Electronic Supplementary Material (ESI) for Sensors & Diagnostics.

Supporting Information

Highly sensitive room temperature liquid petroleum gas (LPG) sensor with fast response based on TiO_2-reduced graphene oxide (r-GO) composite

Navin Chaurasiya[1,2],

Ajeet Singh[3], Kuldeep Kumar[3],

Bal Chandra Yadav[3],

Pramod Kumar Yadawa[1]* (Orcid ID: 0000000295252205)

Sandip Kumar Singh[2],

Kajal Kumar Dey[4]* (Orcid ID: 0000000189306708)

[1]Department of Physics, Prof. Rajendra Singh (Rajju Bhaiya) Institute of Physical Sciences for Study and Research, V. B. S. Purvanchal University, Jaunpur, UP- 222003, India
[2] Department of Mechanical Engineering, UNSIET, V.B.S. Purvanchal University, Jaunpur, UP - 222003, India
[3]Nanomaterials and Sensors Research Laboratory, Department of Physics, Babasaheb Bhimrao Ambedkar University, Lucknow, UP- 226025, India.
[4]Centre for Nanoscience & Technology, Prof. Rajendra Singh (Rajju Bhaiya) Institute of Physical Sciences for Study and Research, V. B. S. Purvanchal University, Jaunpur, UP- 222003, India

*Corresponding authors:

itstiyash@gmail.com (Kajal Kumar Dey), pkyadawa@gmail.com (Pramod Kumar Yadawa)

S I. FT-IR spectrum of the composite

Figure S1 provides the FT-IR spectrum of the TiO_2-rGO composite. The peaks observed at the lower wavenumbers such as 545 cm^{-1} and 670 cm^{-1} correspond to vibrational modes of the TiO_2 molecule; ν (Ti-O) or ν (Ti-O-Ti) to be more exact (Verma et al., 2017). The intense and broad peak observed at ~3440 cm^{-1} could be attributed to the O-H stretching vibrations of the residual functional groups of the reduced graphene oxide or of surface adsorbed moisture (Chen et al., 2019). The peak observed at ~ 1025 cm^{-1} corresponds to the epoxide C-O-C or the alkoxy C-OH functional group of rGO. A relatively sharp peak observed at ~1650 cm^{-1} could be assigned to the bending vibrational modes from the aromatic C=C of the graphene skeleton. An intense peak observed at ~2358 cm^{-1} is generally associated with the asymmetric stretching of CO_2 adsorbed from the atmosphere. The transmittance peak observed at 2921 cm^{-1} can be attributed to the combinational band of TiO_2 (Verma et al., 2017). Its neighboring weak transmittance peak observed at ~2860 cm^{-1} could be attributed to C-H stretching vibrations.

