NT05: Sixth International Conference on the Science and Application of Nanotubes

Göteborg, Sweden

June 26 - July 1, 2005

http://nanotube.msu.edu/nt05/

Introduction to Focussed Poster Sessions, and Concluding Remarks at NT'05

A.1	**Annick Loiseau**	Monday, June 27
A.2	**Esko I. Kauppinen**	Tuesday, June 28
A.3	**Marcos Pimenta**	Tuesday, June 28
A.4	**Jack Fischer**	Tuesday, June 28
B.1	**Pavel Nikolaev**	Thursday, June 30
B.2	**Apparao Rao**	Thursday, June 30
B.3	**Tony Heinz**	Thursday, June 30
B.4	**Gianaurelio Cuniberti**	Friday, July 1
B.5	**Yoshiyuki Miyamoto**	Friday, July 1
CR	**Mildred Dresselhaus**	Friday, July 1

NT'05 SCIENTIFIC PROGRAM

Time	Sun 26	Mon 27	Tues 28	Wed 29	Thurs 30	Fri 1
08:30-09:00		registration	registration			
09:00-09:45			Maurizio Prato	Morinobu Endo	David Tomanek	Paul L. McEuen
09:45-10:15		Welcoming address (09:30-10)	Alan Windle	Susumu Katagiri	Jean-Louis Sauvajol	Nadine Kam
10:15-10:45		Sumio Iijima (10-10:45)	Jerry Tersoff	Jean Dijon	Junichiro Kono	Cheol Jin Lee
10:45-11:15		Steven G. Louie	Coffee	Coffee	Coffee	Coffee
11:15-11:45		Coffee	Young Hee Lee	Jong-Min Kim	Tony Heinz	Brian LeRoy
11:45-12:05		Humberto Terrones (11.45-12.15)	Yoshinori Sato	Atsuko Nagataki	A.V. Krasheninnikov	S. W. Lee
12:05-12:25		Lars Samuelson (12.15-12.45)	lunch	A. K. Swan	lunch	lunch
12:25-14:00		lunch (12.45-14.20)		lunch		
14:00-14:20			Pavel Nikolaev	Boat trip and conference dinner	G. Seifert	Pertti Hakonen
14:20-14:40		Feng Ding	Vincent Jourdain		B. Gao	A. Wall
14:40-16:00		Masahiko Ishida (14.40-15)	Poster Session A		Poster Session B	Poster Session B
16:00-18:00	registration	Poster Session A				
18:00-19:00	Welcome party					Snacks 19:00
19:00-21:00		Göteborg reception				Concluding Remarks 20.00

Welcoming address at 09:30 on Monday by the Chancellor of Göteborg University.

Welcome party, welcoming address, registration, talks, posters, lunch and Friday evening snacks are in the Chalmers University Student Union Building, located at the main entrance to Chalmers University of Technology.

Göteborg Reception is on Monday evening at 'Börsen' in the heart of Göteborg, about 30 minutes walk from the Student Union. Guides (if needed) leave the Student Union at 18:15.

On Wednesday buses leave from the Student Union to the boat trip at 14:00.

Poster sessions include reports by the poster chairs

Posters

Poster abstracts are listed from page XX, and are identified according to a sorting category given below.
Posters in categories I-VIII will be presented in Session A (Monday and Tuesday).
Posters in categories IX-XXI will be presented in Session B (Thursday and Friday).

I. CVD Synthesis of Carbon Nanotubes
II. Non-CVD Synthesis of Nanotubes
III. Formation and Characterization of Unusual Nanostructures
IV. Raman Characterization of Nanotubes
V. Other Characterization of Nanotubes
VI. Nanotube Dispersion and Purification
VII. Chemical Modification of Nanotubes
VIII. Non-Carbon Nanotubes
IX. Nanotube-Based Composites
X. Morphology and Application of Modified Nanotubes
XI. Photo-Induced Reactions in Nanotubes
XII. Thermal and Mechanical Properties of Nanotubes
XIII. Atomic Structure of Carbon Nanotubes
XIV. Transport in Nanotubes
XV. Field Electron Emission
XVI. Optical Properties and Optoelectronics
XVII. Transport in Complex Nanostructures
XVIII. Electron-Phonon Coupling in Complex Nanostructures
XIX. Nanotube-Based Transistors
XX. Magneto-Transport and Magnetism
XXI. General Studies of Carbon Nanostructures

NT'05 contributions

In the spirit of the NT Conference series, oral presentations will consist of plenary, keynote and contributed talks. However, most contributions are presented as posters, and over half of the conference is dedicated to the poster exhibitions. Due to the large number of poster presentations, the NT'05 program does not include the two minute 'poster+' presentations that were a feature of preceding NT conferences. Instead, posters will be introduced by poster 'chairs', which leaves most of the time for discussion at the individual posters.

