

Metrology of carbon nanotubes using near-field optical spectroscopy

Achim Hartschuh*(1), Huihong Qian(1), Carsten Georgi(1), Tobias Gokus(1), Hayk Haratyunyan(1), Neil Anderson(2) and Lukas Novotny(2)

(1) Department fuer Chemie und Biochemie, LMU Muenchen and CeNS, Germany

(2) The Institute of Optics, University of Rochester, Rochester NY, USA

Photoluminescence and Raman spectroscopy are powerful tools for carbon nanotube metrology. Both techniques offer single nanotube sensitivity and can be applied simultaneously to achieve complementary chirality specific information [1]. Experiments on individual nanotubes remove *ensemble averaging* involving different nanotube chiralities and other possible inhomogeneities such as nanotube length and defect variations allowing for a detailed sample characterization. The spatial resolution achieved in conventional optical microscopy, on the other hand, is limited by diffraction to about half the wavelength of the excitation light. The spectroscopic data obtained is thus affected by *spatial averaging* over ~300 nm. Metrology of high density samples used for example for integrated device applications and along individual nanotubes is restricted.

Near-field optical spectroscopy overcomes the diffraction limit and provides information on the sample composition and properties on the nanometer scale. The technique we apply is based on the local field enhancement effect at a laser-illuminated metal tip that is used to enhance the optical response of the sample. We present simultaneous photoluminescence and Raman spectroscopy and microscopy of carbon nanotubes with a spatial resolution of about 10 nm [2,3]. We visualize the spatial extent of electronic states, probe emission energies and investigate chirality variations along individual nanotubes [4,5].

We review the experimental requirements for near-field optical measurements and describe the most relevant challenges and difficulties. The potential of the presented near-field technique for nanotube metrology and its limitations are discussed.

Acknowledgment:

Financial support by DFG (grant HA4405/3-1 and "Nanosystems Initiative Munich (NIM)"), DOE (grant DE-FG02-05ER46207), NSF (grant CHE-0454704), and the DAAD (Probral) is gratefully acknowledged.

References:

- [1] A. Hartschuh et al., *Science* **90**, 095503 (2003).
- [2] A. Hartschuh et al., *Phys. Rev. Lett.* **90**, 095503 (2003).
- [3] N. Anderson et al., *J. Am. Chem. Soc.* **127**, 2533 (2005).
- [4] A. Hartschuh et al., *Nano Lett.* **5**, 2310 (2005).
- [5] N. Anderson et al. *Nano Lett.* **7**, 577 (2007).

