

# BIO-FET BASED MOLECULAR COMMUNICATION DEVICES

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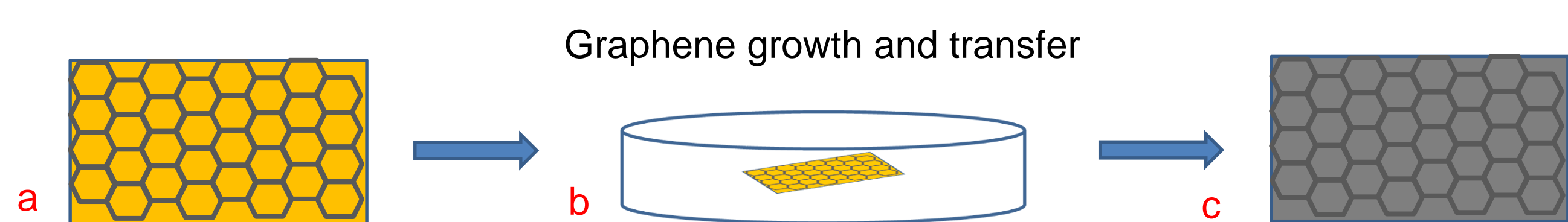
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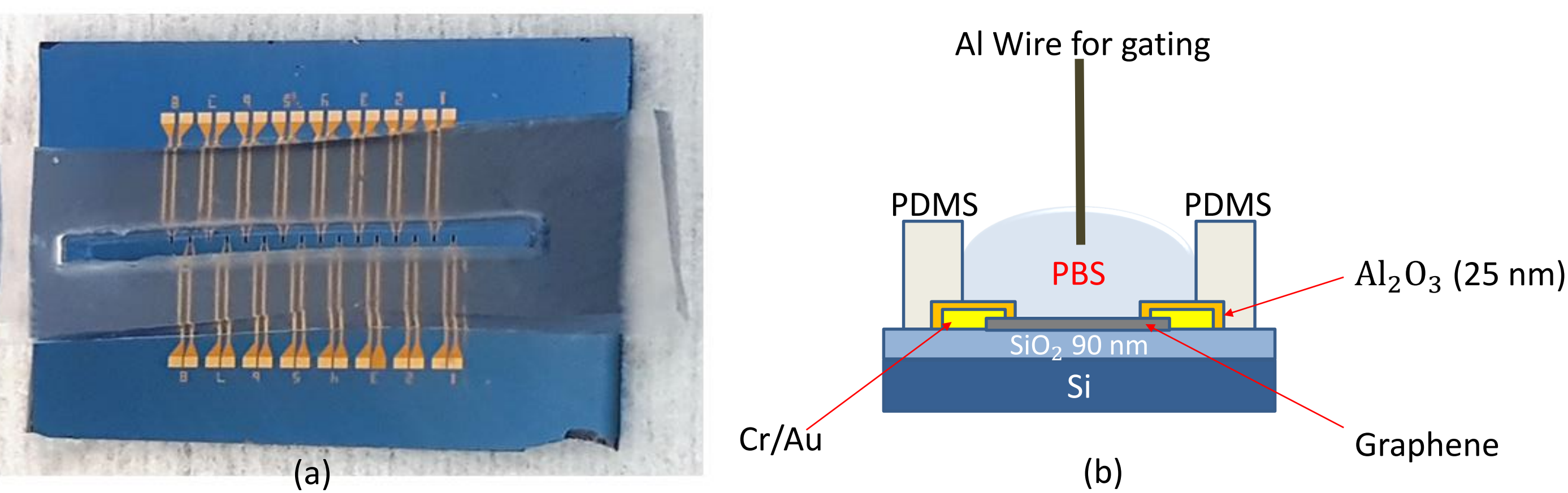
## Abstract