There are two poster sessions.

- Session A is on Monday and Tuesday and includes posters I.1 – VIII.12.
- Session B is on Thursday and Friday and includes posters IX.1 – XXI.30

These two sessions are divided into sub-sessions that will be introduced by the chairs. In addition, it is expected that contributors are available at their posters after the presentation of their sub-session.

Sub-session	Posters	Poster chair	Presentation by chair
A.1	I.1-I.40	Annick Loiseau	Monday, June 27
A.2	I.41-I.81	Esko I. Kauppinen	Tuesday, June 28
A.3	II-IV	Marcos Pimenta	Tuesday, June 28
A.4	V-VIII	Jack Fischer	Tuesday, June 28
B.1	IX-X	Pavel Nikolaev	Thursday, June 30
B.2	XI-XIII	Apparao Rao	Thursday, June 30
B.3	XIV	Tony Heinz	Thursday, June 30
B.4	XV-XVIII	Gianaurelio Cuniberti	Friday, July 1
B.5	XIX-XXI	Yoshiyuki Miyamoto	Friday, July 1

A.1 Annick Loiseau Monday, June 27

POSTER SESSION A I1 - I40

Syntheses via CV techniques

A few words about CVD

Principle: - Decomposition of a carbonaceous gas at the surface of a metallic particle in a furnace (T = 500 - 1100°C)
- metallic particles prepared on a substrate prior to reaction with C gas or in situ

CVD are more and more used for the synthesis of MWNTs and SWNTs due to many advantages:

- flexibility: choice of the substrate, possible localized growth
- control of the catalyst preparation and particle size
- control of NT diameter and possibly helicity
- possible oriented growth (alignement)
- the most promising route to high purity samples with no need of costly post synthesis purification processes
- the most promising technique for industrial production
- synthesis of selectively MWNT, DWNT and SWNT
- heteroatomic tubes, doping, filling…

Highlights of the session - 1

- Majority of studies concern synthesis of SWNT

  22 : SWNT (I5, 6, 9, 10, 11, 12, 17, 19, 21, 23, 24, 25, 26, 29, 30, 34-40)

  16 : MWNT (I2, 3, 4, 7, 8, 14, 15, 16, 18, 20, 22, 27, 28, 32, 33, 38)

  1: DWNT (I13)

- Nature of the CVD process used:

  PECVD : now for both MWNT (I2, I3, I18) and SWNT (I21, 25, 26, 35)

  (discussion of interest of PECVD for SWNT in I26, 35)

  thermal CVD (I19, 29, 38)

  Fluidized bed (I7, 34, I37)

  Aerosol (I10, 15, 39)

  Hot filament (I27, 40)

  New techniques: continuous injection of prepared supported Fe (I6)

  Hot wire generator (I11, 12)

  laser irradiated CVD (I24)

Highlights of the session -2

- Studies on the catalyst: preparation nature

  12 posters (I2, 9, 10, 11, 19, 20, 23, 28, 33, 36, 38, 40)

- Studies on the growth conditions , growth mechanism:

  7 posters (I7, 12, 15, 18, 29, 30, 34, 37)

  special mention to synthesis on membranes allowing direct

  TEM observations (I12, 17)

- Modeling of growth:

  3 posters (I1, 5, 31) but see also other sessions !

- Growth of NT in devices:

  2 posters (I8, 17)

- Filling MWNT:

  3 posters (I14, 22, 27)

- Alignement:

  2 posters (I15, 25)

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NT05

A.2 Esko I. Kauppinen Tuesday, June 28

HIGHLIGHTS IN POSTER SESSION A.2.

POSTERS I.41 – I.81

CVD SYNTHESIS

Tuesday June 28 14:45 – 16:30

by

Esko I. Kauppinen

Dept. of Physics & Center for New Materials,

Helsinki University of Technology (HUT)

