Sustainable low temperature carrier gas-free growth of graphene on non-catalytic substrates

Laurance Papale,[a] Bronson Philippa,*[a] Boris Makarenko, [b]Oomman K. Varghese,[c,d] and Mohan V. Jacob*[e]

[0a] *James Cook University, 1/14-88 McGregor Road, Cairns, Australia. E-mail: bronson.philippa@jcu.edu.au*

[0b] *Department of Chemistry, University of Houston, Houston, Texas 77204, USA.*

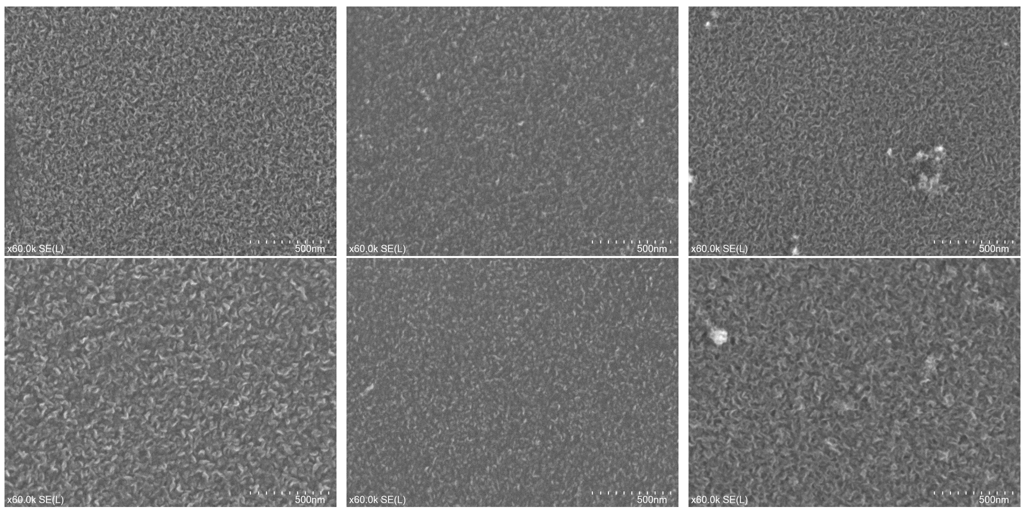
[0c] *Nanomaterials and Devices Laboratory, University of Houston, Houston, Texas 77204, USA.*

[0d] *Texas Center for Superconductivity, University of Houston, Houston, Texas 77204, USA.*

[0e] *James Cook University, James Cook University Drive, Townsville, Australia. E-mail: mohan.jacob@jcu.edu.au*

S1 Additional SEM images

Fig. S1 shows SEM images taken of samples grown on silicon and quartz substrates at a range of temperatures.



(a) 800°C (b) 600°C (c) 500°C

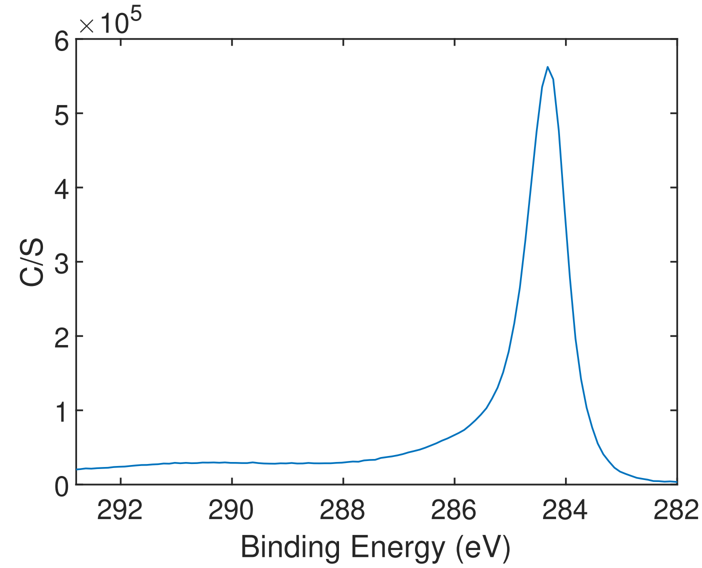
Figure S1: SEM of various samples grown at different temperatures (Top: silicon substrate, Bottom: quartz substrate)