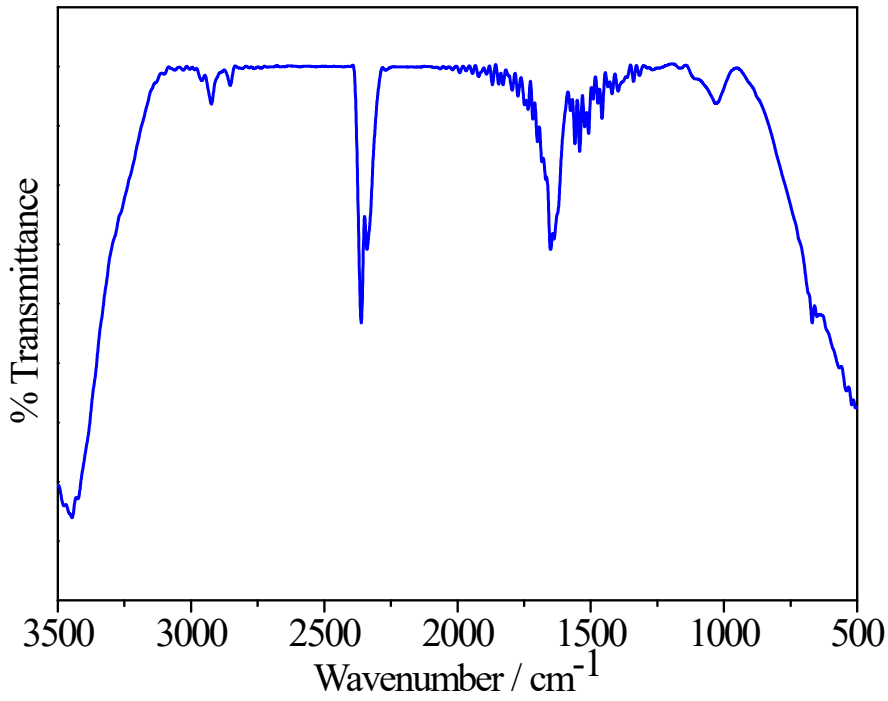

Figure S1 FT-IR transmittance spectrum of the TiO_2-rGO composite.

S II. Elemental composition from EDS

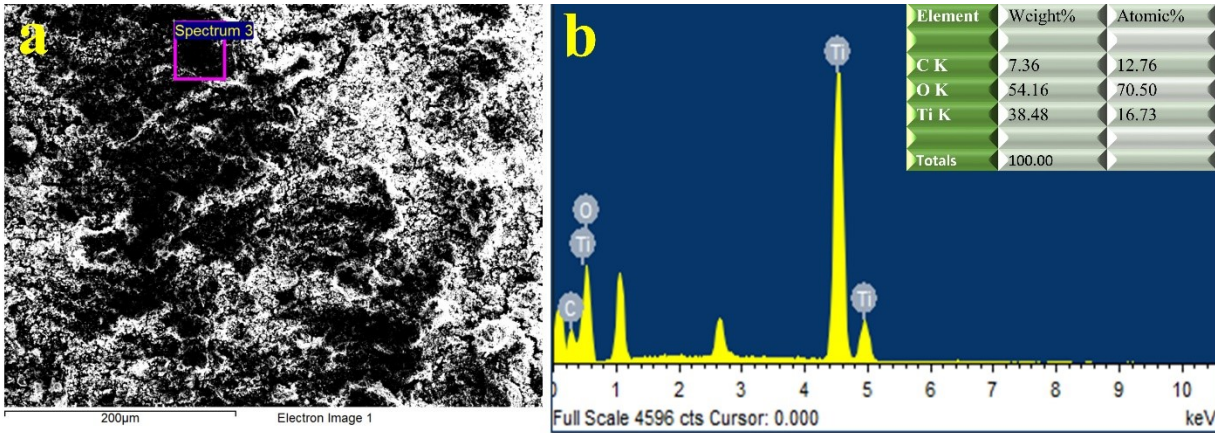

Figure S2 (a) SEM micrograph of the rGO-TiO_2 composite; (b) EDS spectra of the composite revealing the presence of C, O and Ti.

Figure S2 provides the EDS spectrum of the rGO-TiO_2 composite. S2a provides the associated SEM micrograph and S2b provides the EDS spectrum where we can clearly see the presence of C (coming from reduced graphene oxide), O (coming from TiO_2 and the oxygenated functional groups of rGO), and Ti (coming from TiO_2). The spectrum was obtained by scanning an area of ~2500 μm^2 of the sample. The atomic percentage observed indicated a Ti/O/C ratio of 16.7:70.5:12.3. However, because of the localized nature of electron microscopic measurements, the ratio most probably does not indicate the real atomic ratio within the composite. Additionally, there were peaks of elements such as Au, Sn etc that would accompany the spectrum due to the experimental requirements. These peaks were not indexed not accounted for while calculating the elemental ratio.

S III. Electron microscopy images of graphene oxide (GO)

