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Facile E-nose based on single antenna and graphene oxide for sensing volatile organic compound gases with ultrahigh selectivity and accuracy

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ABSTRACT

Volatile organic compounds (VOCs) gases exist as important indicators in various processes such as human breath, food spoilage, plant disease, and industrial production, which makes VOC sensing a promising nondestructive detection method. Nanomaterial enabled electronic noses (e-noses) are gaining increasing attention for their exceptional ability to distinguish between multiple VOCs. To achieve this, multiple sensors with distinct nanomaterials are crucial for providing enough diversity for successful discrimination. Apparently if e-nose can be implemented solely on single sensor with single common nanomaterial operating at room temperature, the complexity and power consumption can be greatly decreased. In this study, a significant milestone is achieved as, for the first time, a single antenna sensor coated with commercial graphene oxide, demonstrates comparable performance to array-based e-noses, and even outperforms them in terms of the ultimate ambition of selectivity—isomeric VOC classification. An impressive classification accuracy of 96.7 % is attained for multiple VOC gases, including isomers. Additionally, the concentration of each component in VOC isomer mixtures is accurately determined. Unlike conventional antenna sensors, the sensor maintains stable communication during sensing operations. Finally, the practical feasibility of the antenna e-nose (Ant-nose) is successfully demonstrated with a series of food quality assessments.

1. Introduction

VOC gas sensing, as a promising nondestructive detection technology finds diverse applications in agriculture [1], environmental protection [2], fruit freshness [3], meat spoilage [4], disease diagnosis [5], and public safety [6]. In practical applications, diverse VOCs may share similar characteristics but have distinct levels of toxicity or impact on humans and the environment [7], necessitating discrimination between multiple VOC analytes. Additionally, it is common for multiple VOCs to coexist as indicators, evident in scenarios such as postharvest fruit damage [8], fruit ripening [3,9], and plant disease diagnosis [10]. Furthermore, the real-life detection process can be complicated by potential interference from irrelevant VOCs. Faced with these challenges, depending on sensors that detect only a specific VOC is impractical. Reliable and robust detection is achieved only through the collective analysis of a panel of VOCs, creating distinct 'fingerprints' of the sample under test.

To meet practical requirements, the nanomaterials-enabled electronic nose (e-nose), inspired by mammalian olfaction [11], stands out as a promising biomimetic device [12–14]. Comprising an array of sensors, each coated with a distinct nanomaterial, the e-noses demonstrate affinity to a range of VOCs, yielding diverse response levels. These responses are collectively processed using a pattern recognition algorithm, resembling the human brain [4]. Attributed to the variety of the sensors in e-nose, profiling the distinct pattern and classification of analytes under test can be achieved. Various transducers and sensitive materials have been extensively explored and applied for e-nose. Taking some state-of-art works as example, Capman et al. introduced a graphene e-nose with 432 sensors, functionalized with 36 distinct receptors, achieving an 89 % discrimination accuracy among 6 different VOCs at 4 concentrations each [15]. Similarly, Kybert et al. introduced a graphene e-nose with 56 sensors functionalized by 4 DNA oligomers, visually separating 8 chemical vapors [16]. Weerakkody et al. presented a five-element biohybrid e-nose effectively discriminating 4 VOCs [11]. Wang et al. introduced a semiconductor metal oxide (SMO) e-nose with 5 sensors made up of 5 types of zinc oxide, achieving 99 % classification accuracy among 6 VOCs [17].

However, use of multiple transducers and sensitive nanomaterials in

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