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Short communication

Flexible polyaniline/carbon nanotube nanocomposite film-based electronic gas sensors

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ABSTRACT

Real-time ammonia (NH_3) detection in anaerobic digestion is highly desirable, due to the ammonia inhibition on methane production. Here, the interconnected nanocomposite network of polyaniline (PANI) nanoparticle-coated carbon nanotube (CNT) and PANI nanofiber is fabricated by adding ammonium persulfate into CNT-containing aniline solution for PANI polymerization and film deposition. The film is assembled as high-sensitive ammonia sensors, exhibiting highly sensitive NH_3 sensing from 200 ppb to 50 ppm, fast response/recovery time, room-temperature operation without external aid, reliable flexibility and excellent selectivity to NH_3 compared to other volatile organic compounds.

1. Introduction

The rapidly growing global concerns over the structure of energy demand and the environment pollution have stimulated efforts to develop renewable energy [1,2]. As a method to produce renewable energy, anaerobic digestion has attracted a lot of attention in the world [3]. Anaerobic digestion technology is an important means to dispose organic solid waste, including manure, industrial waste and food waste, for preventing corruption and stink, and to produce methane by fermentation as valuable renewable energy resources for employed in vehicles after purification [4]. Organic wastes containing nitrogen, such as protein, urea and amino acid, are converted to ammonia (NH_3) by anaerobic digestion. Thus, the concentration of ammonia nitrogen will accumulate in a long term. However, ammonia inhibition of anaerobic digestion caused by ammonia accumulation is one of the main reasons to lead the low efficiency and poor stability for anaerobic digestion [5]. High concentration of ammonia has inhibitory and toxic effects on anaerobic digestion operation for degrading organic matters and methane production [6,7]. Thus, it is highly expected that ammonia inhibition phenomenon can be discovered earlier and timely for real-time adjustment of reaction conditions to eliminate the inhibitory effect on anaerobic digestion for both environmental and economic concern. Therefore, real-time ammonia detection in anaerobic digestion by high-sensitive room-temperature electronic gas sensors, is highly desirable.

Some ammonia detection instruments have actually been available, such as gas chromatograph and the traditional ceramics tube or inter-finger probe based gas sensing devices. However, they are lack of relative portability, real-time sensing, low cost, transparency and flexibility [8,9]. Therefore, they cannot meet the growing future application call for flexible gas sensors.

Recently, flexible conductive film-based gas sensors have attracted widely scientific attention due to the wearability, flexibility, transparency and compatibility over curved substrates of integrated electronics [10–14]. Among the various nanomaterials-based flexible electronic gas sensors, CNT film-based sensors demonstrated stable room-temperature NH_3 sensing performance [15–18]. But they displayed relatively low sensing performance. Meanwhile, polyaniline (PANI) based sensors have been well established due to the facile synthesis, simple acid/base doping/dedoping chemistry and high NH_3 sensing response [19–21]. A dramatic conductance decrease can be observed for PANI gas detection by transforming emeraldine salt form of PANI into its emeraldine base form exposed to the strong electron donating

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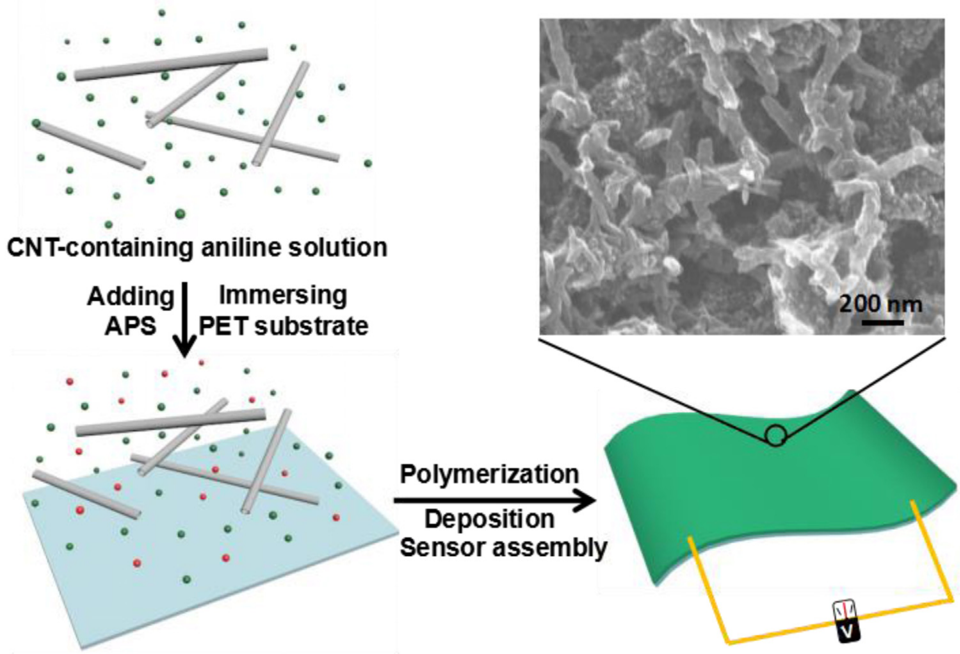

