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# Electrochemical Deposition of Polyaniline on Laser-Induced Graphene for Room Temperature Ammonia Sensing

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**Summary:**

This study explores the electrochemical modification of laser-induced graphene (LIG) with polyaniline (PANI)., resulting in the creation of a flexible chemoresistive PANI@LIG gas sensor for detecting ammonia ($NH_3$) levels at room temperature. The results obtained demonstrate that the deposition of PANI on LIG improves the response to $NH_3$. This work presents the first-time utilization of PANI@LIG for gas sensing and introduces a simple, yet effective, approach for fabricating wearable gas sensors that exhibit promising characteristics, including high sensitivity and flexibility. The findings open new avenues for developing low-cost, efficient, and portable gas detection systems.

**Keywords:** Laser-Induced Graphene, polyaniline, gas sensing, ammonia, flexible sensor

## Introduction

Ammonia measurement is important in diverse applications from air quality monitoring to agricultural regulation and chemical industry safety. Due to the dangerous nature of $NH_3$, it is crucial to develop sensitive sensors for real-time monitoring [1]. In recent years, many $NH_3$ sensors have been developed, employing different technologies such as optical, electrochemical, and chemoresistive with both metal oxides and graphene-based sensors [2]. Among these, graphene-based sensors have increased their interest due to their ability to work at room temperature, making them an ideal candidate for wearable gas sensor applications [3]. However, traditional graphene synthesis methods pose challenges in terms of cost and integration into flexible electronics.

In 2014, a breakthrough approach was introduced for producing porous graphene films from commercial polymer films using a $CO_2$ infrared laser, termed laser-induced graphene (LIG) [4]. LIG exhibits high porosity, excellent electrical conductivity, and good mechanical flexibility making it suitable for various applications including electronic devices, catalysis, water purification, and biosensors [4]. Also, it has been used in gas sensing applications. Despite its potential, the utilization of LIG in $NH_3$ sensing has been limited due to its low response to this gas. Previous works have demonstrated that loading graphene with polyaniline (PANI) improves its sensitivity to $NH_3$ [5]. Building upon this concept, the current research works to develop an electrochemical method for fabricating gas sensors utilizing PANI@LIG.

### Materials and Methods

For the fabrication of the LIG gas sensor (Fig.1 (a)), a commercially available polyimide film (50 µm) was used as a flexible substrate. LIG was synthesized using a $CO_2$ laser operating at a max power of 25 W. The laser beam scanned over the surface at a speed of 200 mm/s, a frequency of 12 kHz and 12% of laser power. The sensor has been designed with a sensing area of 3 x 6 mm$^2$. To improve the connection of the sensor with the measurement system, Ag ink was drop-casted on the region of the electrodes.

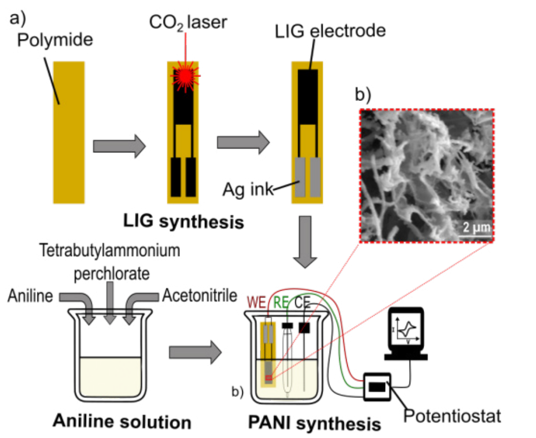


*Fig. 1. Schematic illustration showing (a) the fabrication process and (b) SEM images of the PANI@LIG gas sensor.*

Electrochemical growth was carried out using a potentiostat. A 3-electrode system comprised of bare LIG as working electrode, platinum wire auxiliary electrode, and Ag/AgCl reference electrode was used for experiments. The nanocomposite was prepared by cyclic voltammetry method electrode cycled at 50 mV/s between -0.2 and 1.3 V for 20 cycles in polymerization solution ( 0.1 M aniline/0.5 mM tetrabutylammonium perchlorate as the electrolyte /acetonitrile).

