

Supplementary Information

Figure SI shows AFM images of the Au/glass and Au/GO/glass samples after the annealing process. AFM images of the as deposited Au/glass reference and the treated glass substrate have been added for comparison. The treatment required for a proper GO film formation produces an important roughness of the glass surface with a RMS around 3 nm (left image). The RMS of the Au film on this glass surface is slightly reduced (2.4 nm). The reference sample (Au/Glass) and the Au/GO/Glass sample show a very similar morphology after the thermal annealing up to 350°C. The holes revealed in the AFM images have similar diameter (100-500 nm) and depth (~20 nm) in both samples and therefore seem to be related to the Au film changes upon annealing which originate the wide and undefined Brillouin peaks at temperatures above 250 °C. The surface roughness estimated eliminating the contribution of the holes is higher for the sample with the GO film (3.0 nm) than for the reference one (2.5 nm). This increased roughness may be associated to the irreversible chemical reduction and water ejection processes occurring with temperature.

The root mean square (RMS) of the roughness was evaluated using the histogram of the height of N events over the area of selected images (2-3 per sample), and it is estimated using the expression:

$$rms = \sqrt{\frac{\sum_{i,j} (x_{i,j} - \langle x \rangle)^2}{N}}$$

where $x_{i,j}$ is the height of an event (pixel) and $\langle x \rangle$ is the average height obtained. Since the vast majority of events/heights correspond to the Au layer surface (with a distribution of heights corresponding to the roughness), events-heights with low probability (like hole regions and dust particles) are cut-off and not considered in the RMS estimation.

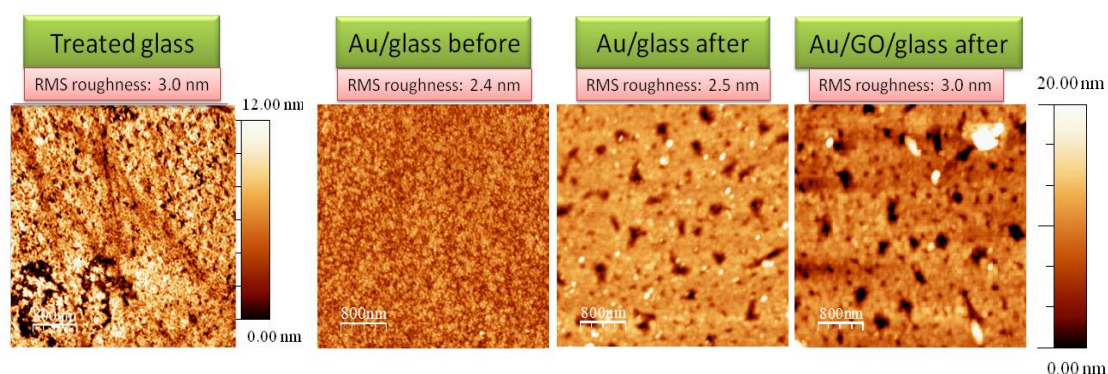


Figure SI: AFM topographic images of the glass substrate, the Au layer as deposited on glass, the Au/Glass and the Au/GO/Glass systems after the annealing treatment. The RMS roughness estimated for every sample is shown above.

Simulations

Table S1 Elastic constants and mass densities of gold and glass used for the calculations.

	Glass	Au	Graphite
ρ (g/cm ³)	2.488	19.3	2.2
c_{11} (GPa)	85.936	207.0	1060
c_{33} (GPa)			36.5
c_{44} (GPa)	30.035	28.5	5.05
c_{12} (GPa)	25.866	150	180
c_{13} (GPa)			7.9
c_{66} (GPa)			440

In order to perform the numerical simulations of the SAW velocity of the Au/GO/Glass system taking into account the different possible orientations of the stacked GO layers, it is necessary to introduce an effective elastic constants matrix (C) for the GO layer. This matrix is formed using the standard Voigt-Reuss-Hill (VRH)ⁱ average method for different orientations of the c -axis with respect to the normal to the substrate plane. As a first approximation only three main orientations have been taken into account. The c -axis of the GO layer parallel to the normal of the substrate C_{cc} , the c -axis of the GO layer perpendicular to the normal of the substrate in the x direction C_{cx} and the c -axis of the GO layer perpendicular to the normal of the substrate in the y direction C_{cy} . The elastic constants matrix of the GO layer is assumed to be of hexagonal symmetry:

$$C_{cc} = \begin{pmatrix} c_{11} & c_{13} & c_{13} & & & \\ c_{13} & c_{11} & c_{12} & & & 0 \\ c_{13} & c_{12} & c_{33} & & & \\ & & & c_{44} & 0 & 0 \\ & 0 & & 0 & c_{44} & 0 \\ & & & 0 & 0 & c_{66} \end{pmatrix}$$

With $c_{66} = (c_{11}-c_{12})/2$ and the numerical values of the elastic constants of Table 1.

