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THESIS OUTLINE

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The title of this dissertation is “Development of a Bioelectronic Sensor for the Detection of Volatile Organic Compounds Using Olfactory Receptor Mimetic Peptides” which consists of six chapters.

In Chapter 1, the overview of the study’s background, including volatile organic compounds (VOCs) and their crucial role in detection applications, as well as the conventional strategies for detecting VOCs and their limitations were described. This chapter provides the objectives, significance, and the structure of the dissertation. VOCs are fundamental elements of odors that contain chemical information about their origin and are extensively employed as non-invasive biomarkers for diverse detection applications. However, limitations of the conventional VOCs detection techniques, which involve sensor platforms and recognition probes, hindering their applications. Thus, this research proposes a novel strategy to overcome these limitations by utilizing olfactory receptor (OR) mimetic peptide-modified graphene field effect transistors (GFET) for the development of sensitive and specific VOCs detection technique.

In Chapter 2, limonene, a characteristic VOC from citrus, was employed as a pilot target for the strategy development. Limonene binding peptide (LBP) was screened from fruit fly’s OR19a, known for its precise limonene detection, by a screening technique utilizing peptide array and gas chromatography. Through the screening process, limonene binding abilities of the entire OR were evaluated and the selected LBP with high affinity and specificity for limonene was selected. The nuclear magnetic resonance analysis revealed the peptide structural transformation upon binding with limonene, indicating crucial amino acids involved in limonene capture. These findings demonstrated the success of the developed peptide screening technique to mimic and miniaturize the VOC binding function of OR into peptides.

In Chapter 3, the fabrication of LBP-modified GFET sensor and its limonene detection were demonstrated. The LBP probe was bifunctionalized via linkage with graphene-binding peptide, enabling a simple one-step immobilization on GFET. The success of peptide functionalization was evaluated using atomic force microscopy images. Next, limonene detection of the LBP-modified GFET sensor was demonstrated. The sensor displayed a rapid response and high affinity for limonene with sensitivity and detection limit at picomolar level, while achieving exceptionally high specificity. The peptide sensing layer not only improved the specificity of the sensor but also enhanced the consistency and reliability in limonene detection. Furthermore, the practical application of the sensor was demonstrated by successfully detecting limonene from a citrus sample.

In Chapter 4, the applicability of the established OR-mimetic peptide screening and GFET functionalization strategy was demonstrated through the development of OR-mimetic peptide-modified GFETs for skatole, a signature VOC from boar taint. The skatole binding peptides (SBPs) were screened from the mosquito’s OR and functionalized onto GFET using identical approach. The SBP-modified GFET sensor exhibited a high affinity for skatole detection. The sensor displayed good specificity by differentiating skatole from its analogs, despite having just one functional group difference. This chapter highlighted the potential of the developed strategy as a proof-of-concept for the advancement of OR-mimetic peptide-modified GFETs for diverse VOC targets.

In Chapter 5, the development of a bioelectronic nose system using an array of OR-mimetic peptide-modified GFETs and principal component analysis (PCA) for the discrimination of VOCs was described. The sensors were exposed to a set of VOCs including limonene, skatole, and other VOCs, to generate response patterns. These patterns were then analyzed using PCA for pattern recognition. The bioelectronic nose system effectively discriminated all the test VOCs, while revealing important analysis parameters for the discrimination. These findings highlighted the potential of the strategy for OR-mimetic peptide-modified GFET-based bioelectronic nose for the detection and discrimination of diverse VOC targets.

Chapter 6 concludes and summarizes the keys findings, implications, and potential future research. In brief, this dissertation proposes a systematic screening of LBP and SBP from OR, their implementation in GFET, and the fabrication and application of a bioelectronic nose for the detection and discrimination of limonene, skatole and other test VOCs. Overall, the strategy utilizing OR-mimetic peptide-modified GFETs and bioelectronic nose system represents a simple and efficient approach with wide applicability to diverse protein-VOC targets and contributes to the advancement of the peptide-based VOCs detection system.