## Results and Discussion

The SEM images show the morphology of PANI@LIG (Fig. 1(b)). The Raman spectra (Fig. 2) revealed prominent peaks corresponding to the characteristic vibrational modes of graphene and polyaniline.

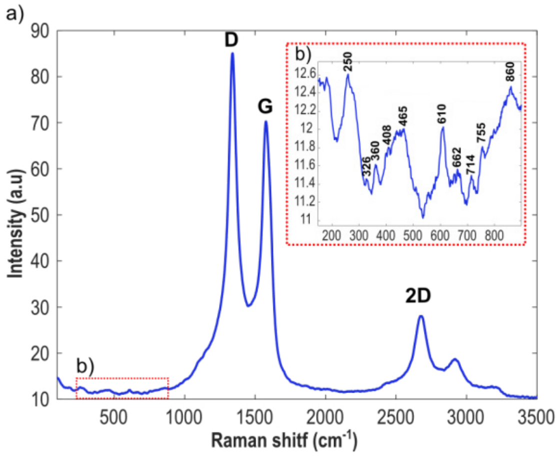


*Fig. 2. Raman spectra of (a) the PANI@LIG gas sensor and (b) peaks corresponding to polyaniline.*

The sensing performance of the LIG gas sensors developed for $NH_3$ detection was assessed through repeated cycles of response and recovery to concentrations of 5, 10, 25, 50, and 100 ppm. Fig. 3 illustrates the typical dynamic responses observed for the bare LIG (blue dots) and the PANI@LIG (red dots) gas sensors. The sensor responses (electrical resistance change) increased upon exposure to the target gas. The raised electrical resistance results from the decreased hole density and electrical conductivity of the p-type LIG upon exposure to the reducing $NH_3$ (electron donating). Fig. 3 demonstrates that the doped sensor shows an improved response and signal-to-noise ratio compared to the bare sensor. The PANI@LIG sensor exhibits responses that are up to 1.5 times higher in terms of the intensity of resistance changes induced by exposure to ammonia, compared to bare LIG.

Based on the experimental results, it can be inferred that although the response of the PANI@LIG sensor is not significant compared to that obtained in other investigations, the combination of these two nanomaterials exhibits a synergistic sensing effect, in which LIG and PANI interact with the $NH_3$, resulting in superior chemical gas sensing performance.

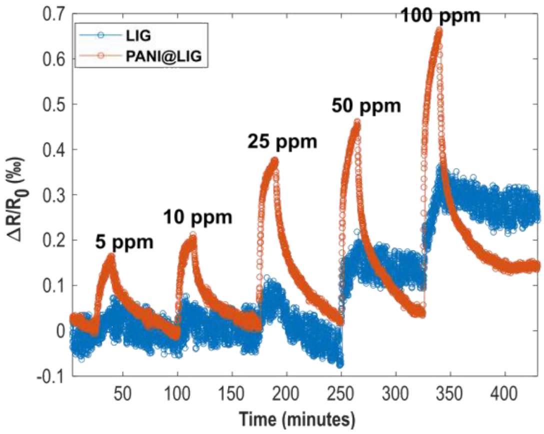


*Fig. 3. Sensing performance of bare LIG (blue dots) and PANI@LIG (red dots) gas sensors to different concentrations of $NH_3$ at room temperature.*

The development of a flexible room temperature chemical resistive sensor opens possibilities for $NH_3$ monitoring systems, offering advantages like a simple interface circuit, cost-effectiveness, low power consumption, and high portability, ideal for wearable gas sensors. Further optimization of electrochemical deposition methods is needed to enhance $NH_3$ sensor response, alongside comprehensive studies on humidity effect, repeatability, stability, and selectivity for future improvements.

## References

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