Novel Approaches

* Catalyst free CVD growth of SWCNT – I46

* Nano-contact printing of colloidal catalyst nanoparticles – I59

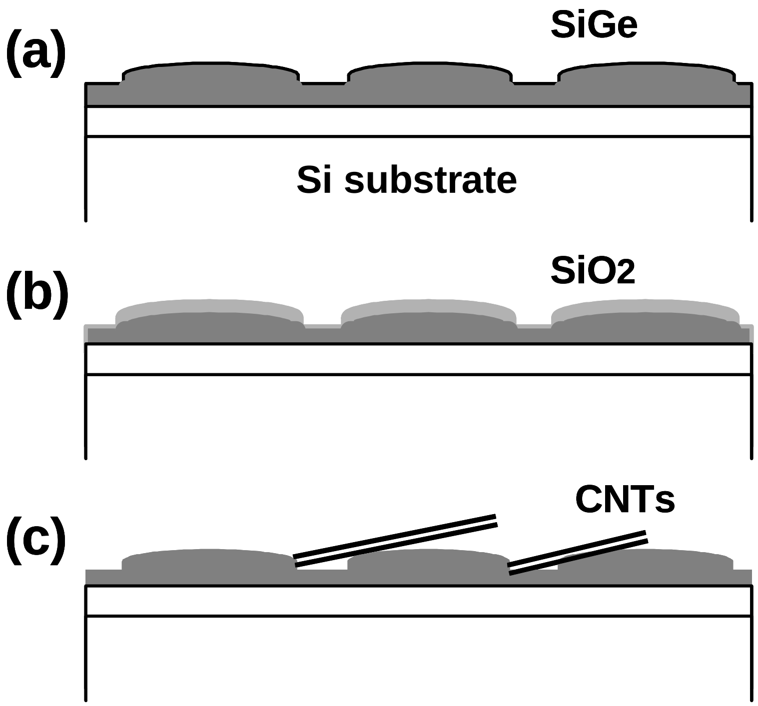
* Three-dimensional internal order of N-doped MWCNT – I60

* Aligned growth of SWCNT utilizing the crystalline structure of oxide catalyst support - I67

* Use of carbon-13 isotope to study precursor reaction mechanisms during ACCVD of SWCNT – I69

University of Southampton

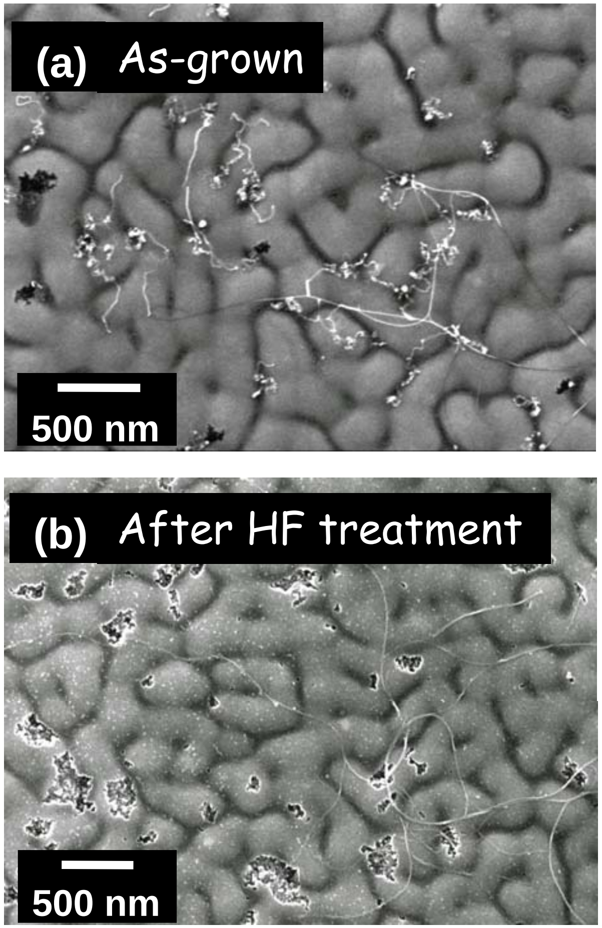
Metal catalyst free low temperature direct growth of carbon nanotubes on SiGe islands and Ge quantum dots



- 50 nm thick SiGe (Ge 30%) islands were grown on the Si substrates by CVD.
- C ion implantation: 2%
- Formation of 0.5 nm oxide by chemical oxidation with H_2O_2.
- CNT growth by CVD using CH_4 (1slm) and H_2 (0.3slm) at 850°C after preheating at 1000°C.

Fig.1. Schematic diagram process flow of CNT growth.

