Nanotube Strain Sensors by Micro-Raman Spectroscopy

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Abstract: Micro-Raman Spectroscopy is regarded as is an effective, noncontact technique with micrometer spatial solution for strain measurement,[1] but is restricted to those so-called Raman-active materials whose spectra have typical and visible Raman modes sensitive enough to strain.[2] This limitation may be break by using Raman-active materials as sensing media. As a new Raman-active material, Carbon nanotubes(CNTs) are potential for sensing strain[3,4] because of their outstanding mechanical[5] and spectral[6] properties.

In this work, we present a study of nanotube strain sensor in terms of micro-Raman spectroscopy for the strain measurement. The CNTs uniformly dispersed on the surface of (or inside) the measured body are taken as sensors. The theoretical model of CNT strain sensor is developed by applying the resonant and polarized Raman properties of CNTs and calculating the synthetic contributions from individual CNTs in random directions to the entire Raman spectrum. The proposed model provides an analytic relationship between the in-plane strain components (ε_X, ε_Y and γ_{XY}) to be measured and the Raman-shift increment ($\Delta\Omega$) detected through Raman tests, whose simplified form is as follows (where φ is the polarized direction).

$$\Delta\Omega^{(\varphi)} = \frac{1}{6}\Psi_{Sensor}\cdot\left[(3+2\cos 2\varphi)\varepsilon_X + (3-2\cos 2\varphi)\varepsilon_Y - 2\sin 2\varphi\cdot\gamma_{XY}\right]$$

Based on this model, we introduce a novel noncontact technique of strain measurement named Raman Strain Rosette, which detects the Raman-shift increments of the spectra from a same sampling spot with three different polarized directions, and then substitute them into the analytic relationship above to compose a simultaneous equations set. By solving it, the strain components are achieved. This proposed technique is applied in several experiments. The experimental results are consistent with the actual values as a whole, which verifies that Raman Strain Rosette is practicable to quantitative measuring all the in-plane components of the strain tensor (including both normal and shear strains) and it is further applicable to achieving the strain fields through Raman mapping

Acknowledgements

The authors wish to thank the financial supports by the National Natural Science Foundation of China (Nos.10732080 and 10972047)

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