Hydrogen gas detection of gold nanoparticles on self-activated graphene layers

Yeonhoo Kim1, Yong Seok Choi2, Seo Yun Park1, Taehoon Kim1, Seung-Pyo Hong1, Cheon Woo Moon1, Byung Hee Hong2, Jong-Heun Lee3, Donghwa Lee4, and Ho Won Jang1

1 Department of Materials Science and Engineering, Research Institute for Advanced Materials, Seoul National University, Seoul 08826, Republic of Korea
2 Department of Chemistry, Seoul National University, Seoul 08826, Republic of Korea
3 Department of Materials Science and Engineering, Korea University, Seoul, Republic of Korea
4 Department of Materials Science and Engineering, Pohang University of Science and Technology, Pohang, Gyeongbuk, 37673, Republic of Korea

E-mail: hwjang@snu.ac.kr

Abstract:
Graphene is a leading candidate for next-generation gas sensing applications because of various advantages such as high sensitivity at room temperature, transparency, and flexibility. However, poor selectivity, and sluggish sensing behavior at room temperature are major drawbacks for practical use of graphene-based materials. To overcome the disadvantages, many kinds of noble metals are decorated on graphene surfaces. Here, we present room temperature hydrogen detection of Au nanoparticles deposited on self-activated graphene. The Au decorated graphene sensors with self-activation exhibit enhanced gas sensing properties such as rapid response, full recovery, and high selectivity. We discovered improvement in \( \text{H}_2 \) detection which has never been reported for Au decoration on any materials. The hydrogen sensing mechanism of Au nanoparticles on self-activated graphene is investigated by density-functional theory calculations. This discovery of a new functionality in the existing material broadens the possibility of metal nanoparticle/graphene heterostructures for diverse research areas.

Key words: Graphene, Gas sensor, Gold nanoparticles, Self-activation, Flexible, Hydrogenation, DFT calculations.

Result & Discussion
Gold as bulk metal is well known for the least active towards atoms and molecules. On the other hand, gold nanoparticles smaller than 10 nm have exhibited great potential for various research fields such as selective oxidation and hydrogenation by the gold catalytic effect. Although palladium and platinum catalysts have been mainly explored for hydrogen chemisorption, gold nanoparticles supported on metal oxide also have shown great potential for chemisorption of hydrogen molecules in recent studies. For these reasons, studies on interactions between gold nanoparticles and hydrogen molecules are attracting enormous attention in many research fields.

Graphene is a two-dimensional (2-D) material which has attracted significant research interest owing to its remarkable properties such as tremendous thermal and electrical conductivity, flexibility, transparency, and atomically thin structure. Due to these remarkable merits, studies on graphene for varied applications have become active from few years ago. Furthermore, since gas molecules are easily adsorbed on graphene, graphene is considered as a promising material for gas sensors.

In this work, we report hydrogen gas detection of gold nanoparticles on graphene layers which are self-activated by applied bias voltage from 1 to 60 V. Graphene used for the device is prepared by chemical vapor deposition method. Since graphene is a 2-D material, sensing area and electrodes composed of graphene can be defined by facile lithography processes. Gold nanoparticles are deposited by e-beam evaporator. The responses of the gas sensor to target gases such as \( \text{H}_2 \), \( \text{CH}_3\text{COCH}_3 \), and \( \text{NO}_2 \)
have been measured with varying input bias voltages at room temperature.

Our results show hydrogen gas detection of gold nanoparticles supported on graphene layers at room temperature. Also, the results open a potential of noble metal/graphene heterostructures for further studies.

References