Metal catalyst free low temperature direct growth of carbon nanotubes on SiGe islands and Ge quantum dots



- Two types of fibers were observed
  Thick, curly oxide fibers
  Thin, straight carbon nanotubes
- Oxide fibers were removed by HF
- Carbon nanotubes were removed by annealing in air above 400 °C
- EDX measurements detected no metal contaminants

Fig.2. SEM images of the fabricated nanofibers

NANO-CONTACT PRINTING OF COBALT COLLOID CATALYST FOR GROWTH OF VERTICALLY ALIGNED CARBON NANOTUBES

NT05

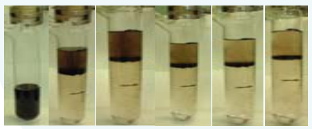
UNIVERSITY OF CAMBRIDGE

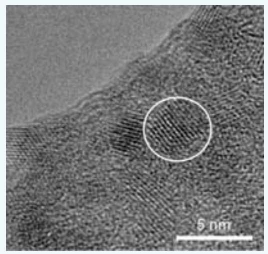
M. Cantoro[1], V. B. Golovko[2], S. Hofmann[1], H. W. Li[2,3], B. Kleinsorge[1], J. Geng[2], Z. Yang[2,3], D. A. Jefferson[2], A. C. Ferrari[1], B. F. G. Johnson[2], W. T. S. Huck[2,3], J. Robertson[1]

1 Engineering Dept.
2 Chemistry Dept.
3 Nanoscience Centre

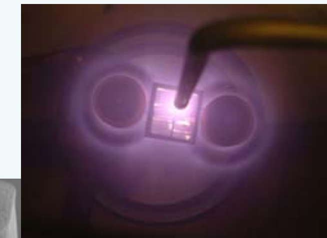
Chemistry, nanofabrication, and carbon nanotube growth techniques are brought together to realize uniform arrays of vertically aligned CNTs by nano-contact printing.

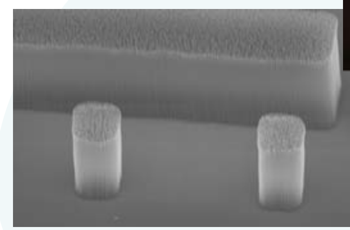
CHEMISTRY





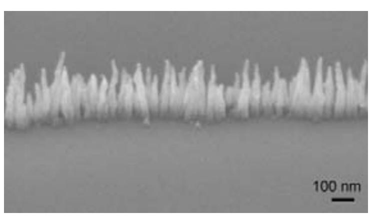
A highly purified and concentrated Co colloid to act as a catalyst for CNT growth has been developed. Co nanoparticles are 2-4 nm in diameter.



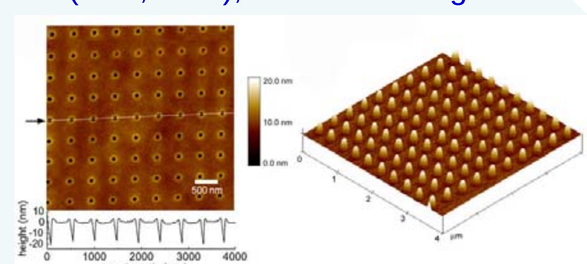


CNT GROWTH

Plasma-Enhanced CVD conditions has been optimised to grow well-defined vertically aligned carbon nanotubes.



A nano-contact printing stamp to enable catalyst ink to be printed in nano-sized patterns (dots, lines), has been designed.



NANOFABRICATION

After CNT growth, patterns are uniform over large areas. Nano-contact printing provides feature sizes down to **100 nm**, small enough to allow the nucleation of single, isolated and small diameter CNTs.

Nano-contact printing is a **low-cost**, **large-area**, **reliable** patterning method, alternative to e-beam lithography and other patterning techniques.

