DNA Detection Using Graphene Field-Effect Transistors

Jiri Cervenka
Department of Thin Films and Nanostructures, Institute of Physics ASCR, v. v. i., Cukrovarnicka 10/112, 162 00 Prague, Czech Republic
cervenka@fzu.cz

Abstract

DNA is a nucleic acid molecule encoding genetic information, which has a vital role for the development and functioning of all known living organisms. Therefore, sensitive and selective detection of DNA is of fundamental importance for a large number of applications in medicine and biotechnology. Recent advances in graphene-based electrical sensors have demonstrated their unprecedented sensitivity to adsorbed molecules, which holds great promise for label-free DNA sequencing and detection.

Here we present a comparative study of the electronic detection of DNA on graphene field-effect transistors (GFETs) in vacuum and liquids. We compare the device sensitivity for direct detection of DNA on GFETs and using specific binding of target DNA with complementary DNA molecules attached to graphene, providing an estimate of the GFET sensitivity limit. Furthermore, we analyze the ability of GFETs to directly discriminate individual DNA nucleobases in electronic transport measurements. We demonstrate that GFETs are able to measure distinct, coverage dependent, conductance signatures upon adsorption of DNA nucleobases in vacuum (Figure 1) [1]. This method allows for electronic discrimination of individual DNA nucleobases on GFETs, providing a first step towards graphene based electronic DNA sequencing. The existence of molecule specific signatures in electronic transport measurements is verified by independent synchrotron-based X-ray photoelectron spectroscopy (XPS) measurements. To get a deeper insight into the origin of the sensing mechanism and molecular recognition in GFET measurements we performed ab initio electronic structure calculations using density functional theory (DFT). The molecular recognition is found to be closely linked with specific noncovalent molecular interactions of DNA nucleobases with graphene. The absorption of molecules resulted in the electronic structure change of graphene which is driven by complex interplay between molecule-graphene and intermolecular interactions, interface dipole moment, charge transfer, work function change and screening effects. These effects open up a range of new opportunities for molecular recognition of different biomolecules in graphene-based electronic sensing.

References

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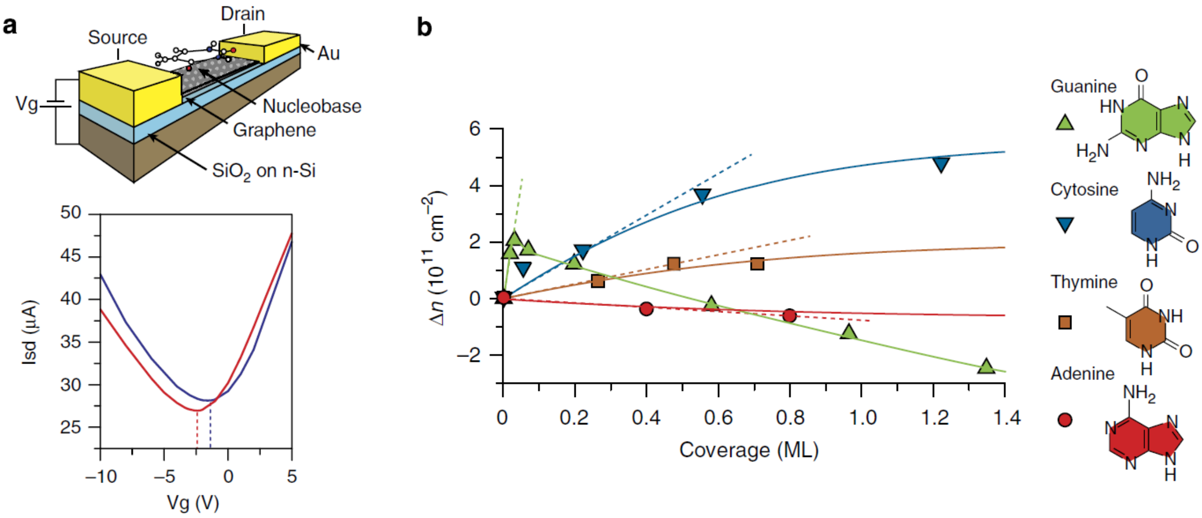

Figure 1 a Detection of DNA nucleobases using GFETs, which is based on measurements of shifts of the Dirac point. **b** Coverage dependence of induced charge carrier density (determined from the Dirac point shifts) in GFETs by DNA nucleobases [1].