

Gas Sensors Based on Electrospun Nanofibers



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1. Introduction

A gas sensor is a device which detects the presence of different gases in an area, especially those gases which might be harmful to humans or animals. The development of gas sensor technology has received considerable attention in recent years for monitoring environmental pollution. It is well known that chemical gas sensor performance features such as sensitivity, selectivity, time response, stability, durability, reproducibility, and reversibility are largely influenced by the properties of the sensing materials used. Many kinds of materials such as polymers, semiconductors, graphite, and organic/inorganic composites have been used as sensing materials to detect the targeted gases based on various sensing techniques and principles. It is worth noting that the sensitivity of chemical gas sensors is strongly affected by the specific surface area of sensing materials. A higher specific surface area of a sensing material leads to a higher sensor sensitivity, therefore many techniques have been adopted to increase the specific surface area of sensing films with fine structures, especially to form the nanostructures, taking advantage of the large specific surface area of nanostructured materials [1].

2. Global Market

Figure 1 shows the market growth data for gas sensors which is characterized by moderate overall growth during the next 5 years. Nanofibers used for applications within the sensor sector are currently in the development stage, and expected to generate sales of \$2.9 million by 2012. After 2012, sales of these materials are expected to increase rapidly, supported by strong demand for biosensors and sensors for hard-to-detect toxic gases. During the period 2012 through 2017,

nanofiber revenues for sensors and instrumentation are projected to increase at a 55.5% CAGR, reaching \$26.4 million by 2017 [2].

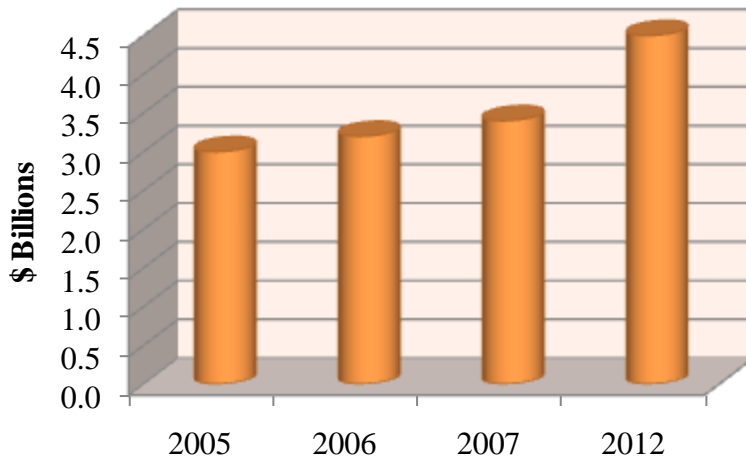


Figure 1. Market growth of gas sensors [2]

3. Electrospun Nanofibers for Gas Sensors

Electrospun fibers with controllable membrane thickness, fine structures, diversity of materials, and large specific surface are expected to be an ideal candidate as the structure of sensing materials. So far, many attempts (listed in Table 1) are carried out to prepare ultrasensitive gas sensors to detect vapors of NH_3 , H_2S , CO , NO_2 , O_2 , CO_2 , moisture, and VOCs (CH_3OH , $\text{C}_2\text{H}_5\text{OH}$, $\text{C}_5\text{H}_{10}\text{Cl}_2$, $\text{C}_6\text{H}_5\text{CH}_3$, $\text{C}_4\text{H}_8\text{O}$, CHCl_3 , $\text{C}_2\text{H}_2\text{Cl}_2$, $\text{C}_3\text{H}_6\text{O}$, $\text{C}_3\text{H}_7\text{NO}$, C_2HCl_3 , N_2H_4 , $(\text{C}_2\text{H}_5)_3\text{N}$, C_6H_{14} , etc.) with new and improved detection limits using electrospun nanofibrous membranes as sensing structures. The types of prepared gas sensors mainly include acoustic wave, resistive, photoelectric, and optical gas sensors. Electrospun fibers with polyelectrolyte components, conducting polymer composites, and semiconductors are successfully applied as gas sensing interfaces with the fiber arrangement of single fiber, oriented fibers, or nonwoven membranes at room or elevated operating temperature [3-10].

Table 1. Types of electrospun nanofibers based gas sensors

Types	Material	Structure	Gases Tested	Operating Temperature (°C)	Detection Limit
Acoustic Wave	PAA-PVA	Nonwoven	NH ₃	RT	50 ppm
	PAA	Nonwoven	NH ₃	RT	130 ppb
	PEI-PVA	Nonwoven	H ₂ S	RT	500 ppb
Resistive	HCSA-PANI/PEO	Single	NH ₃	RT	500 ppb
	PDPA-PMMA	Nonwoven	NH ₃	RT	1 ppm
	PANI	Nonwoven	Amines	RT	100 ppm
	PMMA-PANI	Nonwoven	(C ₂ H ₅) ₃ N	RT	20 ppm
	TiO ₂	Nonwoven	NO ₂	150-400	500 ppb
	TiO ₂	Nonwoven	CO, NO ₂	300-400	50 ppb
	LiCl-TiO ₂	Nonwoven	H ₂ O	RT	11%
	SnO ₂	Nonwoven	C ₂ H ₅ OH	330	10 ppb
	MWCNT/SnO ₂	Nonwoven	CO	RT	47 ppm
	WO ₃	Nonwoven	NH ₃	350	50 ppm
	SrTi _{0.8} Fe _{0.2} O _{3-δ}	Nonwoven	CH ₃ OH	400	5 ppm
Photoelectric	Co-ZnO	Nonwoven	O ₂	RT	0.32 Torr
Optical	Oxides-PAN	Nonwoven	CO ₂	RT	700 ppm

High selectivity, enhanced sensitivity, short response time, and long shelf-life are some of the key features sought in solid-state ceramic-based chemical sensors. As the sensing mechanism and catalytic activity are predominantly surface dominated, benign surface features in terms of small grain size, large surface area, high aspect ratio, and open/connected porosity are required to realize a successful material. The nanofibrous structure already possesses these surface features and the size control is achieved by the electrospinning process. The advantage with nanofibers is that they can be coupled with almost any type of transducer piezoelectric, thermal, Hall effect, etc., owing to their nanosize effects which magnify the property change. Nanofibers also display properties that are significant to thin films and have good potential to replace thin film sensors. Scaling up of production of nanostructures is possible only through electrospinning thereby making it an indispensable tool for sensor fabrication [11].

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