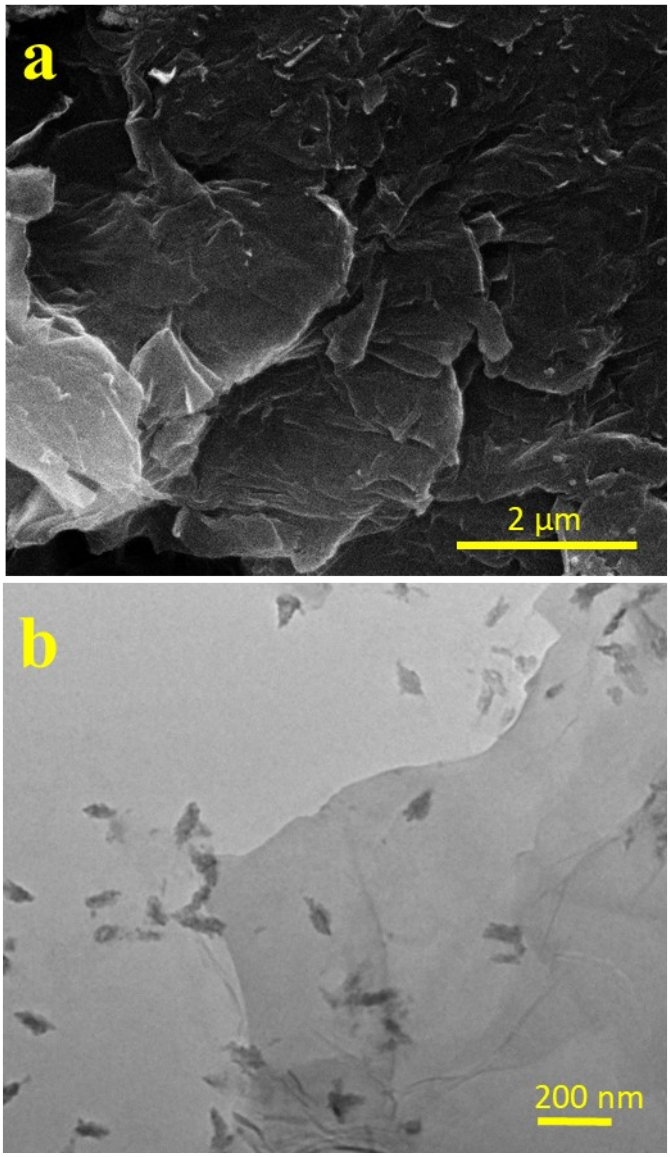

Figure S3 (a) FESEM micrograph and (b) TEM micrograph of the as synthesized GO particles. Both the images depict the sheet like morphology of GO. The smaller particles observed in (b) are the broken sheets due to sonication during sample preparation for TEM

S IV. TEM micrographs of reduced graphene oxide (rGO)

