Electric Field Induced van der Waals Bonding Memory in Graphene Gas Sensors

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Improving the response of graphene gas sensors by electrically inducing specific graphene-gas molecule van der Waals (vdW) interactions is ubiquitous in gas sensing. This electric field modulation of the graphene-molecule vdW complex bonding has also been shown to induce signature charge transfer which could be applied for molecular identification of the adsorbed gases.[1] However, to exploit the vdW bonding induced charge transfer for molecular identification in graphene-gas sensors, an understanding of the vdW bonding stability is necessary. Hence, in this work we investigate the vdW bonding retention in the electric field induced vdW complexes using their doping and gas-adsorption induced scattering characteristics.

The experiment involved monitoring the room temperature conductivity response of the graphene sensor to CO_2 adsorption while applying a specific tuning voltage (TV). The TV experiment was interrupted for about 30 second to obtain the transfer characteristics. This was done until 56 minutes for TV = 40 V, 36 V, 0 V, -20 V, and -40 V separately. Thereafter, the TV experiment was stopped completely and only the transfer characteristics were monitored in intervals of 30 minutes until 206 minutes. The experimental procedure and device schematic are shown in **Figures 1a and b** respectively. Remarkably, after the TV experiment was stopped (after 56 minutes in **Figure 1c,** blue region) the different TV-induced states still maintained doping and gas adsorption induced scattering characteristics unique to each TV-induced vdW bonding state. Using DFT simulations, the binding energies of the vdW complexes were shown to be ~290 - 296 meV which are an order of magnitude higher than the measurement thermal energy (25 meV), consequently the vdW bonding memory was observed. This vdW bonding memory is necessary for the molecular identification of adsorbed gases on graphene.

Acknowledgments: This research is supported by TAIYO YUDEN Co. Ltd and Grant-in-Aid for Scientific Research No 18k04260 from Japan Society for the Promotion of Science (JSPS).

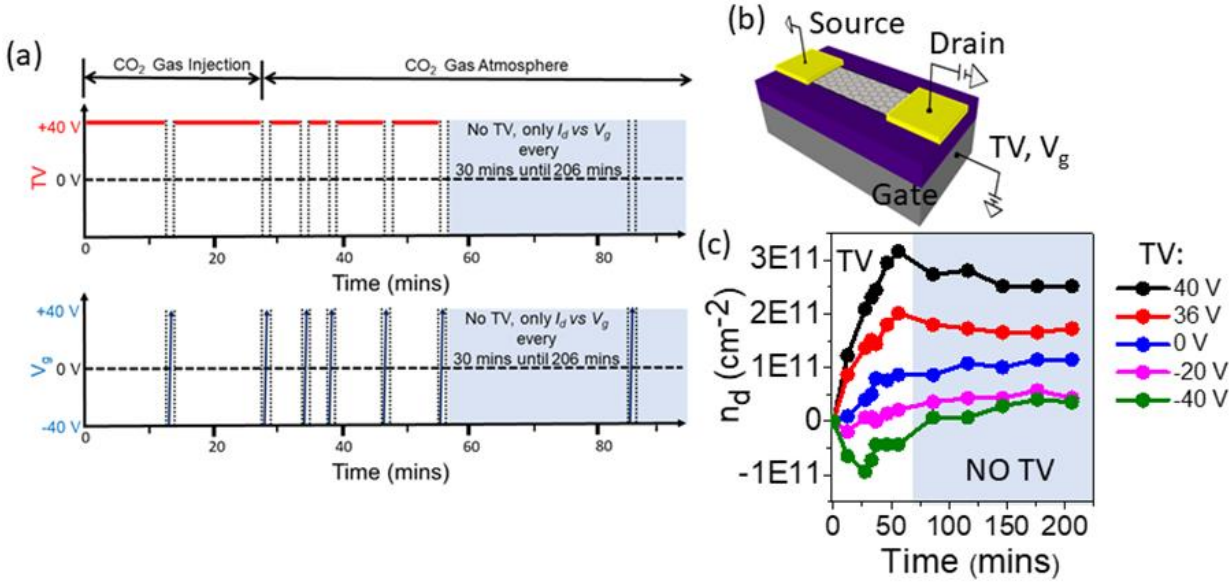

Figure 1: (a) Experimental schematic. Red lines = conductivity measurement with TV, dark blue lines = transfer characteristics measurement. (b) Device schematic. (c) Doping characteristic vs time showing vdW bonding memory (blue region)

Reference:

[1] M. Muruganathan, J. Sun, T. Imamura, H. Mizuta, *Nano Lett.* **2015**, *15*, 8176.