Graphene possesses properties and functionalities such as biocompatibility, chemical stability, flexibility and non-toxicity. Moreover, its high surface to volume ratio, possibility of functionalisation and tunable conductivity by field effect or doping makes it an ideal material for biosensing or molecular communication (MC) devices. These devices can be used for disease detection and neural interfacing etc [1-7]. In this work the fabrication of graphene field effect transistor (GFET) is demonstrated for the detection of a target (T20) single stranded DNA (ssDNA) by its combination with probe ssDNA (P20). The graphene surface is modified noncovalently by 1-pyrenebutanoic acid succinimidyl ester (PBASE), which acts as a linker molecule for immobilisation of 5' amine modified probe ssDNA. The functionalisation of PBASE showed the reduction in source to drain current ( $I_{ds}$ ) indicating increase in sheet resistance of graphene due to  $\pi$ - $\pi$  stacking of pyrene group of PBASE on graphene surface. Furthermore, hybridisation of probe DNA resulted in positive shift in the charge neutrality point (CNP), while addition of target ssDNA resulted in negative shift in CNP. These shifts in the CNP has been consistently seen on all GFET devices that makes it a viable method for detection of different molecules. Further investigations along various directions such as substrate effects, selectivity, binding kinetics, concentration effects, microfluidic channel geometry and sensitivity of device are being carried on for their ultimate use in MC devices.

## Device fabrication



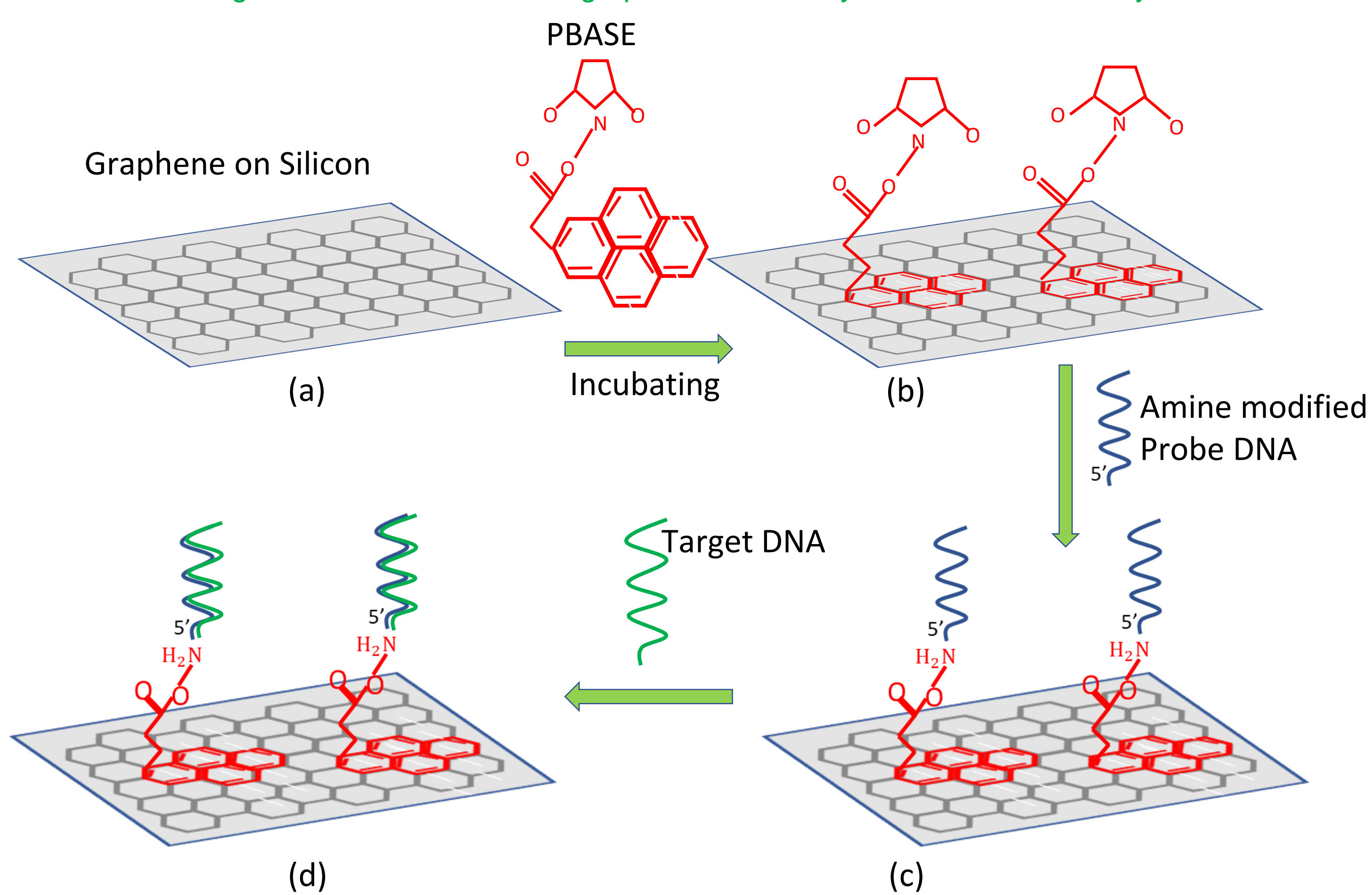
**a):** Graphene grown on copper by chemical vapour deposition (CVD). **b):** Wet etching of PMMA coated graphene by ammonium per sulphate solution in deionized water. **c):** Graphene layer transferred to silicon substrate having 90 nm thick silicon oxide layer