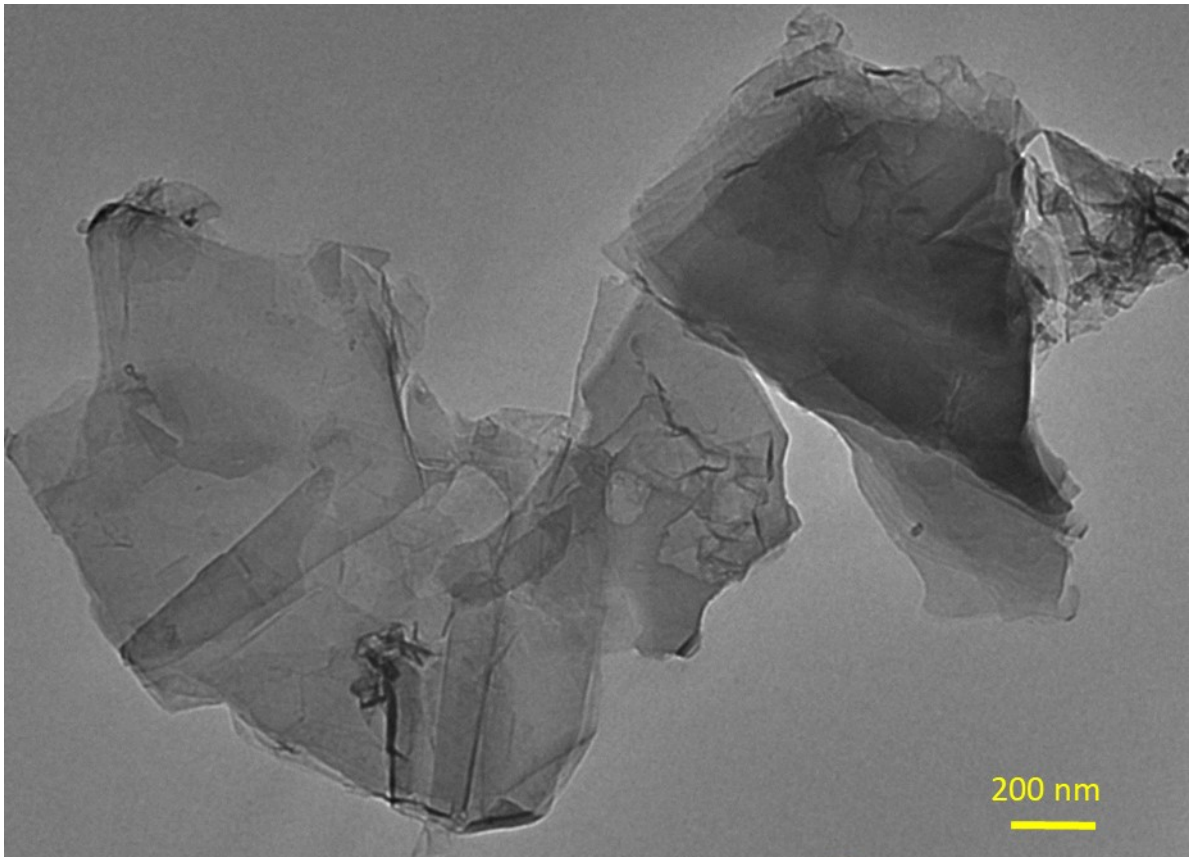

Figure S4 TEM micrograph of the reduced graphene oxide (rGO) displaying its sheet-like morphology. The wrinkles visible are characteristic of its sheet morphology.