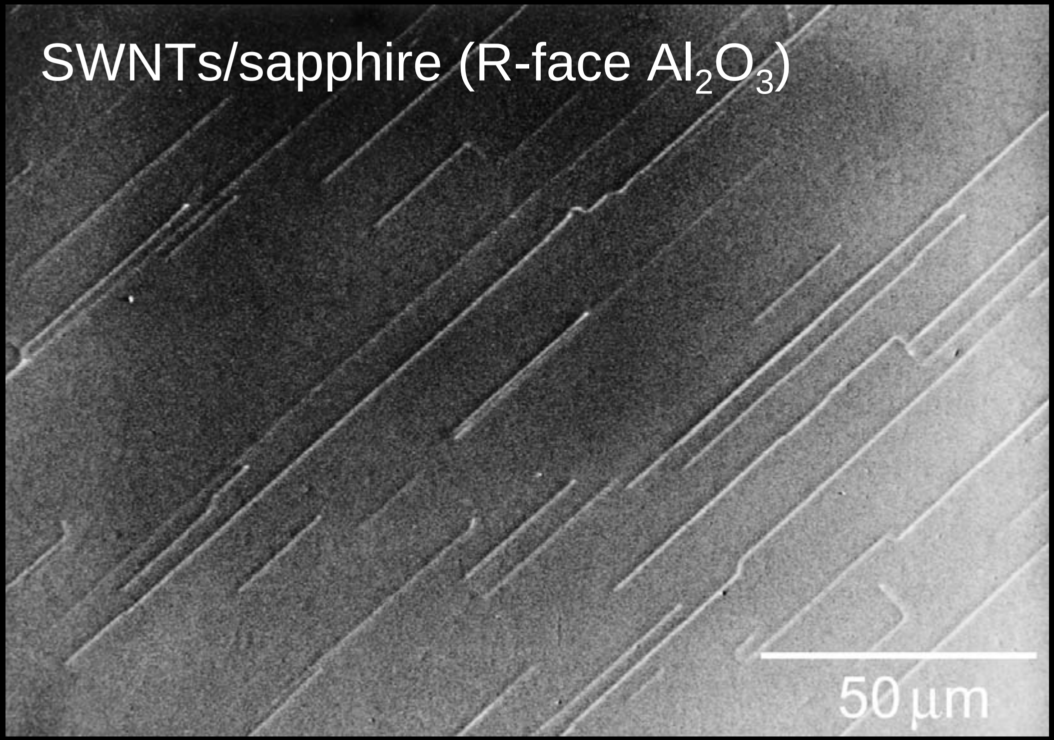
I.67 (P315)

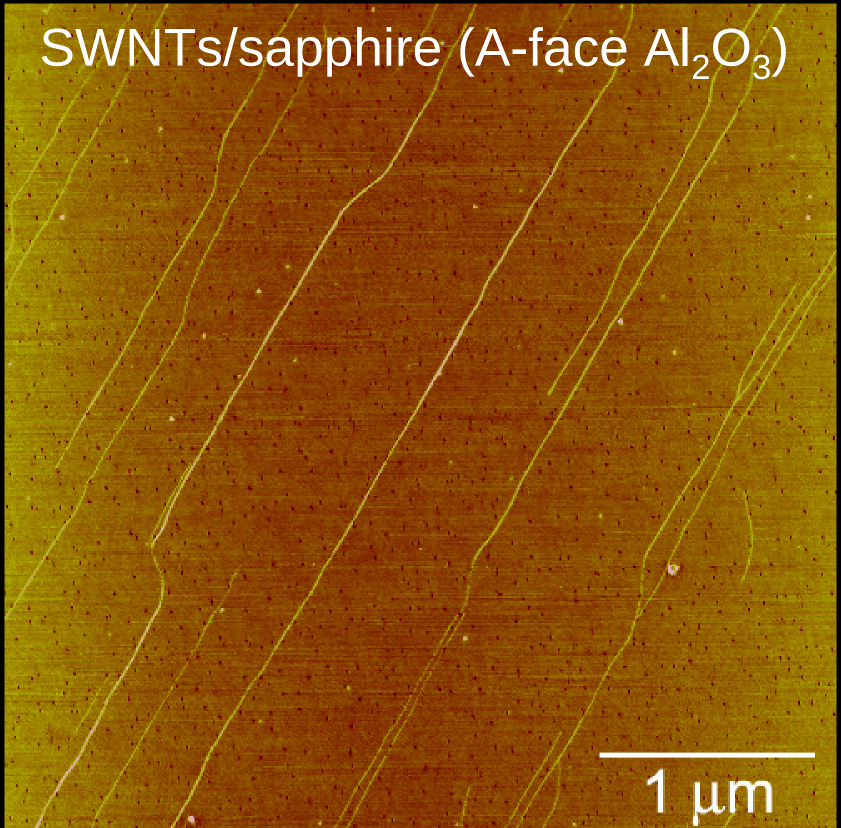
Aligned Growth of Isolated Single-Walled Carbon Nanotubes Programmed by Atomic-Arrangement of Crystalline Surfaces

