Interfacial Stress Transfer in Graphene Oxide Nanocomposites

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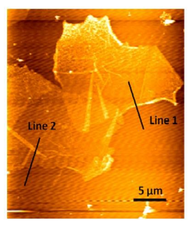
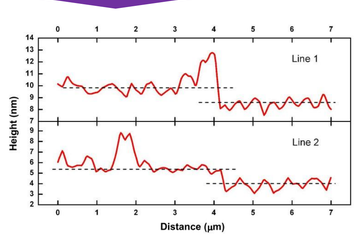
Introduction

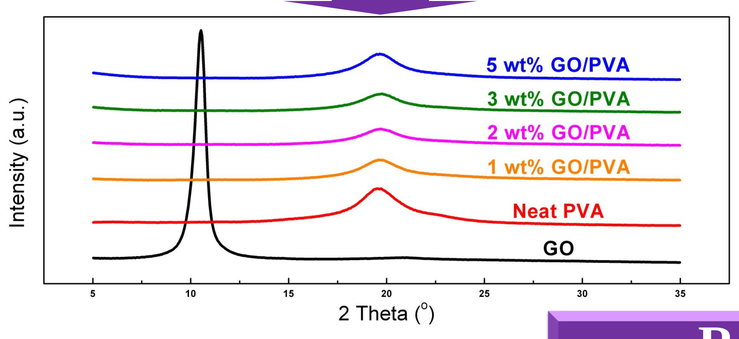
Raman spectroscopy has been used for the first time to monitor interfacial stress transfer in poly(vinyl alcohol) (PVA) nanocomposites reinforced with graphene oxide(GO). The nanocomposites were prepared by a simple mixing method. It was found that GO was fully exfoliated and they tended align in the plane of films. It was shown that the Raman D band at ~1335 cm^{-1} downshifted as the nanocomposites were strained as a result of the interfacial stress transfer. With the knowledge of Grüneisen parameter, it was possible to estimate the effective Young's modulus of GO from the Raman D band shift rate per strain to be the order of 120 GPa, similar to those from dynamic mechanical analysis. The lower effective modulus, compared with the accepted 200 GPa may be due to a combination of finite flake dimension, waviness and misalignment of GO flakes.

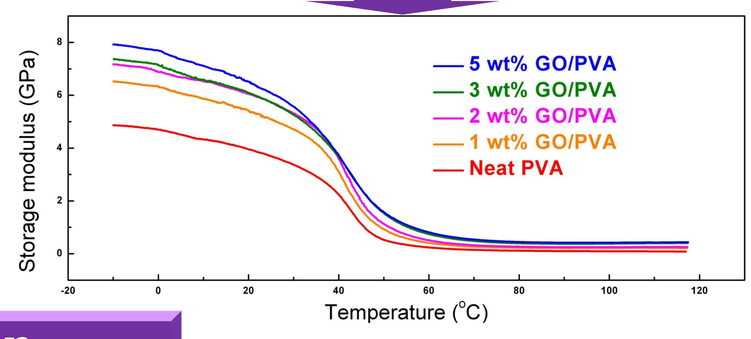
Experimental Section and Results

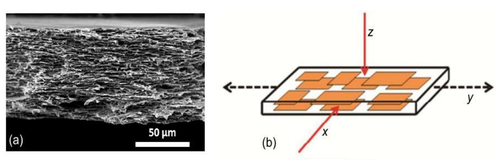
Graphene Oxide + Poly(vinyl alcohol) → GO/PVA Nanocomposites → AFM, XRD, DMTA, Raman