S V. Elemental mapping of the TiO_2-rGO composite

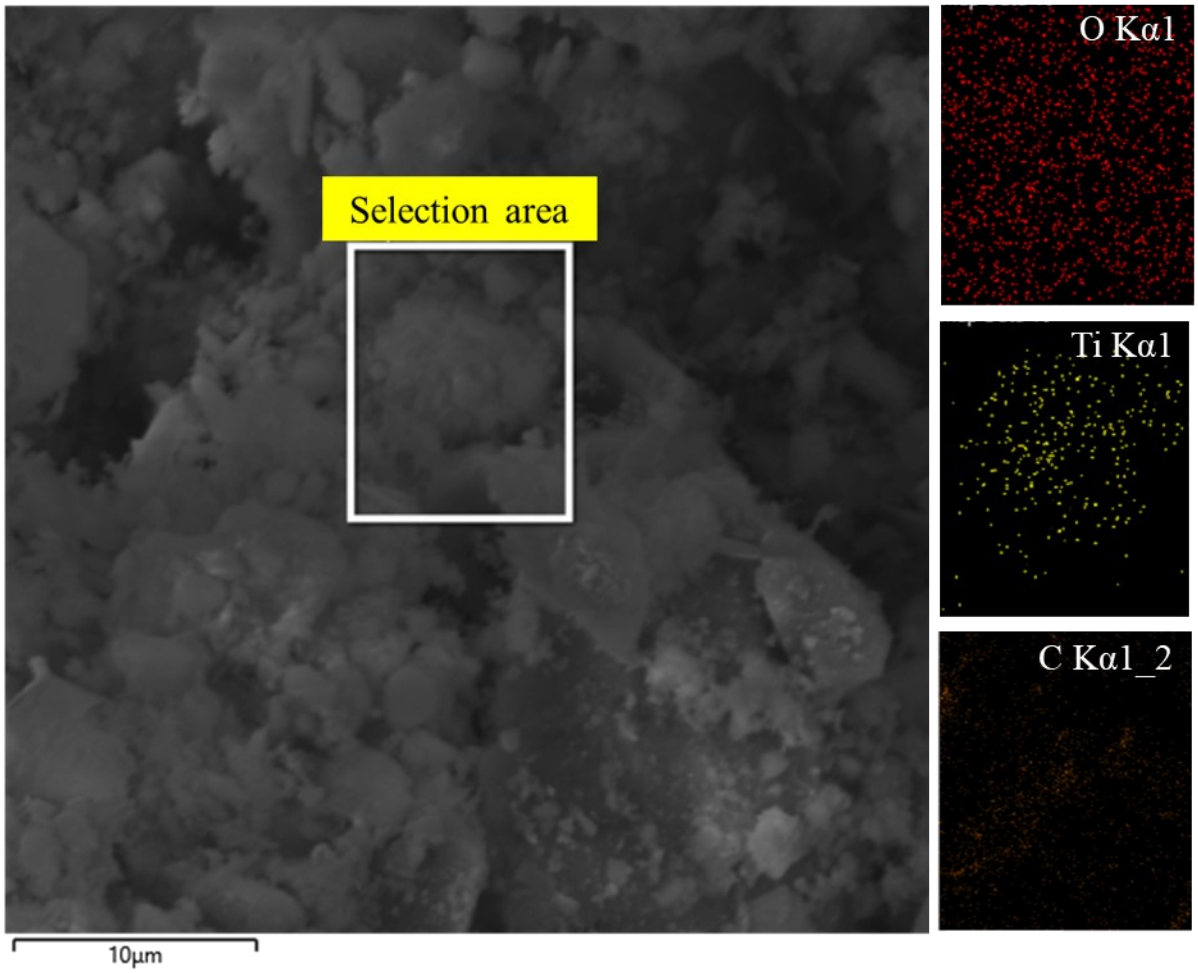

Figure S5 Elemental mapping of the TiO_2-rGO composite obtained from a portion of the micrograph. The mapping clearly shows how the rGO sheet (carbon) is all around the TiO_2.

S VI. Hydrodynamic particle size of the rGO-TiO_2 composite

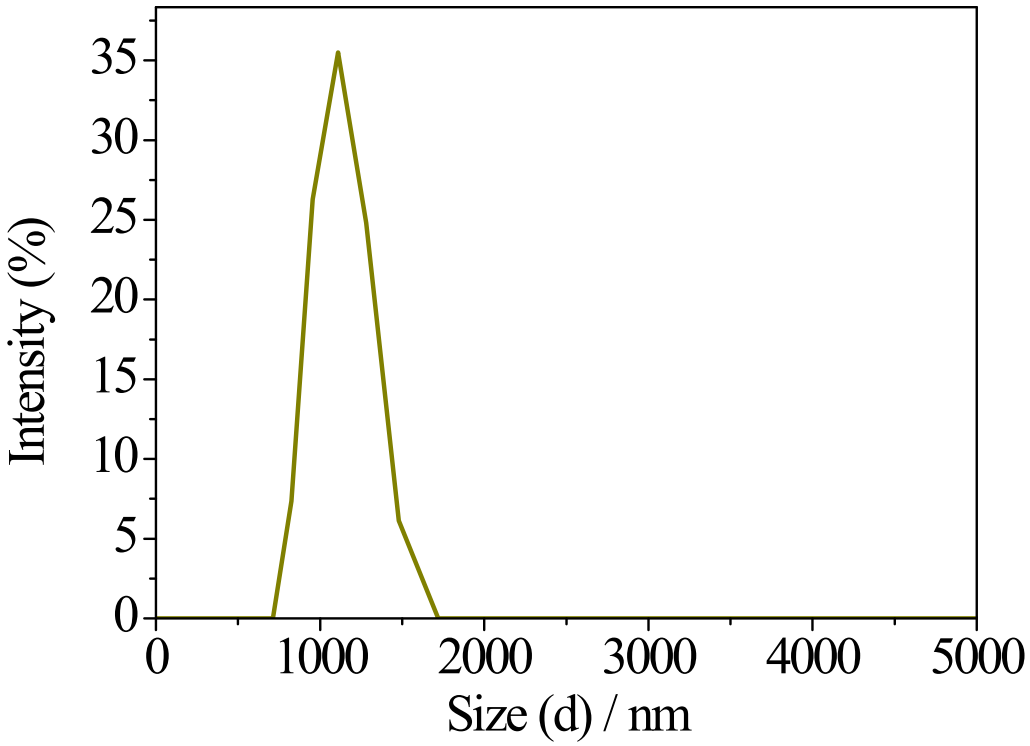

Figure S6 Intensity based particle size distribution (obtained from DLS technique) of the TiO_2-rGO composite material

