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A Simple Model Relating Gauge Factor to Filler Loading in Nanocomposite Strain Sensors

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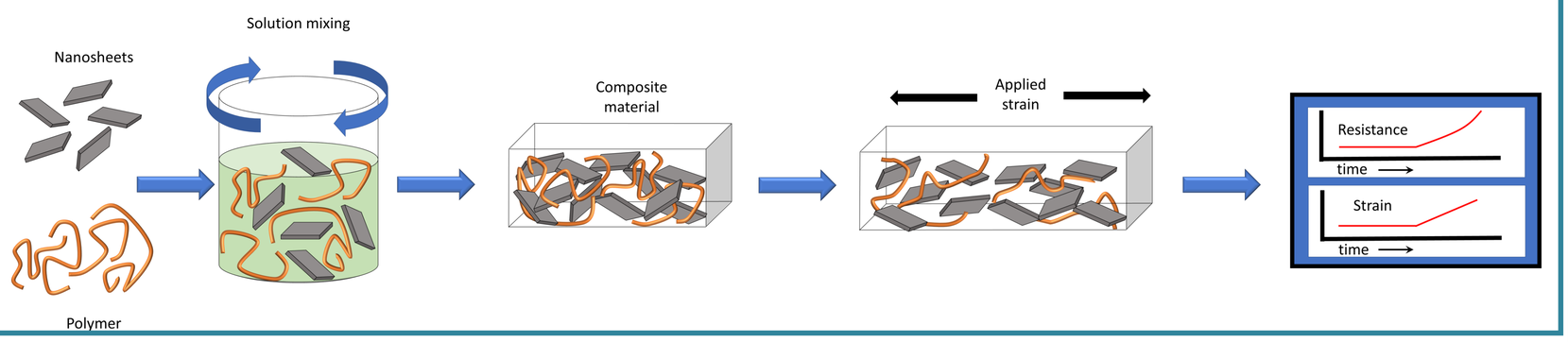
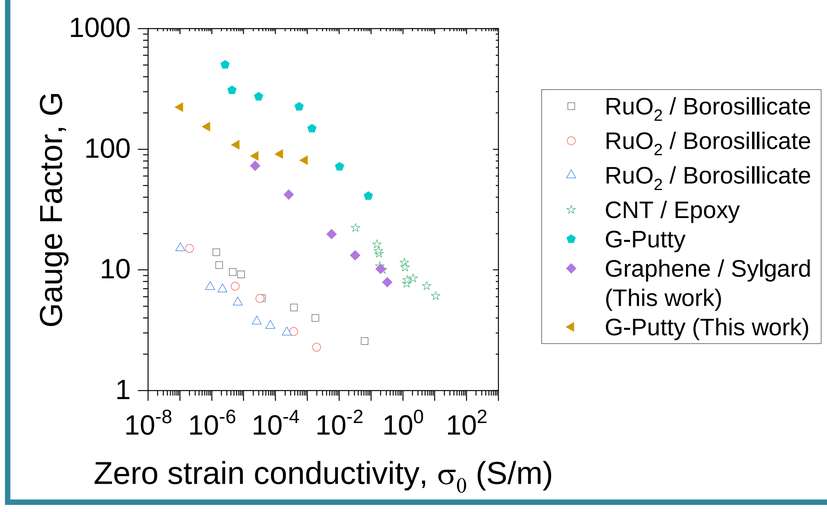
POLYMER NANOCOMPOSITE STRAIN SENSORS



LITERATURE DATA[1,2,3,4]



MODELLING NANOCOMPOSITE GAUGE FACTOR RESPONSE

Percolation: $\sigma = \sigma_c(\phi - \phi_c)^t$ (1)

Gauge Factor: $G \approx 2 - \frac{1}{\sigma_0}\left(\frac{d\sigma}{d\varepsilon}\right)_0$ (2)

Where '0' subscript denotes the quantity is taken in the low strain limit

Combining equations (1) and (2) yields:

$$G \approx \left[2 - \frac{1}{\sigma_{c,0}}\left(\frac{d\sigma}{d\varepsilon}\right)_0\right] + \left[\left(\frac{dt}{d\varepsilon}\right)_0 \ln(\phi - \phi_{c,0})^{-1}\right] + \left[\left(\frac{d\phi_c}{d\varepsilon}\right)_0 \frac{t_0}{\phi - \phi_{c,0}}\right] \quad (3)$$

