The Reinforcement of Nanocomposites with Graphene Oxide

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Summary. The mechanisms of reinforcement of nanocomposites with graphene oxide are explored and the prospects of using the material in engineering applications are discussed.

1 INTRODUCTION

Since it was first successfully exfoliated in 2004, graphene has attracted a rapid increase in attention for applications in a variety of fields, including nanoelectronics, graphene-based actuators and graphene-reinforced nanocomposites. Its derivative graphene oxide (GO) is playing an increasingly important role, because of its excellent properties and the ability to produce it in large quantities at relatively low cost. Although the interface between the reinforcement and matrix may be stronger than for graphene in GO-based nanocomposites due to the chemical functionality, the mechanical properties of GO are inferior to those of graphene [1]. A balance therefore needs to be struck between the mechanical properties of the reinforcement and the strength of the interface in the graphene-based nanocomposites [1].

2 RESULTS AND DISCUSSION

Raman spectroscopy has been used for the first time to monitor interfacial stress transfer in poly(vinyl alcohol) (PVA) nanocomposites reinforced with GO. The GO nanocomposites were prepared by a simple mixing method and casting from aqueous solution. They were characterized using scanning electron microscopy, X-ray diffraction and polarized Raman spectroscopy and their mechanical properties determined by tensile testing and dynamic mechanical thermal analysis [2]. The GO was fully exfoliated during the nanocomposite preparation process confirmed by the disappearance of the characteristic GO peak in X-ray diffraction. The stiffness and yield stress of the nanocomposites were found to increase with GO loading but the extension to failure decreased. The effective modulus was calculated from the dynamic mechanical analysis data (Fig. 1a) using the 'rule of mixtures' and was found to decrease with GO loading [2]. The Raman spectra for neat PVA, neat GO and a 1 wt% GO/PVA nanocomposite are shown in (Fig. 1b). Polarized Raman spectroscopy with VV polarization [2], in which the laser beams were parallel to *x* and *z* axes, respectively was used to characterize orientation of the GO in the nanocomposites. Similar to what has been found before with graphite, the Raman band intensity variation shows a $\sim\cos^4$ dependence on orientation angle with the laser beam parallel to the *x* axis (Fig. 2a), but stays constant when parallel to the *z* axis. It was concluded therefore that the GO nanoplatelets tended to be aligned in the plane of the films. It was found that the Raman D band at ~1335 cm^{-1} downshifted as the nanocomposites were strained as a result of the interfacial stress transfer between the polymer matrix and GO reinforcement [2] (Fig. 2b).

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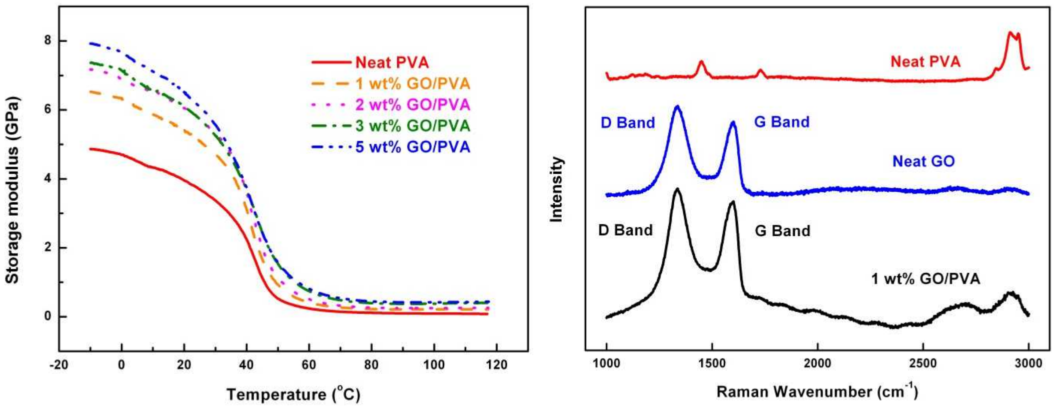

Fig.1 GO/PVA nanocomposites. (a) Storage modulus with different loadings of GO and (b) Raman spectra.

It was possible to estimate the effective Young's modulus of the GO from the Raman D band shift rate per unit strain [2]. It was found to be of the order of 120 GPa, a similar value to that estimated value from dynamic mechanical testing. The accepted value is in excess of 200 GPa and it is suggested that the lower effective Young's modulus values determined may be due to a combination of finite flake dimensions, waviness and wrinkles, aggregation and mis-alignment of the GO flakes.

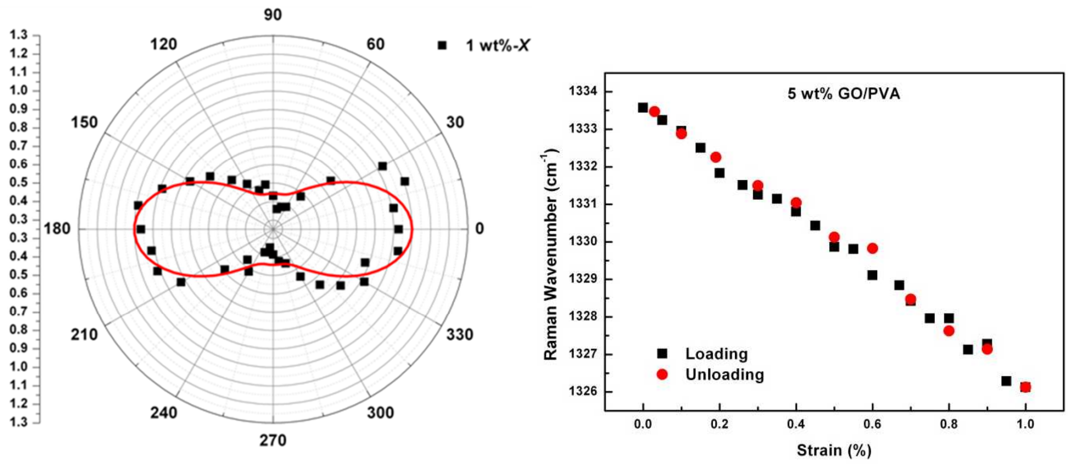

Fig. 2 Raman analysis of the GO/PVA nanocomposites. (a) Polar plots of the normalized intensity of the Raman D band and (b) Shift of the D band with strain.

3 CONCLUSIONS

A new insight has been obtained into the reinforcement of PVA by GO through the use of Raman spectroscopy. It has been shown that there is a preferred orientation of GO flakes in the plane of the nanocomposite film and that it is possible to use polarized Raman spectroscopy to quantify the levels of both orientation and reinforcement. It is clear that these materials have significant potential for engineering applications.

REFERENCES

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