In situ refreshing enabled parts-per-quadrillion gas detection with pristine carbon nanotubes and graphene

P7

Gugang Chen and Avetik R. Harutyunyan*

Honda Research Institute USA Inc., 1381 Kinnear Road, Columbus, OH 43212, USA
*(*aharutyunyan@honda-ri.com)*

Single-walled carbon nanotube (SWNT) and graphene are very promising for ultrasensitive gas detection since they consist solely of surface so that every atom is in direct contact with nearby analyte molecules. However, it is very challenging to achieve super-sensitivity due to virtually unavoidable interfering species present in the detection environment. This may partially explain why we are still far from what a pristine SWNT or graphene can offer even after more than a decade of research. Here we illustrate a novel route to address this issue. Through *in situ* refreshing of the sensor surface with continuous ultraviolet light illumination during the course of detection, we have observed 2 to 4 orders of magnitude better sensitivity than current state-of-the-art results for a range of gas molecules, and for the first time entered parts-per-quadrillion (PPQ) detection level at room temperature [1, 2]. The study further points out how to exploit the intrinsic sensitivities of other nanomaterials.

[1] G. Chen, T. M. Paronyan, E. M. Pigos, and A. R. Harutyunyan, Scientific Reports 2, 343 (2012)
[2] G. Chen, T. M. Paronyan, and A. R. Harutyunyan, Appl. Phys. Lett. 101, 053119 (2012)

Density-controlled CVD growth and selective removal by thermal-lithography for horizontally-aligned single-walled carbon nanotubes

P8

Shohei Chiashi, Taiki Inoue, Keigo Otsuka, Daisuke Hasegawa, Saifullah Badar, Shigeo Maruyama*

Department of Mechanical Engineering, The University of Tokyo, Japan
*(*maruyama@photon.t.u-tokyo.ac.jp)*

Horizontally-aligned single-walled carbon nanotubes (HA-SWNTs) are often used for the fabrication of SWNT field-effect transistors (FETs). In order to improve SWNT-FET performance, high density and only semiconducting HA-SWNTs are desirable. Here, we showed the CVD gas pressure dependence of the HA-SWNT density [1] and discussed the alignment mechanism based on the incubation time of SWNT growth. Additionally, we applied the thermal lithography technique for selective removal of metallic SWNTs [2]. We used iron nanoparticles as the catalyst, ethanol vapor as the carbon source and R-cut crystal quartz substrates [3]. CVD growth was performed at 800 °C. Decreasing CVD gas pressure, the density of HA-SWNTs increased although the amount of grown SWNT simply decreased. At higher pressure, many SWNTs simultaneously start to grow (with uniform incubation time), get entangled each other and form bundle structure. The bundle structure disturb the interaction between SWNTs and the quartz substrate surface and degenerate the alignment growth. For selective removal of metallic SWNTs, we used thermal-lithography technique [2]. HA-SWNTs were covered with molecular glass thin film and applied electric voltage to HA-SWNTs. Only metallic SWNTs were Joule-heated and they became exposed owing to thermocapillary flow of molecular glass. By etching metallic SWNTs, the SWNT-FETs with higher on/off ratio could be obtained. We will discuss the lateral resolution of the thermal-lithography, which depend on the sample temperature and the applied voltage.

[1] T. Inoue, *et al.*, *submitted* (2013) [2] S. H. Jin, *et al.*, Nature Nanotechnology, 8 (2013) 347
[3] S. Chiashi, *et al.*, J. Phys. Chem. C, 116 (2012) 6805