

# Humidity Amplified Sensitivity in a highly selective H<sub>2</sub>S Gas Sensor Using MXene-conjugated Polymer Composite

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## Summary:

Highly sensitive and selective H<sub>2</sub>S sensors are required for human health and environmental monitoring. However, the humidity in the real working environment always harms either the sensitivity or selectivity of the H<sub>2</sub>S sensors. Here we reported a significant amplified sensitivity towards H<sub>2</sub>S gas induced by the variation of humidity for a chemiresistive sensor, which is based on Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> MXene-conjugated polymer composite. The sensor also provides a unique selectivity to H<sub>2</sub>S with a negative response, while positive to water vapor and most of the other analytes.

**Keywords:** H<sub>2</sub>S sensing, Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> MXene, humidity effect, intercalation, conjugated polymers

## Introduction

Humidity is often regarded as a prevalent factor that diminishes the sensitivity and selectivity of various types of gas sensors based on nano-materials [1-3]. In the practical applications, water vapor was inevitably mixed with the analytes, which requires humidity filter to reduce the moisture content prior to analysis. For the chemiresistive gas sensors based on absorption, the water vapor can interfere with the active sensing materials in different manners, e.g., competitive adsorption, surface blocking, chemical reaction, and conductivity modulation, etc. To tackle these issues, researchers have developed anti-humidity gas sensors, where the active surfaces were inert to water vapor. However, the reinforcement of the water humidity resistance always accompanies with reduced sensitivity or selectivity, longer response time, higher cost or complexity, limited measurement range. It is ideal to have a highly sensitive and selective chemiresistive gas sensor which does not affected by moisture, even the performance can be enhanced under high humidity environment.

## New Method

Utilizing the highly negative surface potential of Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> flakes and polar charged nitrogen of conjugated polymers (poly[3,6-diamino-10-methylacridinium chloride-co-3,6-diaminoacridine-squaraine], PDS-Cl), we simply used physical blending to fabricate the sensing material. The PDS-Cl has intercalated in the

MXene layers, preserving the high selectivity of MXene while enhances the sensing response of composite sensor [4].

The humidity amplification effect was seldom reported in gas sensor systems [5,6]. To the best of our knowledge, this is the first demonstration that MXene based gas sensor can have an enhanced sensitivity in higher humidity environment. Our work has demonstrated the versatility of MXene-based gas sensors in real-life scenarios.

## Results

Figure 1 demonstrates the H<sub>2</sub>S sensing response of the MXene-polymer sensor for different concentration of analytes at relative humidity (RH) of less than 10%. The lowest limit of detection for sensor is 0.5 ppm.

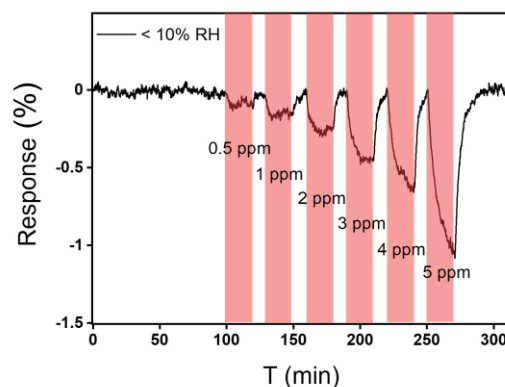


Fig. 1. Dynamic sensing response of MXene-polymer for different concentrations of H<sub>2</sub>S. The

baseline is subtracted for clarity and readability of the signal.

### Gas sensing response

The gas response is calculated using Equation 1:

$$S(\%) = \frac{R_g - R_0}{R_0} \times 100\% \quad (1)$$

where  $R_0$  and  $R_g$  are the resistances of the sensor upon exposure to  $N_2$  and the target gas, respectively.

Strikingly the sensing response of sensor under higher level of RH will improve, as indicated in Figure 2. The sensing response, summarized in Table 1, shows a linear sensing response at different RH level.

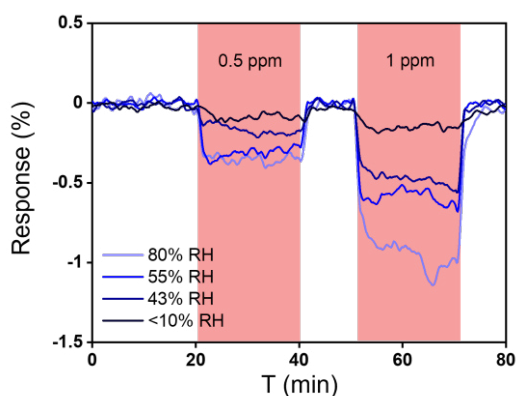


Fig. 2. The gas sensing response of sensor under different RH for 0.5 and 1 ppm  $H_2S$ .

### Sensing mechanism

In the case of MXene/PDS-Cl composite, the polymer opens the interlayer spaces and by increasing the RH level, the  $H_2O$  molecules will intercalate between layers and provide even higher number of accessible active sites as shown in Figures 3. This can lead to enhancement of the charge transfer effect and result in higher sensing response.

Tab. 1: Response of MXene composite sensor under different RH

H <sub>2</sub> S Concentration \ RH (%)	0.5 ppm	1 ppm
	<10% RH	-0.1%
43% RH	-0.2%	-0.5%
55% RH	-0.3%	-0.6%
78% RH	-0.4%	-1%

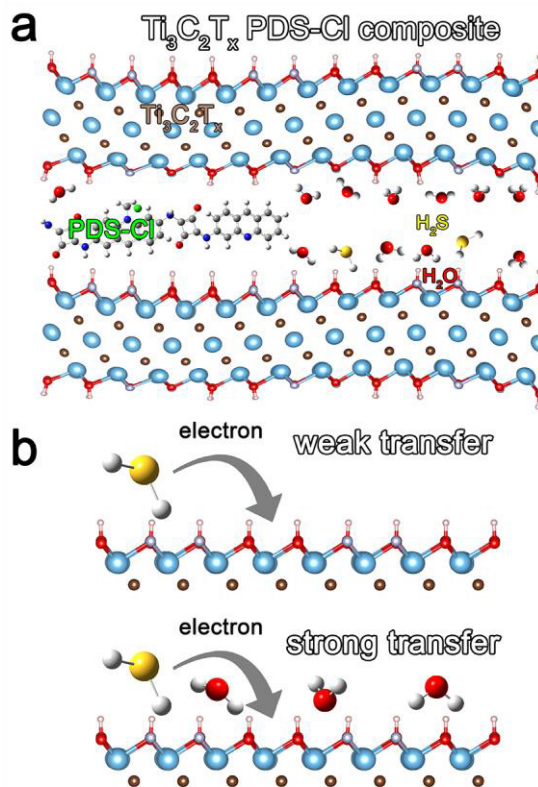


Fig. 3. (a) Schematic illustration of the structure of our MXene-polymer composite. (b) Proposed mechanism of the amplification sensitivity for  $H_2S$  sensing.

### References

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