SIMPLIFIED EQUATIONS FOR EXPERIMENTAL FITTING

Equation 3 provides a theoretical description of the gauge factor, however, this is not suitable for fitting experimental data. Here we present simplified versions of equation in terms of composite conductivity and volume fraction

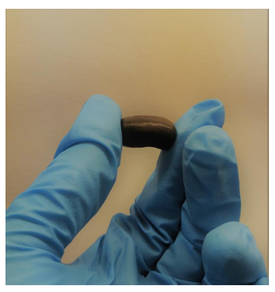
$$G \approx G_{0,\phi} + \frac{G_1}{\phi - \phi_{c,0}} \quad (4)$$

$$G \approx G_{0,\sigma} + \left(\sigma_1 / \sigma_0\right)^{1/t_0} \quad (5)$$

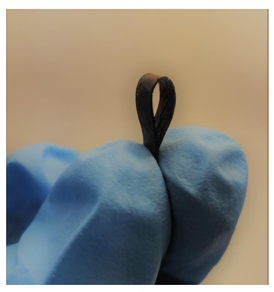
Importantly, equation 4 predicts that the gauge factor will diverge as the percolation threshold is approached from above, while equation 5 predicts a near power law relationship between gauge factor and conductivity.

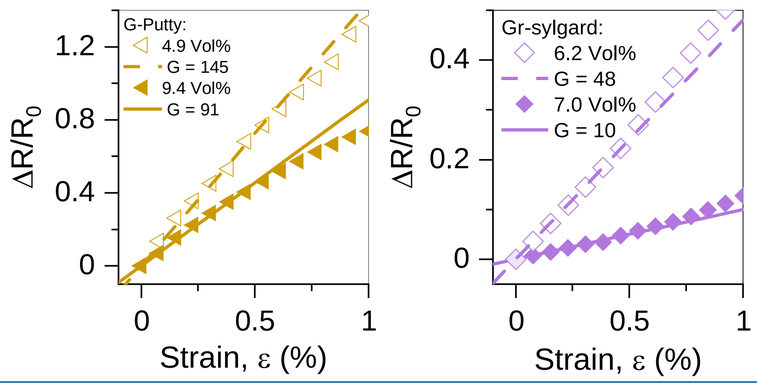
GRAPHENE BASED NANOCOMPOSITE SENSORS

G-putty



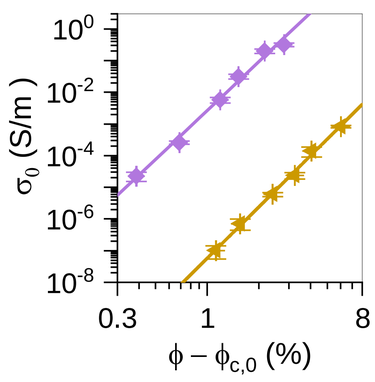
Graphene -Sylgard



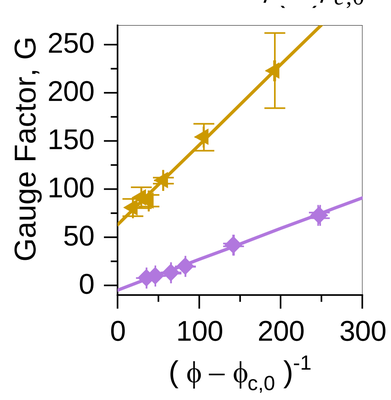


FITS TO PROPOSED MODEL

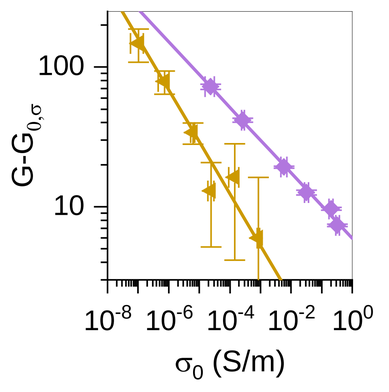
$$\sigma_0 = \sigma_{c,0}(\phi - \phi_{c,0})^{t_0}$$