Fig. 1. Schematic illustration for the fabrication of the interconnected nanocomposite networks of PANI nanoparticle-coated CNT and PANI nanofiber, and the assembled flexible gas sensor.

NH_3. However, they are lack of long-term environmental stability. Conductive polymer nanocomposites based gas sensors have been well reported. J. F. Feller and co-workers fabricated polycarbonate-CNTs transducers with hierarchical structure prepared by spray layer by layer for vapour sensing [22]. S. Abdulla and coworkers demonstrated a room temperature gas sensor based on PANI/CNTs nanocomposite for ammonia detection [23]. However, compared to these sensors, highly sensitive room-temperature electronic gas sensors are greatly desirable. Thus, the combination of these materials into nanocomposite network films with intrinsic mobility, chemical stability, and high-sensitive NH_3 performance for NH_3 sensors remains to be addressed.

Herein, we fabricated a hierarchical polyaniline/carbon nanotube (PANI/CNT) nanocomposite network films to be assembled

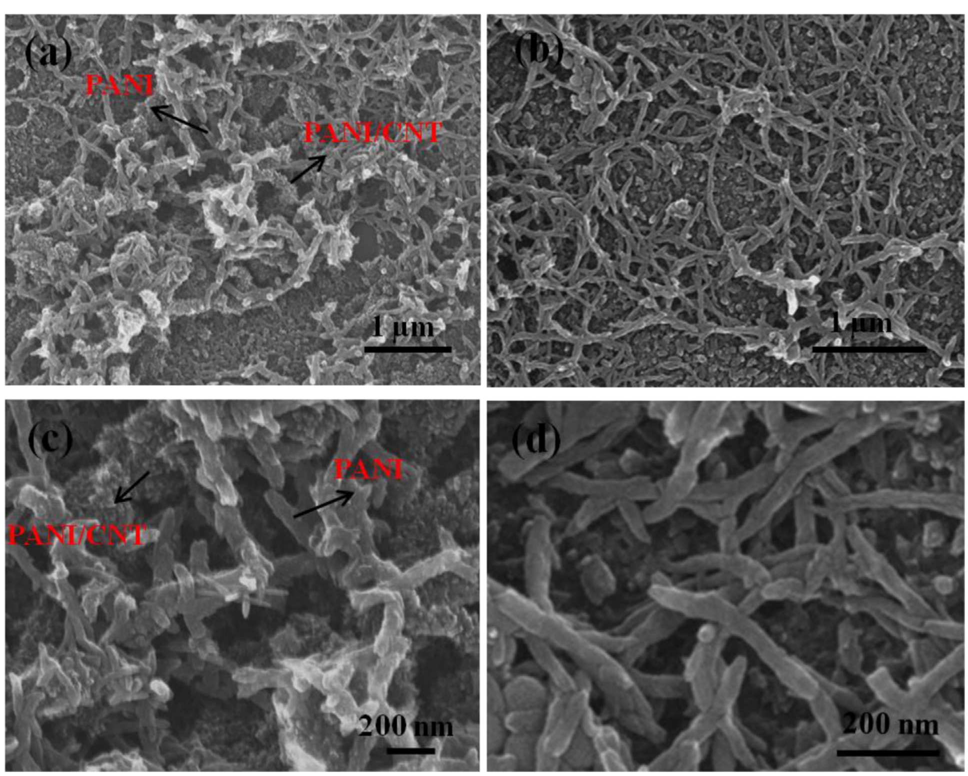

Fig. 2. SEM images of (a) PANI/CNT network (scale bar: 1 μm) and (b) PANI fiber (scale bar: 1 μm). Enlarged SEM images of (c) PANI/CNT network (scale bar: 200 nm) and (d) PANI fiber (scale bar: 200 nm).