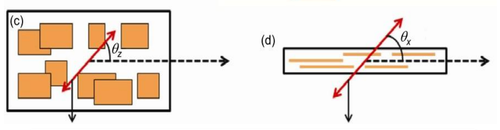


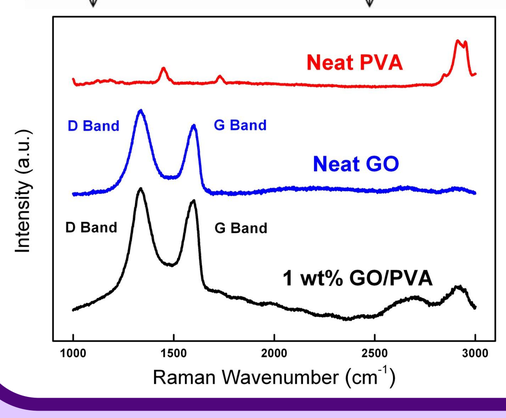


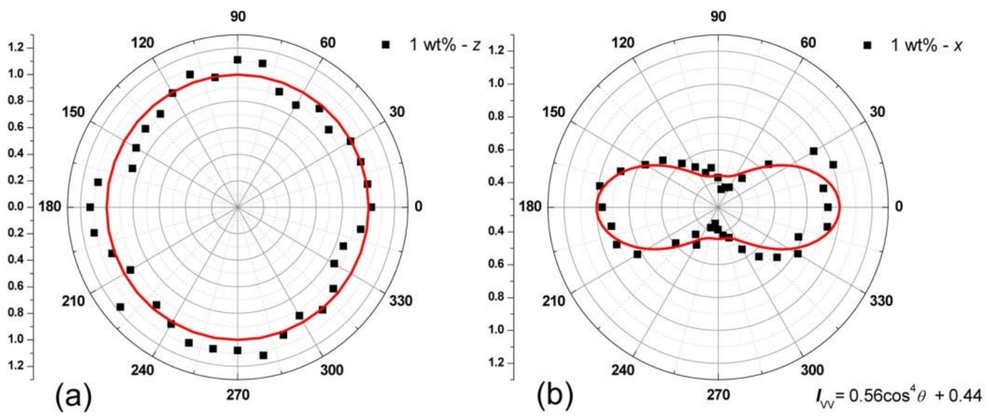




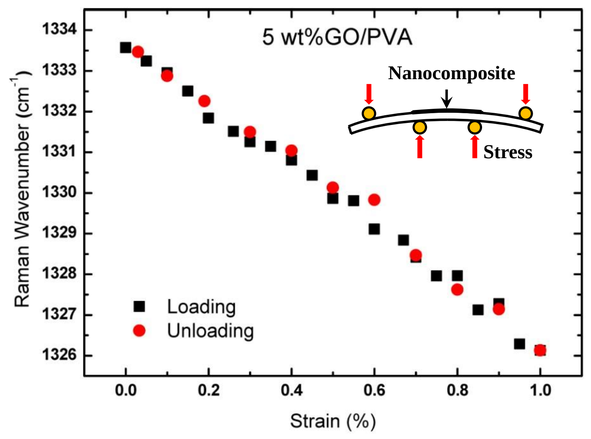








Polar plot of the normalized D band intensity using VV polarization (a) parallel to *z*, (b) parallel to *x*. The red line represents unit '1' and I_D= 0.56 $\cos^4\theta_x$ + 0.44 for (a) and (b).



Shift of the D band with strain for 5 wt% GO/PVA nanocomposite, for loading to 1 % strain followed by unloading.

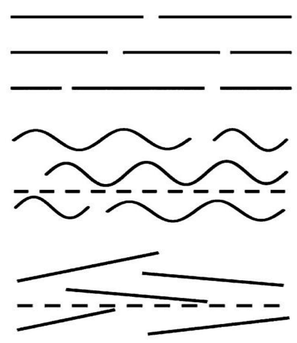
Discussions

$$\gamma = -\frac{1}{\omega_0}\frac{\partial \omega_h}{\partial \varepsilon_h}$$

γ : Grüneisen parameter
ω_0/ω_h : Raman wavenumber at zero/applied strain
ε_h : Strain

GO/PVA (wt%)	RoM* Effective Modulus (GPa)	D Band Shift Rate (cm^{-1}/%)	Grüneisen Effective Modulus (GPa)
1	121 ± 21	-8.8 ± 0.1	125 ± 2
2	113 ± 8	-8.3 ± 1.4	118 ± 19
3	99 ± 2	-8.3 ± 1.5	118 ± 21
5	74 ± 8	-7.5 ± 0.4	106 ± 6

* RoM: rule of mixtures



Conclusions

1. There is a preferred orientation of GO in the nanocomposites film, according to the polarized Raman spectroscopy.
2. The interfacial stress transfer in GO/PVA nanocomposites can be characterized by the Raman D band shift.
3. The Grüneisen parameter can be used to estimate the effective modulus of GO, which is around 120 GPa, similar to those obtained with 'rule of mixtures' using the measured storage modulus.

References

1. Li, Z.; Young, R. J.; Kinloch, I. A. Interfacial Stress Transfer in Graphene Oxide Nanocomposites. *ACS Applied Materials & Interfaces* **2013**, 5, 456-463.
2. Young, R. J.; Kinloch, I. A.; Gong, L.; Novoselov, K. S. The Mechanics of Graphene Nanocomposites: A Review. *Composites Science and Technology* **2012**, 72, 1459-1476.

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