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].

![Market growth of gas sensors](image)

**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 NH₃, H₂S, CO, NO₂, O₂, CO₂, moisture, and VOCs (CH₃OH, C₂H₅OH, C₅H₁₀Cl₂, C₆H₅CH₃, C₄H₈O, CHCl₃, C₂H₂Cl₂, C₃H₆O, C₃H₇NO, C₂HCl₃, N₂H₄, (C₂H₅)₃N, C₆H₁₄, 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  | NH₃          | RT                        | 50 ppm          |
|                     | PAA            | Nonwoven  | NH₃          | RT                        | 130 ppb         |
|                     | PEI-PVA        | Nonwoven  | H₂S          | RT                        | 500 ppb         |
| Resistive           | HCSA-PANI/PEO  | Single    | NH₃          | RT                        | 500 ppb         |
|                     | PDPA-PMMA      | Nonwoven  | NH₃          | RT                        | 1 ppm           |
|                     | PANI           | Nonwoven  | Amines       | RT                        | 100 ppm         |
|                     | PMMA-PANI      | Nonwoven  | (C₂H₅)₃N    | RT                        | 20 ppm          |
|                     | TiO₂           | Nonwoven  | NO₂          | 150-400                   | 500 ppb         |
|                     | TiO₂           | Nonwoven  | CO, NO₂      | 300-400                   | 50 ppb          |
|                     | LiCl-TiO₂      | Nonwoven  | H₂O          | RT                        | 11%             |
|                     | SnO₂           | Nonwoven  | C₂H₅OH       | 330                       | 10 ppb          |
|                     | MWCNT/SnO₂     | Nonwoven  | CO           | RT                        | 47 ppm          |
|                     | WO₃            | Nonwoven  | NH₃          | 350                       | 50 ppm          |
|                     | SrTi0.8Fe0.2O3-δ| Nonwoven  | CH₂OH        | 400                       | 5 ppm           |
| Photoelectric       | Co-ZnO         | Nonwoven  | O₂           | RT                        | 0.32 Torr       |
| Optical             | Oxides-PAN     | Nonwoven  | CO₂          | 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].

References

[1] Sensors 2009, 9, 1609-1624.
[2] BBC Research, Market Research Report, Nanofibers: Technologies and Developing Markets (2007).
[3] Sens. Actuat. B-Chem 2004, 101, 373-380.
[4] Sens. Actuat. B-Chem 2005, 106, 477-483.
[5] Nova Science Publishers: New York, USA, 2006; pp. 1-28.
[6] Nano Lett. 2004, 4, 671-675.
[7] IEEE Trans. Nanotechnol. 2007, 6, 513-518.
[8] J. Phys. Chem. C 2008, 112, 8215-8222.
[9] Sens. Actuat. B-Chem 2008, 133, 644-649.
[10] Sens. Actuat. B-Chem 2008, 129, 621-627.
[11] Journal of Applied Physics 102, 2007.