**(a)** Array of graphene field effect transistors fabricated on the Si/SiO<sub>2</sub> substrate. PDMS microfluidic channel is placed on the substrate in a way to expose channels for electrolyte gating. **(b)** Schematic illustration of bio-FET device

## Mechanism

Different stages of functionalisation of graphene surface by PBASE and DNAs hybridisation

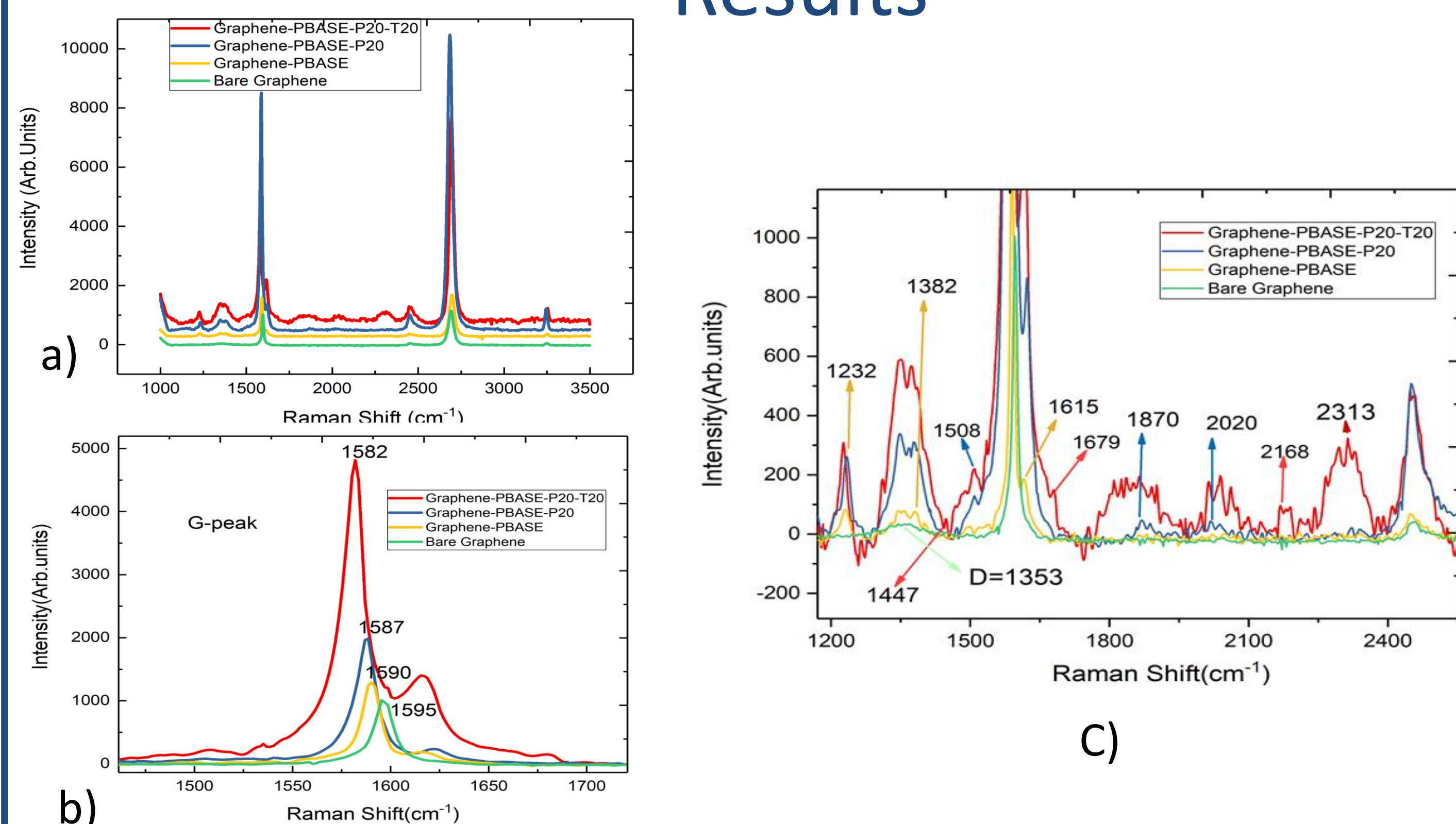


**(a)** Graphene on Silicon **(b)** Functionalization of graphene with PBASE **(c)** Hybridisation of amine modified single stranded probe DNA is attached to PBASE **(d)** Detection of target DNA by probe DNA [6,8]

## References

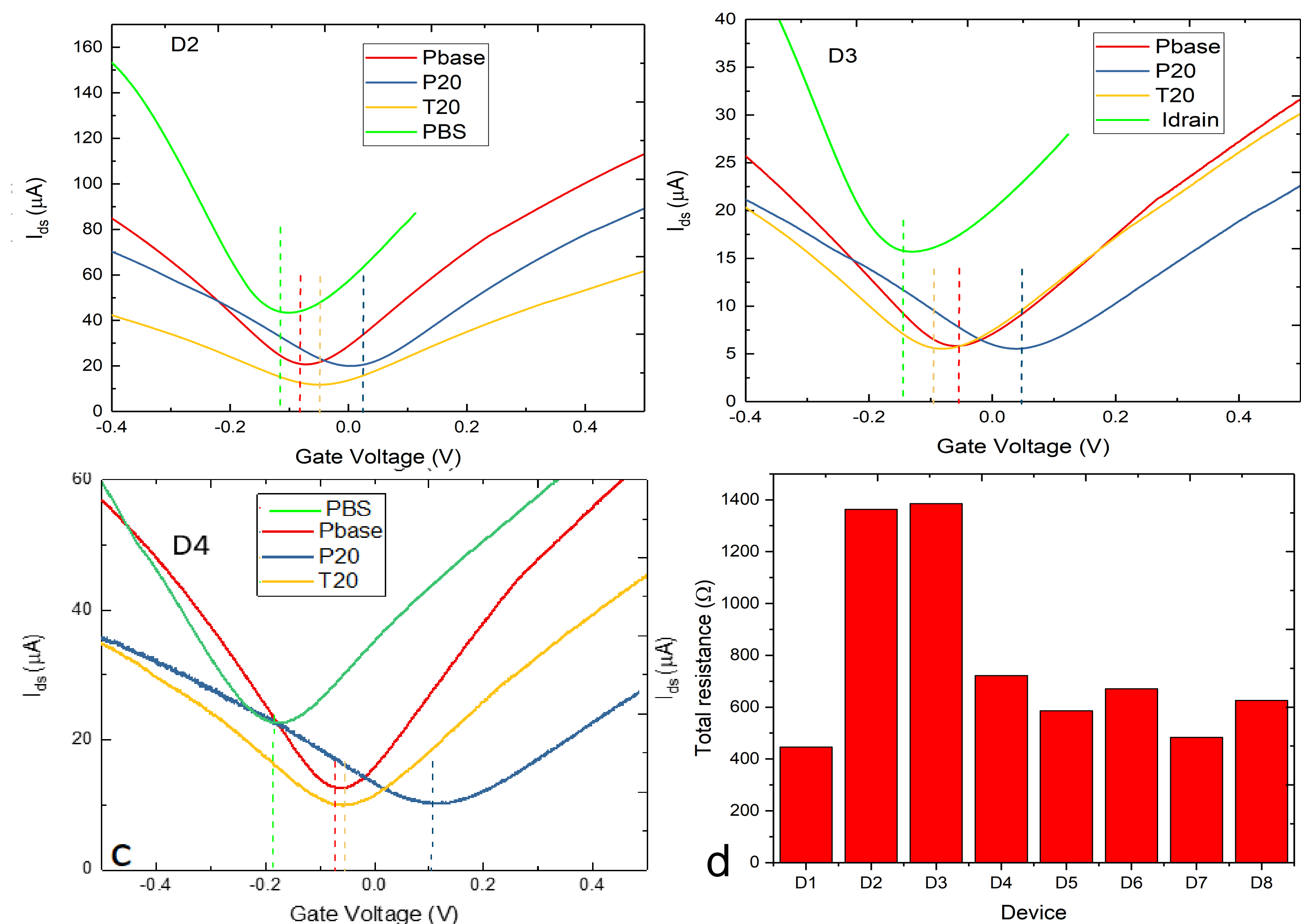
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## Results



