Green highlighted = changes from thesis as submitted

Abstract

The ability to detect volatile organic compounds in a highly sensitive and selective manner is desirable for applications as varied as diagnosis of illnesses at a remote clinic, monitoring of air in an industrial setting, or identification of invasive organisms at abiosecurity checkpoint. Historically, animal noses have been used for such tasks, as their combined sensitivity and selectivity are superior to traditional artificial sensors. However, training and deploying animals in such situations is both time and cost intensive. In recent years, an improved understanding of *in vivo* biological sensing has led efforts to mimic these highly eﬀicient processes in an artificial sensor format.

To this end, a “bioelectronic nose” was developed. This sensor uses an artificial transducer to amplify responses of an insect odorant receptor protein to specific volatile compounds. Thin-film transistors were used as the amplifier element, given their low cost, small size and extreme sensitivity. Various thin-film morphologies were compared, and their suitability for bioelectronic nose development assessed. Transducers made using a novel steam-assisted thin-film deposition technique were found to have highly consistent device-to-device electrical properties relative to other films. Films made using this process typically showed more surface contamination than other morphologies, but their high sensitivity was nonetheless confirmed with a non-specific sensing series in an aqueous environment.

One of the major challenges encountered in this thesis was variability in the quality of sensor functionalisation. Raman spectroscopy and fluorescence microscopy confirmed an existing non-covalent attachment method could successfully immobilise nanodiscs onto the transistor channel region. However, various sensors functionalised using the same procedure often exhibited no sensing activity. Extensive electrical characterisation indicated the presence of an unidentified contamination layer preventing electrical interaction between the insect odorant receptors and transducer thin-film. It was shown that this layer was unlikely to be directly associated with the thin film morphology used for the transducer.

Subsequently, an alternative biotin-based non-covalent method was used for functionalisation of the proteins, which eliminated several possible contamination sources. This alternative biotin-based method was used to demonstrate successful aqueous sensing of femtomolar concentrations of methyl salicylate by an iOR10a-functionalised device. When tested in a custom-built vapour delivery system, a similar bioelectronic sensor was shown to be highly sensitive to the target vapour. However, consistent reproduction of the biotin-based method was challenging due to the harsh cleaning method involved. It was therefore diﬀicult to determine conclusively whether sensor responses were selective. By finding new, systematic approaches to address the major barriers to sensor success carefully identified in this work, there are promising signs that a highly reliable vapour-phase bioelectronic nose can be produced.