Nanoscale low-energy molecular sensors with thermal awareness

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In the IoT era, it is critically important to develop ultra-low energy, small gas sensors that can selectively detect low-concentration, low-molecular-weight substances. The sensors will be seamlessly integrated with mobile devices. Therefore, users can utilize them unintentionally and pervasively. To check health conditions of users, the sensors should selectively recognize metabolic substances in breath and sweat. However, the recognition of specific molecular substances related with health condition or disease has been a challenging task. Moreover, power-consumption of electrical sensors is unacceptably high for mobile applications because of necessity to heat up sensor materials for achieving stable, high-speed operations. The power is mainly consumed not by sensors but by heaters. Therefore, increasing the efficiency of heaters has been a main strategy to make low-energy gas sensors. In this work, our research aiming at ultra-low power consumption by the elimination of heaters will be introduced.

To lower the power consumption of sensors, self-heating effect (SHE) in nanoscale devices has been utilized. In low-dimensional materials, because of increased phonon-scattering at the surfaces/interfaces, thermal resistance of the materials decreases as size decreases. Therefore, the temperature increase by Joule heating is greater in smaller low-dimensional materials. By utilizing SHE, the temperature of nanoscale sensors becomes high enough for stable, high-sensitivity operation, which make it possible to eliminate external heaters. In addition, pulse technique further reduces the power-consumption thanks to long thermal time constant of nanoscale sensors. We have demonstrated a) sub-mW operation of graphen-based hydrogen sensors and b) pJ energy-consumption in oxide-semiconductor nanowire sensors by utilizing pulse self-heating technique [1].

[1] G. Meng et al., ACS Sensors, 1 (8), pp997-1002, 2016.