Graphene deflectometry for sensing molecular processes at the nanoscale

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Single-molecule sensing is at the core of modern biophysics and nanoscale science, from revolutionizing healthcare through rapid, low-cost sequencing to understanding various physical, chemical, and biological processes at their most basic level. However, important processes at the molecular scale are often too fast for the detection bandwidth or otherwise outside the detection sensitivity. Moreover, most envisioned biophysical applications are at room temperature, which further limits detection due to significant thermal noise. Here, we theoretically demonstrate reliable transduction of forces into electronic currents via locally suspended graphene nanoribbons subject to ultra-low flexural deflection. The intrinsic sensitivity is less than 7 fN/Hz$^{1/2}$, allowing for the detection of ultra-weak and fast processes at room temperature. The decay of electronic couplings with distance magnifies the effect of the deflection, giving rise to measurable electronic current changes even in aqueous solution. Due to thermal fluctuations, the characteristic charge carrier transmission peak follows a generalized Voigt profile. Room temperature graphene deflectometry presents new opportunities in the sensing and detection of molecular-scale processes, from ion dynamics to DNA sequencing and protein folding, in their native environment.

References

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[2] D. Gruss, A. Smolyanitsky & M. Zwolak, J. Chem. Phys. 147, 141102 (2017)
[3] J. E. Elenewski, D. Gruss, & M. Zwolak, J. Chem. Phys. 147, 151101 (2017)
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Figures

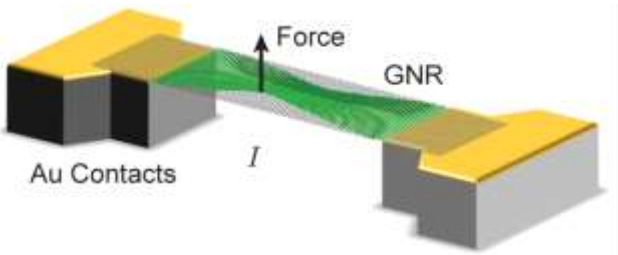

Figure 1: Graphene deflectometer composed of a nanoribbon suspended between two gold contacts in aqueous solution (omitted for clarity). Molecules or hydrated ions deflect the ribbon giving rise to a change in current.

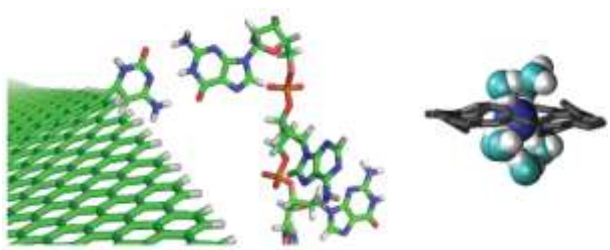

Figure 2: Hydrated ions and molecules can deflect the graphene, e.g., by binding to a functional group at the ribbon edge or by passing through a pore. The deformed ribbon is in green with an exaggerated upward deflection for visual clarity.