Carbon Nanotube Electrodes for Electrochemical Gas Sensors

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Introduction

Carbon nanotubes have high conductivity, excellent strength and chemical stability. In addition, CNTs provide large surface areas [1] and can be functionalized for specific reactivity [2]. New practical applications for CNTs include capacitors, batteries, and sensors [2, 3]. Sensors will be one of the earliest applications for CNTs and herein is presented an amperometric gas sensor using multi-walled carbon nanotube (MWCNT) composite electrodes. The gas sensor electrode was porous and built into a sensor [4, 5].

Experimental

MWCNT dust was prepared with TFE particles as a composite and vacuum filtered onto a hydrophobic membrane and cured. The CNT/TFE working electrode was coupled with two Pt/TFE composite electrodes as a counter (CE) and reference electrode (RE) respectively in a commercial amperometric gas sensor configuration [4]. The CNT loading was 0.3 mg/cm^2 and the electrolyte was 4 M H_2SO_4.

The sensor was characterized by cyclic voltammetry (Gamry Inc., Model 100 Potentiostat, Warminster, PA) with a 10 mV/sec scan rate. The CVs are compared with air, H_2S, and NO_2 background.

Fixed potential operation was accomplished with lab-built potentiostat and data collecting station using a LabView® Data acquisition system mode (National Instruments, Austin, TX). During all sensor testing, the gas flow rate was fixed at 100 cc/min past the back side of the porous hydrophobic membrane [4,5] and all potentials were reported against the Pt/air-QRE.

Results and Conclusion

Fig. 1 shows characteristic CVs of the CNT/TFE electrode with different gas samples. H_2S The air CV shows the allowed operating window in air of about 0.3V cathodic and 0.5 V anodic to the QRE. The NO_2/air CV shows the cathodic reduction current below 0 V typical of reaction 1 below and the H_2S/air CV shows anodic oxidation of H_2S at potentials anodic to 0 V typical of reaction 1 below [5].

The MWCNTs were examined by SEM (Fig.2.). A typical image shows uniformity in diameter of MWCNTs that are more than a micron long and a random network structure such as those used in other sensing applications [1, 2].

Figure 3 illustrates consecutive exposure of 5 different concentrations of NO_2 and H_2S samples at 0 V vs. Pt/air-QRE. The H_2S response shows oxidizing reactions H_2S and NO_2 show reducing reactions.

$$H_2S + H_2O = H_2SO_4 + 8H^+ + 8e^- \qquad [1]$$

$$NO_2 + 2e^- + 2H^+ = NO + H_2O \qquad [2]$$

The sensor response is generally linear with concentration and can be given by a simple expression:

$$I = S\,X \qquad [3]$$

Where S is sensitivity in uA/ppm, I is the signal in µA, and X is concentration (ppm). From equation 3, our data yield:

$y = -0.0563\ X$, $R^2 = 0.9475$
$y = 0.0521\ X$, $R^2 = 0.5029$

for NO_2 and H_2S, respectively. Further work will describe additional analytical characteristics for this application of MWCNTs that may have exceptional stability and other important sensor properties.

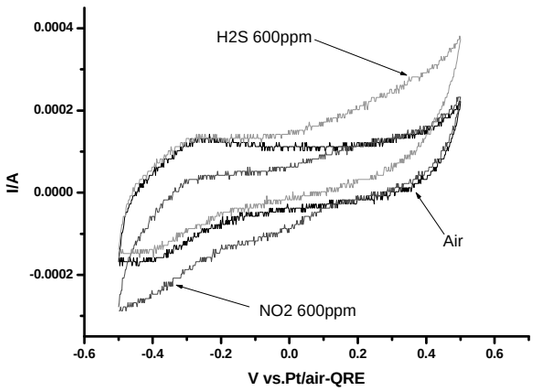

Fig. 1. CV of CNT/TFE sensor with air, 600 ppm of NO_2 and 300 ppm of HS.

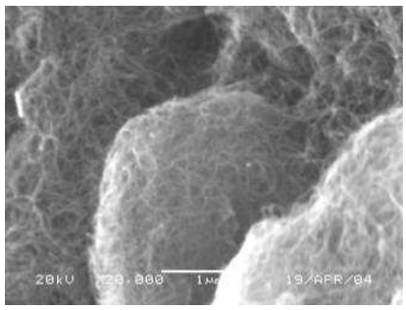

Figure 2. SEM of MWCNT dust.

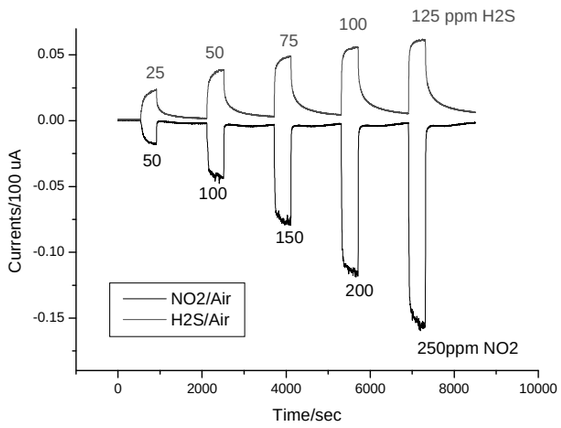

Figure.3 CNT/TFE sensor response with 25-50-75-100-125 ppm of H_2S/air and 50-100-150-200-250 ppm NO_2 air at 0 mV *vs.* Pt/air-QRE

Reference:

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