S2 Additional XPS Glass samples

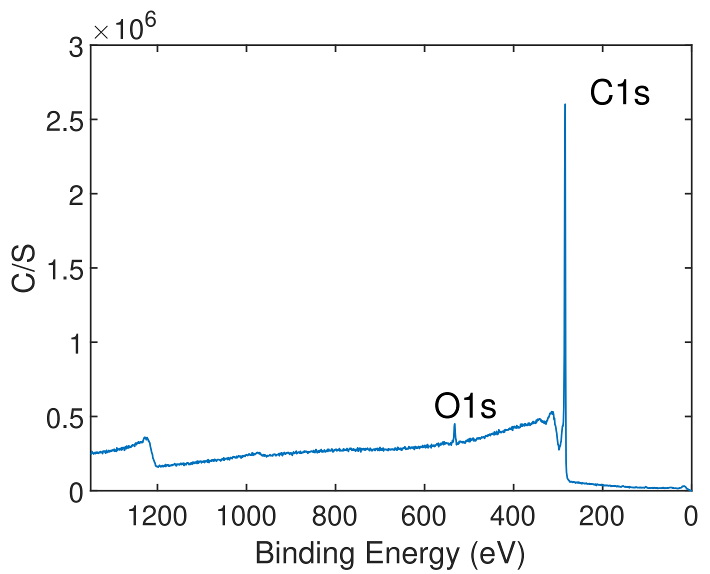
XPS spectra for the graphene grown on glass substrates are shown in Fig. S2. These were taken using a Thermo Scientific Nexsa G2 X-Ray Photoelectron Spectrometer.

S3 Response of graphene humidity sensors

The recorded electrical resistance of the as build graphene humidity sensor grown at 500°C is shown in Fig.S3 along with the recordings taken from the commercial SHT-10 senor. For comparison the response of sensors constructed from graphene grown on a silicon substrate at 500°C and a glass



(a) High resolution C1s



(b) Survey scan

Figure S2: XPS of graphene grown on soda-lime glass substrate

substrate at 600°C are shown in Fig. S4 and Fig. S5 respectively. The range and approximate humidity sensitivity are shown in Table S1

