Orientational order in stretch-aligned single wall carbon nanotubes/polymer photoluminescent films

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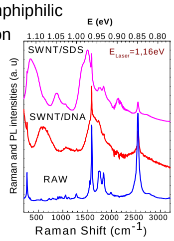
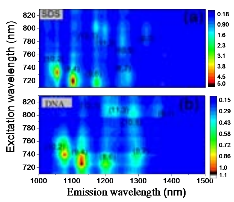
GOALS

1. Measure the orientational order of individualized single wall carbon nanotubes (SWNT) dispersed in polyvinylalcohol (PVA) films as a function of the film elongation.
2. Compare the experimental results with a simple geometric model.
3. Validate an accurate method to measure the scalar orientational parameter order in anisotropic SWNT materials

SWNT-HipCo bundles exfoliation

- Non covalent adsorption of amphiphilic molecules in water, tip-sonication
  - DNA-denatured [1]
  - SDS [2]

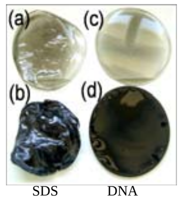




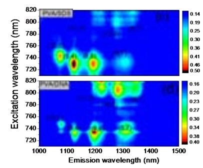
Photoluminescence as an evidence for exfoliation [3]

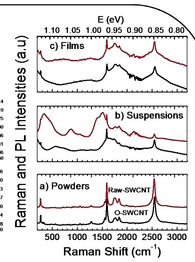
SWNT/PVA FILMS PREPARATION

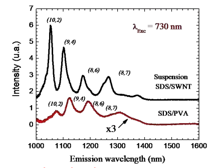
- Mixing 8 ml of aqueous nanotubes suspension with 8 ml of a PVA solution (PVA 10 wt.-%)
  Drying and formation of PVA films

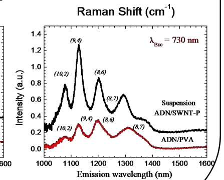


Only DNA-stabilized SWNT Films remain homogeneous





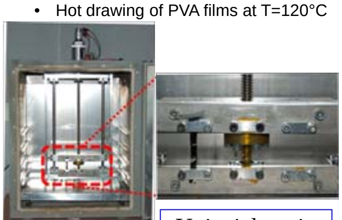




Photoluminescence as an evidence for exfoliation [3]

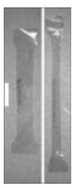
Stretching and Measurements

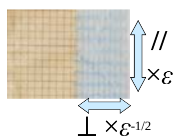
- Hot drawing of PVA films at T=120°C



Uniaxial strain

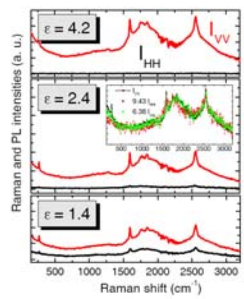
How to measure the deformation





- Measurements of strains (2D)

Raman spectroscopy and photoluminescence



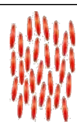
Both signal are very polarized

SWNT orientational order

Typical scalar order parameter

$$S = \frac{1}{2}\langle 3\cos^2\theta - 1\rangle$$

S = 0
Random orientation

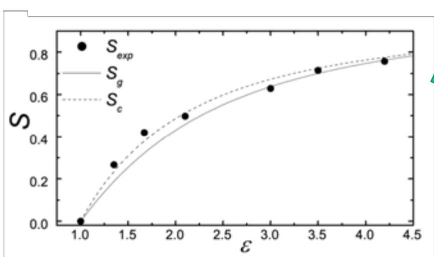


S = 1
perfectly aligned

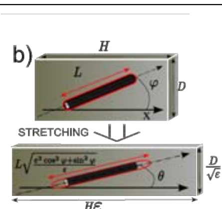
SWNT order parameter from Raman Spectroscopy

$$S_{3D} = \frac{3I_{VV} + 3I_{VH} - 4I_{HH}}{3I_{VV} + 12I_{VH} + 8I_{HH}}$$

We assume that the only component non zero of Raman polarization tensor is ε_{zz} and the director is parallel to the incident light polarization [4, 5]



A simple geometric Model



$$(x, y, z) \Longrightarrow \left(\varepsilon x, \frac{y}{\sqrt{\varepsilon}}, \frac{z}{\sqrt{\varepsilon}}\right)$$

$$p(\theta)d(\theta) = p(\varphi)d(\varphi) = \sin\varphi\, d\varphi$$

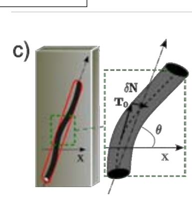
$$\tan\theta = \frac{D}{H\varepsilon^{3/2}} = \frac{\tan\varphi}{\varepsilon^{3/2}}$$

$$\cos^2\theta = \frac{\varepsilon^3}{\varepsilon^3 + \tan^2\varphi}$$

$$S_g = \int_0^{\frac{\pi}{2}} \frac{3\cos^2\theta - 1}{2} p(\theta)d\theta = \frac{\sqrt{\varepsilon^3 - 1}(2\varepsilon^3 + 1) - 3\varepsilon^3 \arctan\sqrt{\varepsilon^3 - 1}}{2(\varepsilon^3 - 1)^{3/2}}$$

Amended model

$$S_c \approx S_g + \frac{3}{2}\int_{\varphi_c}^{\frac{\pi}{2}} \frac{\tan^2\varphi - 2\varepsilon^3}{\varepsilon^3 + \tan^2\varphi}\left(1 - \frac{L(\varepsilon,\varphi)}{L}\right)\sin\varphi\, d\varphi$$



Conclusions

1. S has been measured by Raman and Photoluminescence spectroscopies.
2. A good agreement is found with a simple model considering only stretching-induced geometric changes of the films.
3. We developed a simple and accurate method to measure order parameter in SWNT composites

[1] B. Vigolo, A. Pénicaud, C. Coulon, C. Sauder, R. Pailler, C. Journet, P. Bernier, P. Poulin. Science. 290, 1331- 1334 (2000). [2] S. Badaire, C. Zakri, M. Maugey, A. Derré, J. N. Barisci, G. Wallace, P. Poulin. Adv. Mater. 17 (13), 1673-1676 (2005). [3] M.J. O'Connellet al. Science **297**, 593, (2002). [4] E. Anglaret, A. Righi, J-L. Sauvajol, P. Bernier, B. Vigolo, P. Poulin. Phys. Rev. B. 65, 165426 (2002). [5] C. Zamora-Ledezma, C. Blanc, M. Maugey, C. Zakri, P. Poulin, E. Anglaret. Nano letter. DOI: 10.1021/nl801525x (2008).