**(a)** Raman spectrum of graphene after functionalisation with PBASE, probe and target DNA **(b)** shift in G-peak towards lower frequencies after functionalisation (change in doping) **(c)** Different Raman peaks assigned to PBASE, probe and target DNAs

Electrical Measurement of devices D2, D3 and D4 are presented below, which shows consistent change in CNP after functionalisation and hybridisation of DNAs. It can be seen that before functionalisation  $I_{ds}$  stop increasing and become constant which could be due to leakage current through electrolyte gating. This effect is eliminated after functionalisation indicating reduction in leakage current



**(a), (b) & (c)** Comparison graphs for devices D2, D3 and D4 shows consistent change in Dirac point (indicated by dotted lines) during different stages of electrical measurements of drain to source current  $I_{ds}$  upon varying gate voltage  $V_g$  **(d)** Graphene sheet resistances of different devices

## Conclusions and Future Work

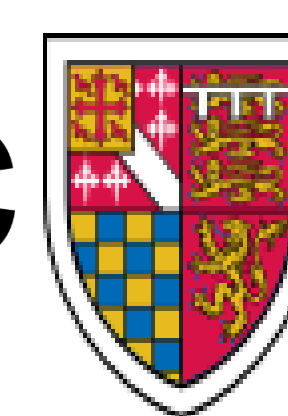
We have shown that GFET is sensitive to DNAs and this effect can be seen in shift in CNP of graphene and change in  $I_{ds}$ . The typical ambipolar behaviour associated with graphene and evident from electrical measurements indicating the conduction through the graphene. Hence, we can say GFET can be used to detect biological molecules and could be integrated in biosensors. Further investigation for its possible use as molecular communication device are under going. The suggestions given below could be used to achieve the goal.

- Time resolved and frequency-domain analysis to characterize the noise and obtain signal-to-noise (SNR) ratio and frequency domain analysis to examine the possibility of devising a detection method based on the difference in binding spectrum
- Studying interference of different kind of molecules in the channel, for example by trying to mimic the physiological conditions
- Trying new target-probe pairs and optimize their characteristics from communication theoretical perspective, i.e., optimize their binding-unbinding rates
- To determine selectivity and sensitivity of the device, by varying different channel parameters (e.g., length, width etc.), concentrations, choice of substrate (e.g., flexible substrate for biocompatibility) needs to be studied

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