If now the c -axis lays parallel to the substrate plane defining the x direction, the corresponding elastic constants matrix is:

$$C_{cx} = \begin{pmatrix} c_{33} & c_{12} & c_{13} & & & \\ c_{12} & c_{11} & c_{13} & & & 0 \\ c_{13} & c_{13} & c_{11} & & & \\ & & & c_{66} & 0 & 0 \\ & 0 & & 0 & c_{44} & 0 \\ & & & 0 & 0 & c_{44} \end{pmatrix}$$

With $c_{66} = (c_{11}-c_{12})/2$ and the numerical values of the elastic constants of Table 1.

It is assumed that it is equiprobable that the c-axis lays perpendicular both to the substrate normal and to the x direction defined above. Thus the corresponding elastic constants matrix is:

$$C_{cy} = \begin{pmatrix} c_{11} & c_{13} & c_{12} & & & \\ c_{13} & c_{33} & c_{13} & & 0 & \\ c_{12} & c_{13} & c_{11} & & & \\ & & & c_{44} & 0 & 0 \\ & 0 & & 0 & c_{66} & 0 \\ & & & 0 & 0 & c_{44} \end{pmatrix}$$

With $c_{66} = (c_{11}-c_{12})/2$ and the numerical values of the elastic constants of Table 1.

Now it is possible to build the VRH average depending on the portion (x) of GO layer lying with its c-axis within the substrate plane.

The Voigt approach assumes uniform strain, thus:

$$C_v = \frac{x}{2} C_{cx} + \frac{x}{2} C_{cy} + (1-x)C_{cc}$$

The Reuss approach assumes a uniform stress, thus:

$$C_R^{-1} = \frac{x}{2} C_{cx}^{-1} + \frac{x}{2} C_{cy}^{-1} + (1-x)C_{cc}^{-1}$$

The VRH average is built as the arithmetic average of the Reuss and Voigt values

$$C_{VRH} = \frac{1}{2} C_v + \frac{1}{2} C_R$$

Once the elastic constants matrix is obtained, it is straightforward to calculate the corresponding values of the Young's modulus (E). E must reflect the symmetry of the studied sample and for elastic anisotropic media, E is also anisotropic. In the case of hexagonal symmetry, as Graphite, the Young's modulus in the basal plane E_{100} and parallel to the c-axis E_{001} are very different.¹ The general form of the **Young's modulus** for hexagonal symmetry in terms of the unit vector **n** and its spatial components, n_1 , n_2 and n_3 is:

$$\frac{1}{E_{(n)}} = (1-n_3^2)^2 s_{11} + n_3^4 s_{33} + n_3^2 (1-n_3^2) (2s_{13} + s_{44})$$

Thus in terms of the hkl directions,

$$\frac{1}{E_{100}} = s_{11}; \quad \frac{1}{E_{001}} = s_{33}$$

$$E_{100} = s_{11}^{-1}; \quad E_{001} = s_{33}^{-1}$$

In any direction of the basal plane (hk0) the Young's modulus is invariant and equal to E_{100} .

The VRH average described above implies a slight change in the symmetry of the elastic constants matrix. It passes from the hexagonal symmetry of the graphite-like system to a tetragonal symmetry (c_{66} is now an independent elastic constant). The general form of the Young's modulus for tetragonal symmetry is:

$$\frac{1}{E_{(n)}} = (n_1^4 + n_2^4)s_{11} + n_3^4 s_{33} + n_1^2 n_2^2 (2s_{12} + s_{66}) + n_3^2 (1 - n_3^2)(2s_{13} + s_{44})$$

Thus in terms of the hkl directions,

$$\frac{1}{E_{100}} = s_{11}; \quad \frac{1}{E_{001}} = s_{33}$$

$$E_{100} = s_{11}^{-1}; \quad E_{001} = s_{33}^{-1}$$

In the basal plane (100) and (010) directions are equivalent and equal to E_{100} but in (hk0) directions this is not the case.

$$\frac{1}{E_{hk0}} = (n_1^4 + n_2^4)s_{11} + n_1^2 n_2^2 (2s_{12} + s_{66})$$

ⁱ Grimvall G. Thermophysical Properties of Materials, edited by E. P. Wohlfarth (North-Holland, Amsterdam, 1986)