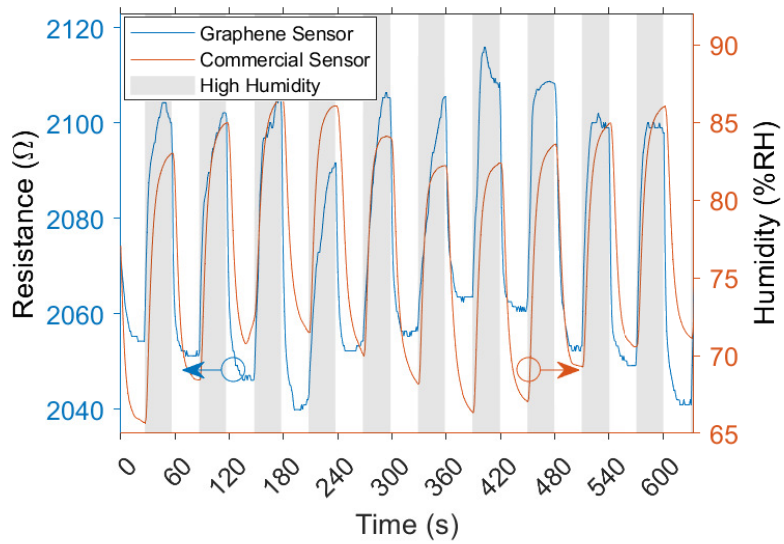


Figure S3: Comparison of sensor responses over multiple cycles

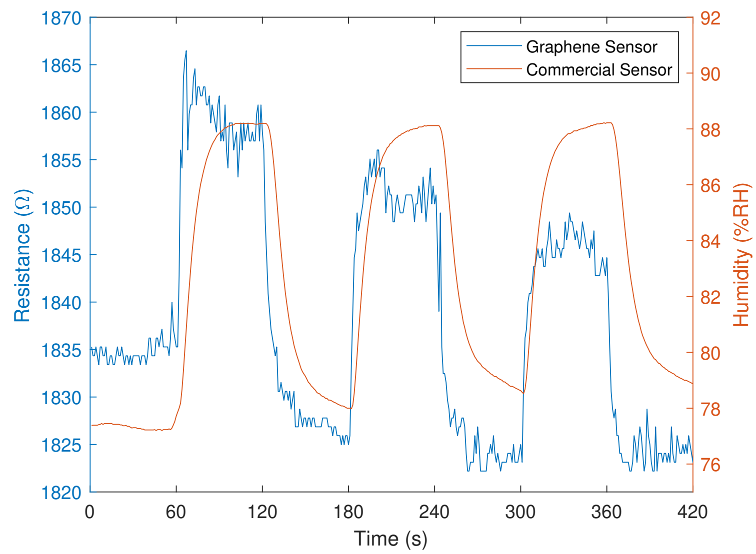


Figure S4: Response of sensor grown on silicon substrate at 500°C

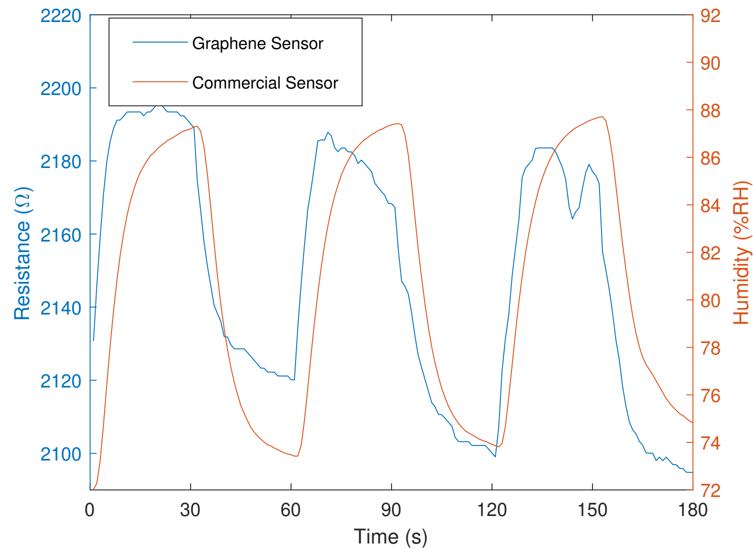


Figure S5: Response of humidity sensor produced from graphene grown on glass at 600°C

Table S1: Comparison of various fabricated sensors

Substrate	Temperature (°C)	Range (Ω)	Sensitivity (Ω %RH^{-1})
Glass	500	1820-1870	3.46
Silicon	500	2040-2110	2.80
Glass	600	2100-2200	5.44

Fig.S6 shows the correlation between resistance, temperature and humidity. Due to the faster response rate of the graphene sensor, data where magnitudes of the gradient of resistance or temperature were greater than 3Ω s^{-1} and 0.3%RH s^{-1} respectively were removed from these plots.

