Volatile Organic Compound Detection Using Insect Odorant-Receptor Functionalised Field-Effect Transistors

by

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Acknowledgements

Thanks for all the fish.

Abstract

This is a thesis skeleton written with quarto. Make a copy of this thesis repo and start to write!

Make a new paragraph by leaving a blank line.

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1 Introduction

This is a book created from markdown and executable code.

See for additional discussion of literate programming.

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2 Carbon Nanotube and Graphene Field-Effect Transistors

2.1 Device Functionalisation

2.2 Insect Odorant Receptors

3 Carbon Nanotube and Graphene Field-Effect Transistors as Biosensor Platforms

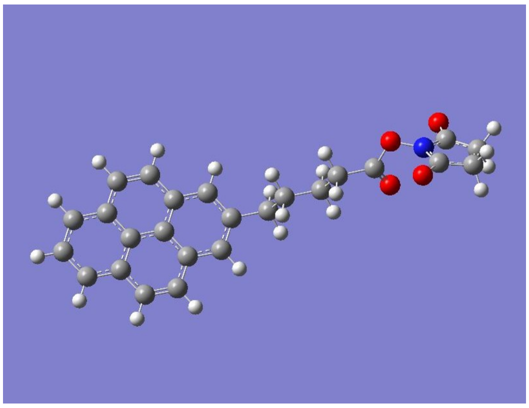
4 Fabrication

Stuff I did to get the results.

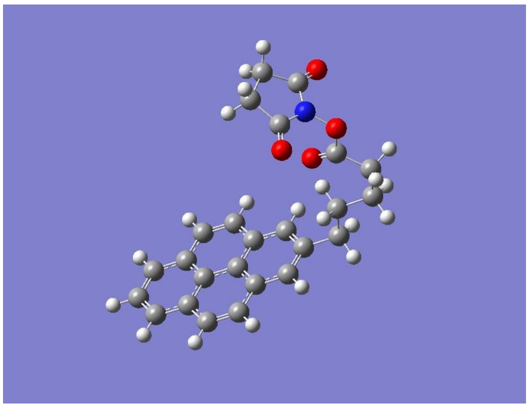
5 Functionalisation of Carbon Nanotubes and Graphene with Odorant Receptors

5.1 Linker molecules

5.1.1 1-Pyrenebutanoic acid N-hydroxysuccinimide ester (PBASE)



(a) Hartree-Fock energy: -3427728.67 kJ/mol (9 s.f.)



(b) Hartree-Fock energy: -3427729.66 kJ/mol (9 s.f.)

Figure 5.1: Two conformations of PBASE molecule with geometry optimised via *ab initio* calculation (computed using Gaussian software [1]). The difference between computed Hartree-Fock energies is 1.0 kJ/mol, small enough that the existence of both conformations is physically possible.

1-Pyrenebutanoic acid N-hydroxysuccinimide ester (variously known commercially and in the literature as 1-Pyrenebutyric acid N-hydroxysuccinimide ester, PBASE, PBSE, PASE, Pyr-NHS, PyBASE, PANHS) is an aromatic molecule commonly used for tethering biomolecules to the carbon rings of graphene and carbon nanotubes. The use of this bifunctional molecule for noncovalent functionalisation of proteins onto a single-walled carbon nanotube was first reported in 2001 by Chen *et al.* [2]. Two methods for protein functionalisation were successfully used, with the only differences being the solvent used to dissolve the PBASE powder (DMF, methanol) and the final concentration of the resulting solutions (6 mM, 1 mM respectively). The lower concentration may have been used for PBASE in methanol as PBASE appears to dissolve poorly in methanol at higher concentrations. Subsequent publications appear to have largely either chosen or adapted one of these two methods, as demonstrated by the frequency of the use of 6 mM PBASE in DMF and 1 mM PBASE in methanol in Table 5.1. Cella *et al.*, Campos *et al.*, Zheng *et al.* and Ohno *et al.* directly cite Chen *et al.* when discussing functionalisation with PBASE [3]–[6].

However, despite these various methodologies appearing to possess a common ancestor, there is a large degree of variation in

We purchased PBASE from two suppliers, Sigma-Aldrich and Setareh Biotech. Sigma recommends DMF and methanol as suitable solvents for dissolving PBASE alongside chloroform and DMSO. Setareh Biotech indicates methanol can be used for dissolving PBASE. The two suppliers have conflicting information for suitable storage of PBASE, with Sigma recommending room temperature storage while Setareh Biotech recommends storage of -5 to -30°C and protection from light and moisture.

Table 5.1: Comparison of PBASE functionalisation processes used for immobilisation of proteins and aptamers onto liquid-gated CNTFET and graphene FET sensors

Solvent	Channel	Conc. (mM)	Incubation type	Time (hr)	Rinse steps	References
DMF	CNTs	5	Immersed	1	PBS	Maehashi *et al.* [7]
		6	Immersed	1	DMF, PBS	García-Aljaro *et al.* [8]
		6	Immersed	1	DMF	Chen *et al.* [2]
		6	Immersed	1	DMF	Cella *et al.* [3]
		6	Immersed	1	DMF	Das *et al.* [9]
	Graphene	-	-	2	DMF	Kwong Hong Tsang *et al.* [10]
		-	-	20	-	Wiedman *et al.* [11]
		0.2	Immersed	20	DMF, IPA, DI water	Gao *et al.* [12]
		1	100 μL droplet	6	DMF, IPA, DI water	Nekrasov *et al.* [13]
		5	Immersed	1	DMF, DI water	Hwang *et al.* [14]
		6	6 μL droplet	2	DMF, DI water	Nur Nasufiya *et al.* [15]
		10	10 μL droplet	2	DMF, DI water	Campos *et al.* [4]
		10	Immersed	2	DMF, PBS	Kuscu *et al.* [16]
		10	Immersed	1	DMF	Xu *et al.* [17]
		10	Immersed	12	DMF, ethanol, DI water	Khan *et al.* [18]
2-Methoxyethanol	Graphene	1	Immersed	1	DI water	Ono *et al.* [19]
Methanol	CNTs	1	Immersed	1	Methanol, DI water	Zheng *et al.* [5]
		1	Immersed	2	Methanol	Kim *et al.* [20]
	Graphene	5	Immersed	2	-	Sethi *et al.* [21]
		5	Immersed	1	Methanol, PBS	Ohno *et al.* [6]
DMSO	CNTs	10	-	1	DI water	Lopez *et al.* [22]
		10	Immersed	1	PBS	Strack *et al.* [23]

6 Results

What I found out.

See for more detailed results

7 Results

What I found out.

See for more detailed results

8 Summary

In summary, this book has no content whatsoever.

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