H. Ago,* K. Nakamura, K. Ikeda, N. Uehara, and M. Tsuji

Kyushu University, Fukuoka 816-8580, Japan

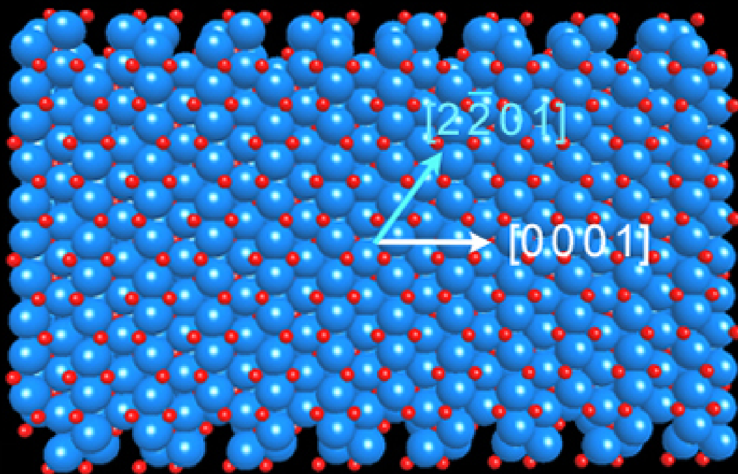
1) SWNTs were aligned horizontally on R- and A- face sapphire substrates by CVD
2) The growth directions were associated with the crystalline orientations
3) Surface Al atoms are likely to guide the SWNT growth

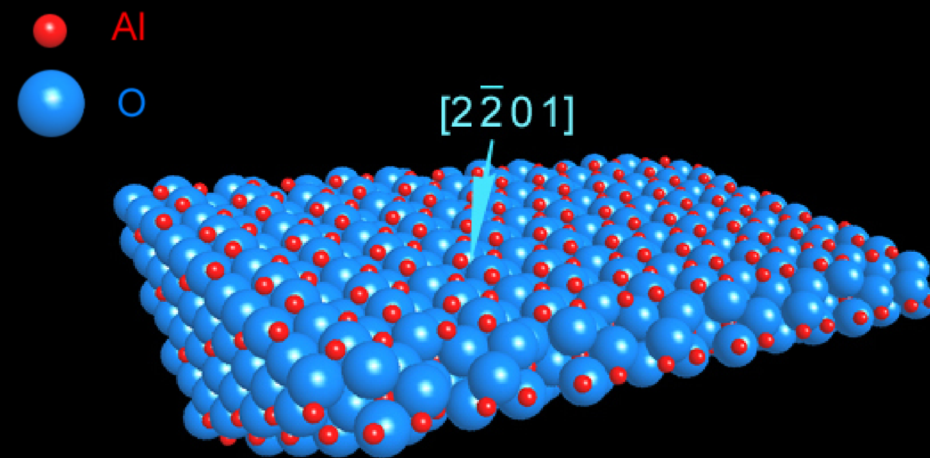


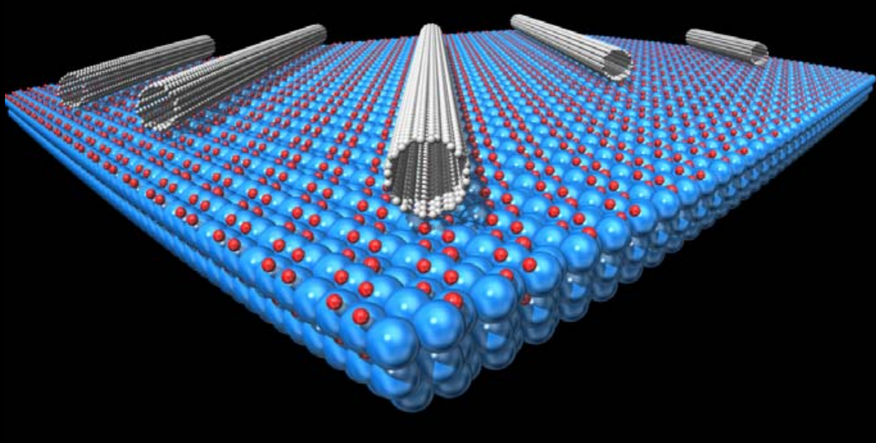


I.67 (P315)