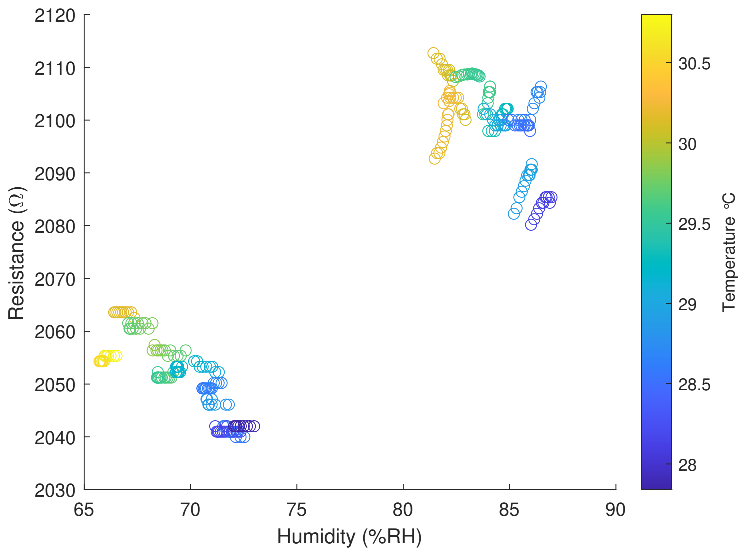


Figure S6: Distribution of high readings showing the correlation between humidity and electrical resistance with the effect of temperature.

S4 Temperature correction

The first 80% of the data was used to train various models using MATLAB's Regression Learner tool, with the remaining 20% used to test the performance of each model. Various neural network (NN), support vector machine (SVM), Gaussian process regression and linear regression models were trialed using the root-mean-square error (RMSE) of the testing set as the performance metric. Linear regression performed best with an RMSE of 1.67 %RH followed by a SVM and NN with 1.68 %RH and 1.90 %RH respectively. The regression plot is shown in Fig.S7

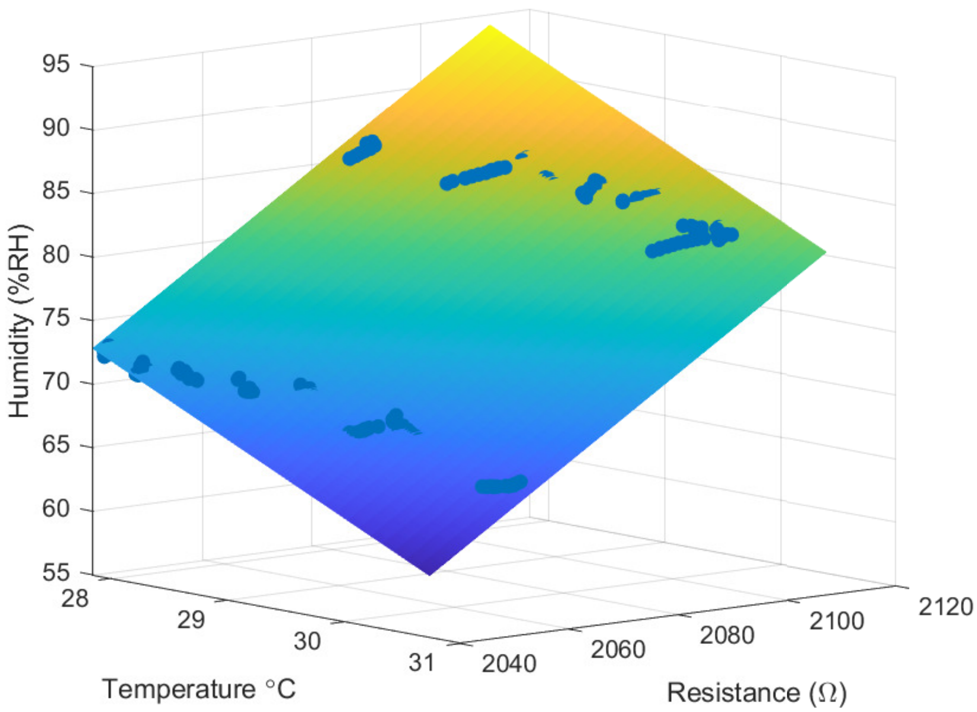


Figure S7: Plain fit to data points for temperature compensation