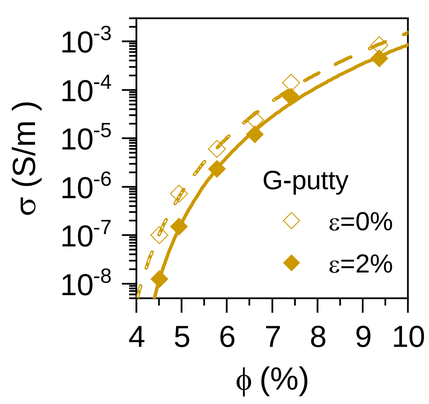
$$G \approx G_{0,\phi} + \frac{G_1}{\phi - \phi_{c,0}}$$

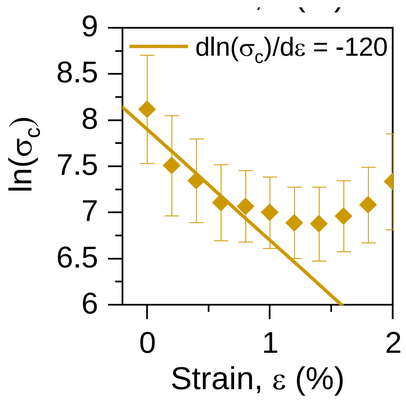


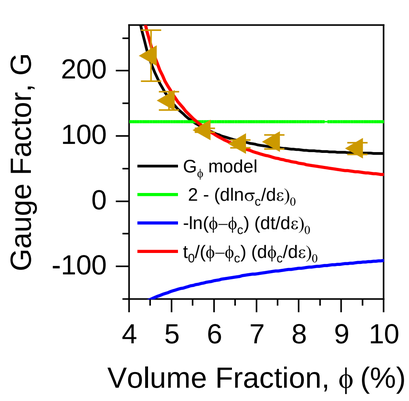
$$G \approx G_{0,\sigma} + \left(\sigma_1 / \sigma_0\right)^{1/t_0}$$

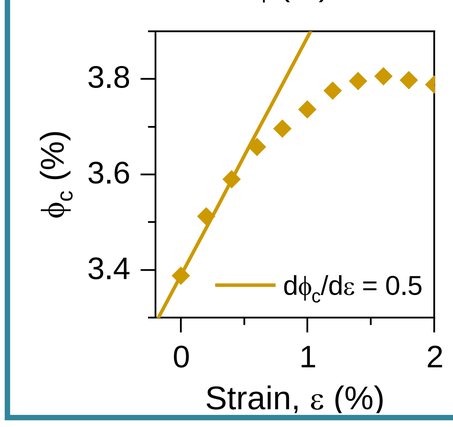


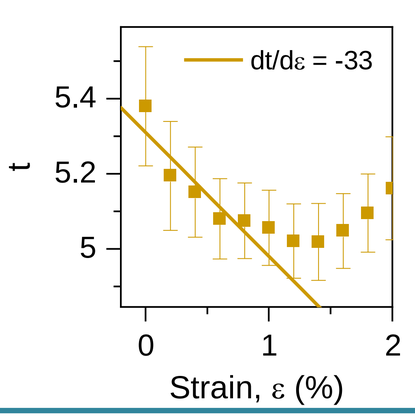
RATE OF CHANGE OF PERCOLATION PARAMETERS WITH STRAIN

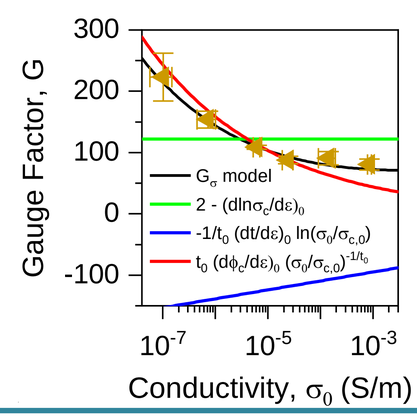












CONCLUSIONS

- Model shows good agreement with experimental data, both measured by the authors and extracted from the literature
- Gauge factor depends strongly on effects associated with the network of filler particles, going beyond effects associated with interparticle resistance.
- Maximisation of gauge factor could be achieved by engineering nanocomposite percolative properties.

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REFERENCES

[1] J R Garcia et al., ACS Appl. Nano Mater. 2021, 4, 3, 2876–2886
[2] Boland et al., Science 2016, 354, 6317, 1257-1260
[3] Hu et al., Carbon 2010, 48, 680 – 687
[4] Carcia et al., Journal of Applied Physics 1983 54, 6002

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