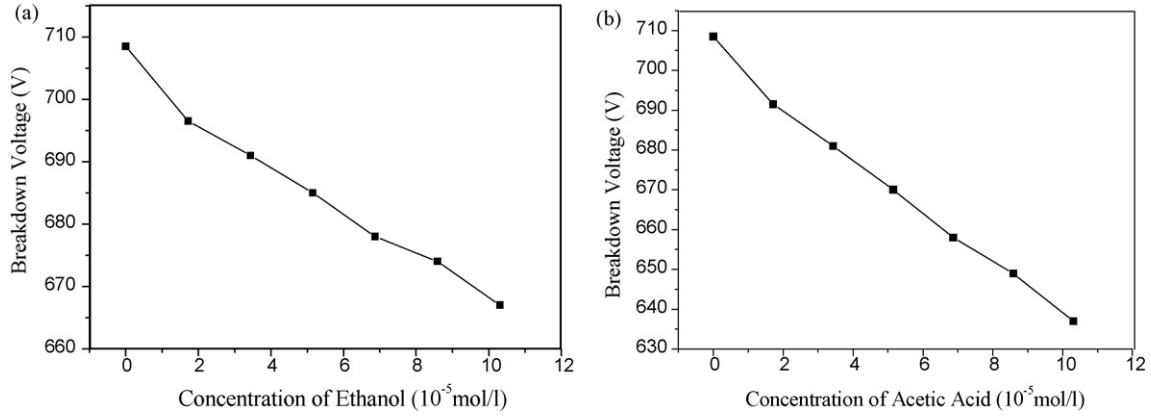

Fig. 3. Changes of the breakdown voltage in different gases: (a) in alcohol; (b) in acetic acid (inter-electrode gap is 50 μm).