S VII. A comparison between the sensing performance of r-GO, TiO_2 and the rGO-TiO_2 composite

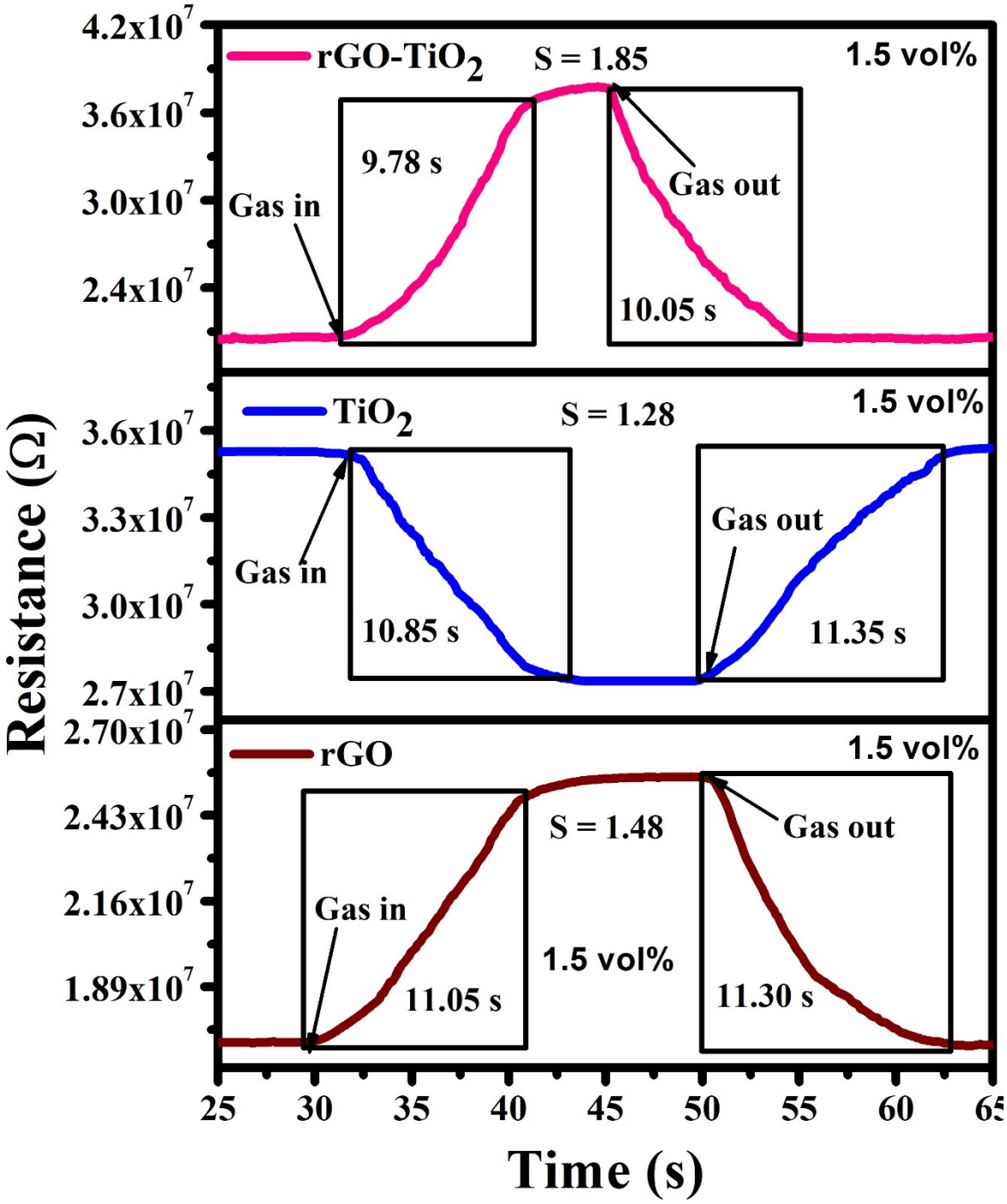

Figure S7: Transient sensor response of the TiO_2-rGO composite sensor, TiO_2 sensor and rGO sensor against exposure to 1.5 vol% LPG