Epitaxial and CVD graphene sensors for NO_2 and ozone sensing

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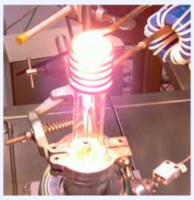
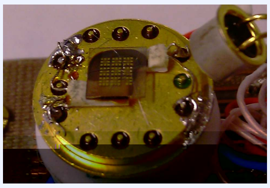
Introduction: Electronic properties of graphene depend on adsorption of molecules, making this material suitable for gas sensing application. We report about fabrication of gas sensors based on epitaxial and CVD graphene films and study their sensing abilities and response to NO_2 and ozone.

Fabrication of epitaxial graphene on SiC

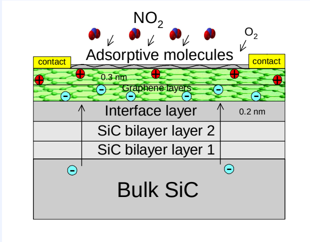


Few layers graphene (FLG) films were grown by annealing single crystal 4H-SiC substrates in Ar ambient at 1600 ºC during 20 min.



Chip with graphene film is assembled on top of TO-8 header. Two Pt100 sensors under chip are used for heating and temperature measurement.

Mechanism of interaction of NO_2 molecules with graphene



Large surface-to volume ratio allows graphene to catch many adsorbates very easily.

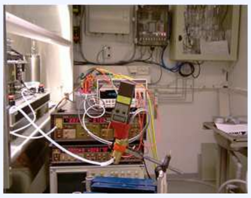
NO_2 molecules induce p-type doping in FLG and reduces resistance of graphene film.

Sensing mechanism is based on the modulation of the carrier density due to the charge transfer between NO_2 or ozone molecules and graphene, where the interacting molecules act as acceptors.

Sensor design

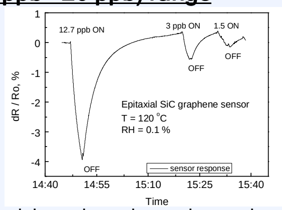
Teflon chamber for sensitivity tests of epitaxial graphene sensor to exposure of NO_2 and ozone.

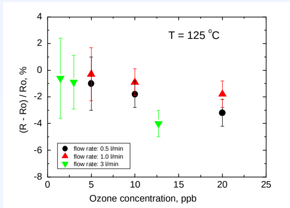
Equipment for gas sensing measurements



NO_2 gas was mixed with dry air and diluted and controlled by a set of mass flow controllers (Aera FC-D980).

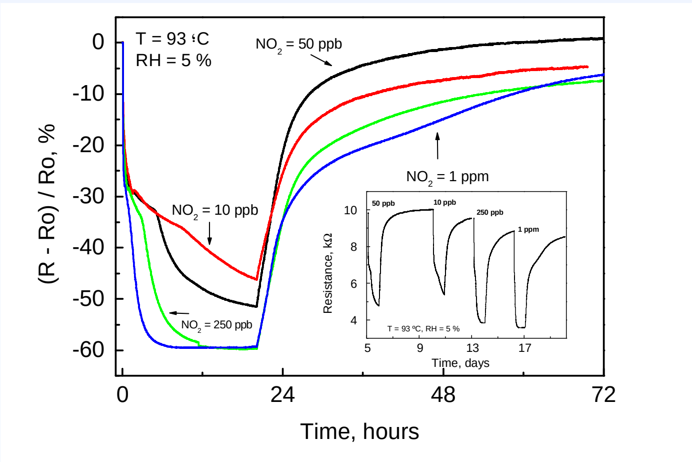
Response of epitaxial graphene sensor to ozone in low concentration (1 ppb - 20 ppb) range



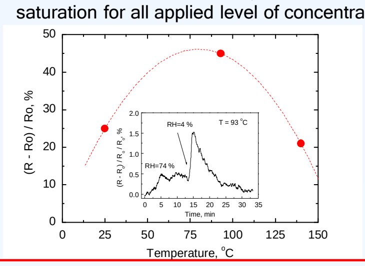


Epitaxial graphene have shown clear response of about several % in low concentration (around 10 ppb) of ozone exposure and fast recovery when the sensor is maintained at elevated temperatures.

Response of epitaxial graphene sensor to NO_2

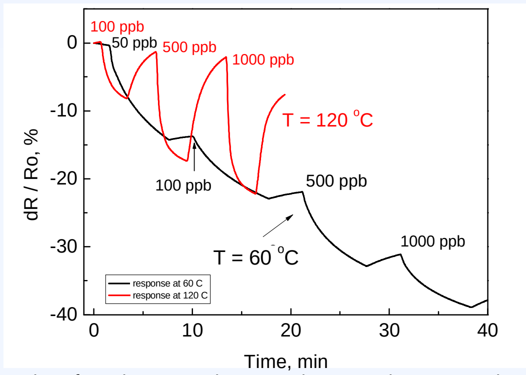


Results of linearity measurements of graphene sensor at 93 ºC and RH = 5 %. After 20 hours of exposure, changes of resistance are 45 %, 50 % and 60 % and came to saturation for all applied level of concentration for 10 ppb, 50 ppb, 250 ppb and 1 ppm.



Temperature dependence of response of graphene sensor on exposure of 10 ppb of NO_2. Optimum temperature for the tested sample is around 100 ºC. Inset demonstrates week dependence on humidity without sample exposure to NO_2.

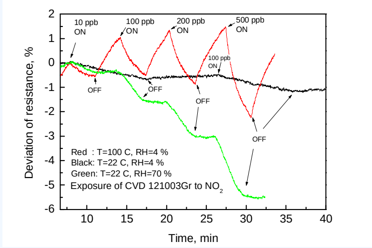
Response of epitaxial graphene to ozone in concentration up to 1 ppm



Influence of heating of graphene sample exposed to ozone in concentration range 10 ppb - 1000 ppb, at two temperatures, T = 58 °C (black line) and at higher temperature at T = 127 °C (red line).

Response of CVD graphene (sample #121003Gr) to NO_2 in 10 ppb - 500 ppb range

CVD graphene based sensor



Increase of the sensor's temperature up to 100 ºC (at RH=4 %), increase the response to -0.7 % of relative resistance change at 10 ppb of the applied NO_2 and up to -4.0 % of resistance change at 500 ppb.

Results and conclusions

• Gas sensors based on epitaxial and CVD graphene films were fabricated and tested. The equipment for the measurement of gas response, including non-reactive enclosures, supporting holders, as well as the gas supplying system and control electronic were designed, fabricated and used in gas sensing measurements.

• Optimization of the fabrication technology and the design of the gas sensors based on few layer epitaxial graphene allowed observing a clear response of about 45 % of resistance change for exposure of NO_2 at concentration level of 10 ppb. It was shown that by optimisation of parameters of SiC graphene, gas detection can be improved considerably by heating the graphene detector to a temperature of about 100 ºC. The obtained results demonstrate ultra high sensitivity of optimized devices in measurement of small amount of ozone and nitrogen dioxide.

Acknowledgements

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