A-face

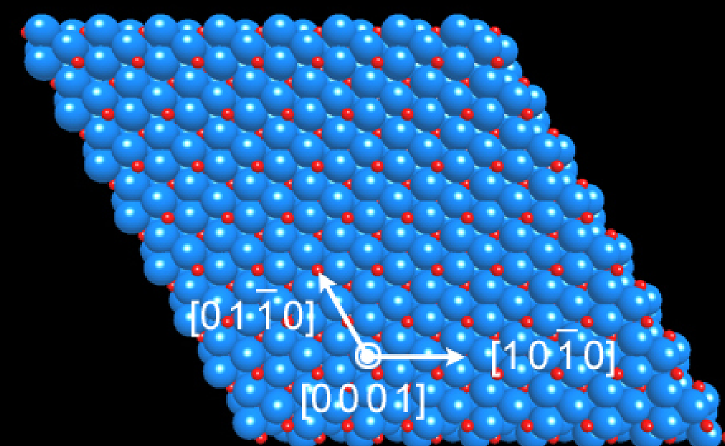






Al atoms guide the SWNT alignment
=> strong Al-SWNT attractive interaction

C-face

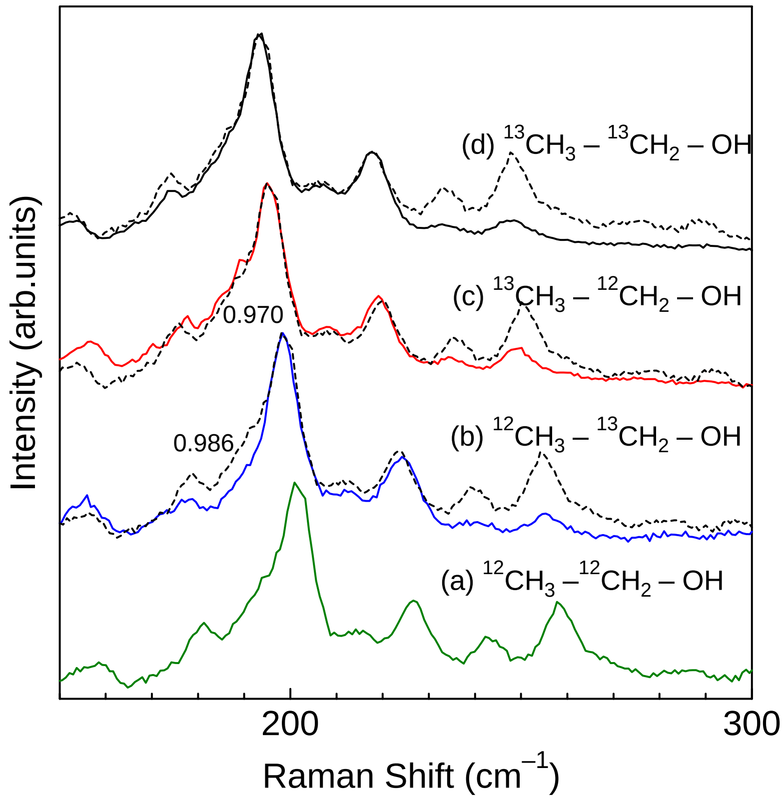


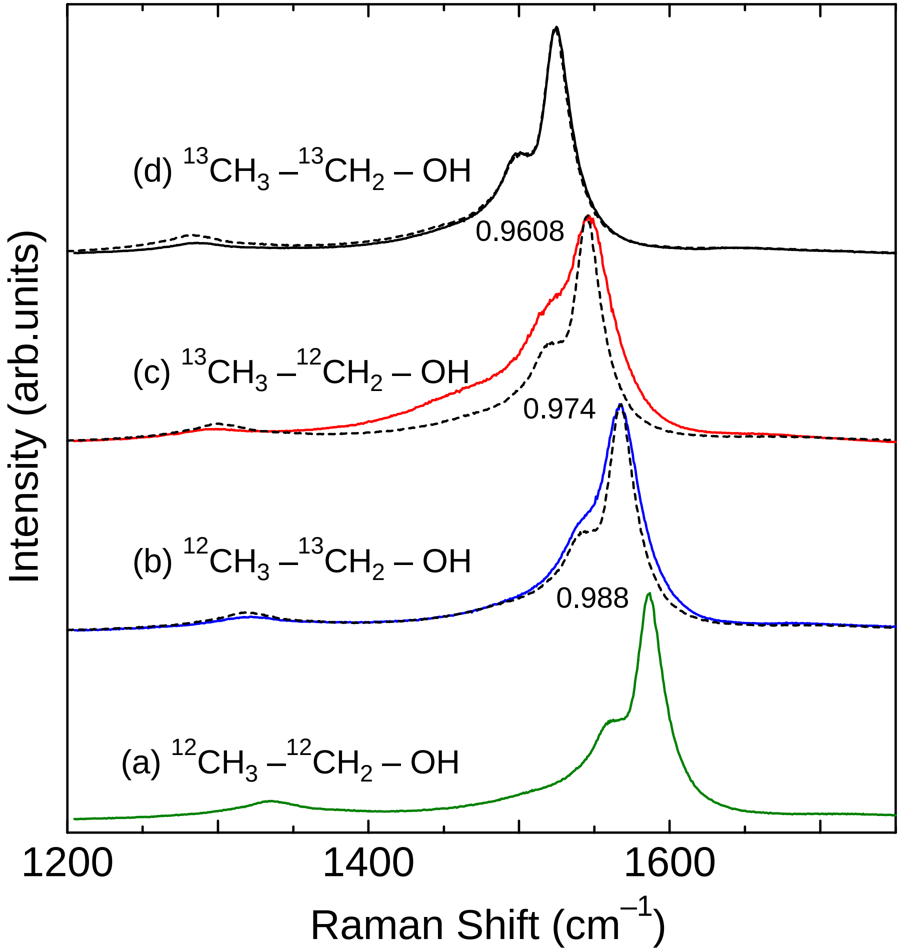
C_3 symmetry => No SWNT alignment

Alcohol CVD Growth, Raman and Photoluminescence Spectroscopy of Single-Walled Carbon-13 Isotope Nanotubes

