

Development of 2D-Borophene conductometric sensor for ammonia detection

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Summary

This study introduces a microconductometric sensor, developed by drop-casting 2D-Borophene film on Interdigitated Electrodes (IDEs) for real-time ammonia gas detection. The sensors were exposed to varying concentration ranges of 10–100 ppm and 100–1000 ppm ammonia vapour at room temperature. The results indicated a lower detection limit (LOD) of 4 ppm and high selectivity and reproducibility. The NH₃ sensor detected with high sensitivity, quick response, and recovery time of 18 s and 27 s respectively, highlighting the potential and effectiveness of Borophene for gas sensing. More study required to understand the potential mechanisms of this new 2D system and its interactions

Keywords: Gas-sensing, facile, Borophene, 2D-materials, microconductometric.

Title

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Objective

This study aims to develop a simple sensor for real-time detection of ammonia with low LOD and fast response time.

Introduction

Ammonia is released into the environment through various anthropogenic activities such as fertilizer application, food processing, and medical diagnostics [1]. It is a significant pollutant that has detrimental effects on human health and industrial output, due to its corrosiveness and toxicity [2]. The Occupational Safety and Health Administration recommends 50 ppm or 35 mg/m³ equivalent as ammonia's permissible exposure limit (PEL) within 8 hours. However, due to its extensive applications, accurate and practical trace-level ammonia detection and monitoring are extremely important [3], to guard against overexposure.

Borophene, a two-dimensional material, has unique properties such as high sensitivity, fast response, and long-term stability, thus unfolding its potential for gas sensing [4]. Several theoretical studies have been done on Borophene with relatively little experimental work. In this

work for the first time, a conductometric transducer is proposed to detect ammonia gas with thin Borophene film.

Materials and Methods

Chemicals: ethanol, methanol, acetone and ammonia were obtained from Sigma Aldrich. Borophene was synthesized using liquid phase exfoliation. An amount of boron was sonicated in ethanol and then centrifuged at 3000 rpm to remove bulk boron and collect borophene sheets. The obtained borophene was dried in an oven at 40 °C overnight. 5 mg of Borophene was dispersed ultrasonically in 200 ml ethanol for 15 mins, and 10 µl were drop-casted onto the surface of the IDEs and dried at room temperature. The conductometric measurements were conducted by applying a low-amplitude sinusoidal voltage (10 mV peak-to-peak at 0 V) with a frequency of 10 kHz to each pair of IDEs using the "VigiZMeter" Conductometer, by placing the IDEs sensors in the headspace above the liquid phase. The variation in conductance (ΔG) was recorded over time.

Results and discussion

The ammonia sensor showed high sensitivity and good reproducibility for each concentration with a slight variation, as shown in Fig. 1 and Fig. 2 respectively. The sensor linear responses increase with increasing NH₃ concentrations. A

low detection limit of 4 ppm was obtained using eq.1, and a fast response and recovery times of 18 s and 27 s respectively. The unique structural characteristic of borophene results in unsaturated bonds with intense electron deficiency, thus, facilitating facile interaction with gas molecules and promoting significant charge transfer at ambient temperature. This results in high sensitivity and rapid response [5]. The results obtained in this study proved that borophene was effective in ammonia sensing. A performance comparison of recently reported NH₃ sensors is shown in Tab 1.

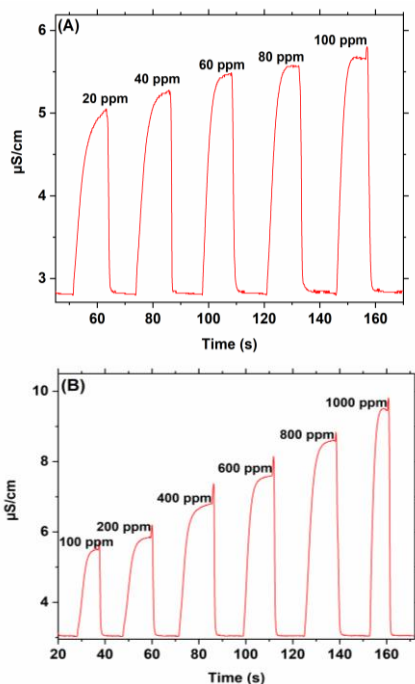


Fig. 1. Gaseous phase of ammonia detection kinetics: (A) 20-100 ppm (B) 100-1000 ppm.

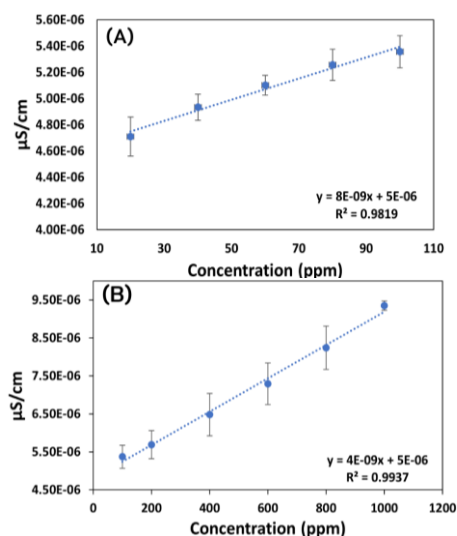


Fig. 2. Calibration curves of the gaseous phase of Ammonia concentrations: (A) 20-100 ppm (B) 100-1000 ppm.

Tab. 1: Comparison of the performances of some ammonia sensors at room temperature

Ammonia sensors	LOD	T _{Res.} (s)	Ref.
Citric acid-PANI	1 ppb	30	[3]
PANI-ZNO	10 ppm	35-21	[6]
NiO-NPs	50 ppm	63	[7]
2D-Borophene	4 ppm	18	This work

Conclusion

The borophene-based gas sensor is observed to be highly sensitive to ammonia gas at room temperature with a wide detection range of 20-1000 ppm. This concentration range can help in preventing severe health issues and monitoring ammonia levels in industry [1]. Further studies are essential to fully maximize its potentials.

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