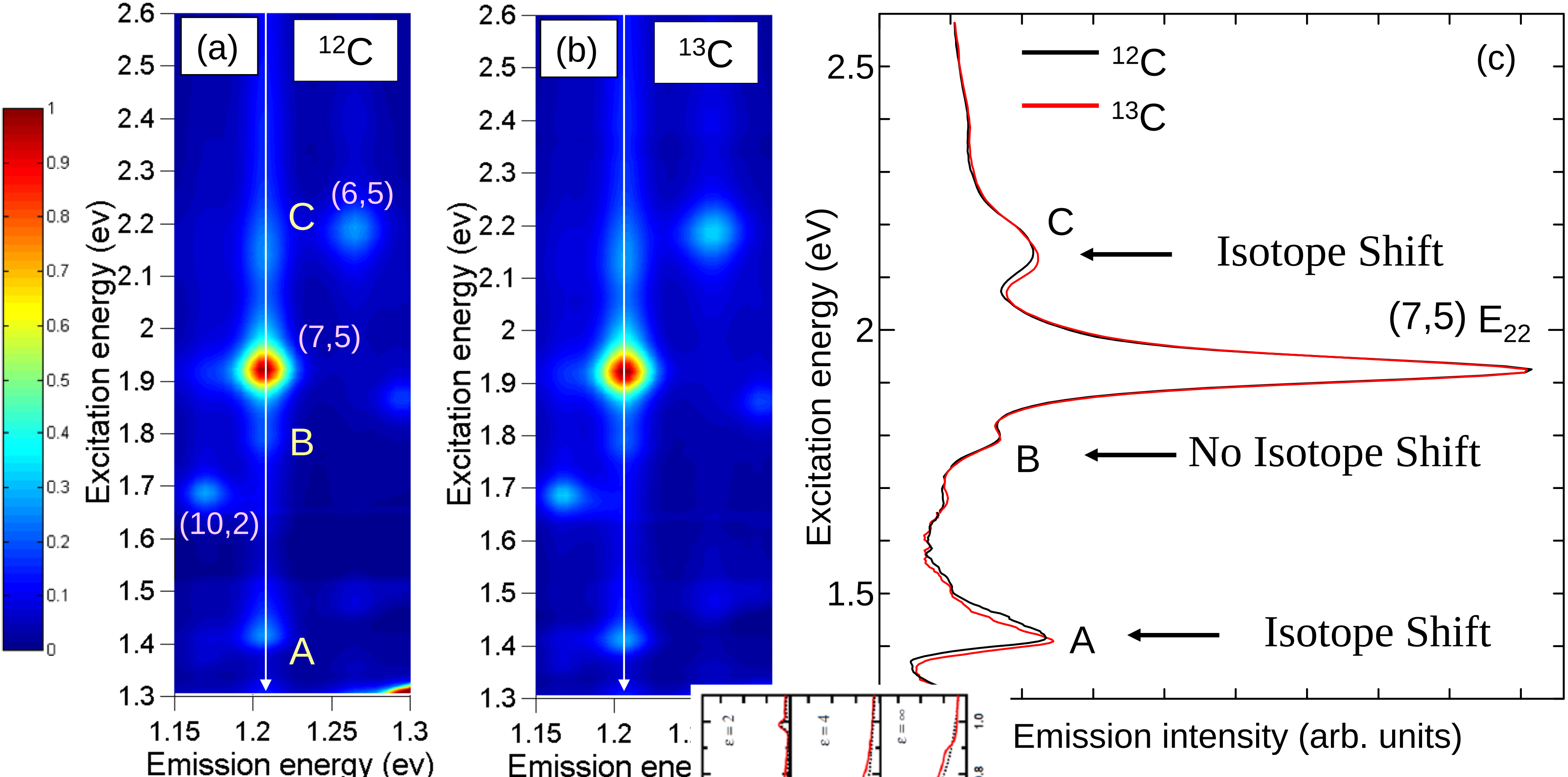
I.69

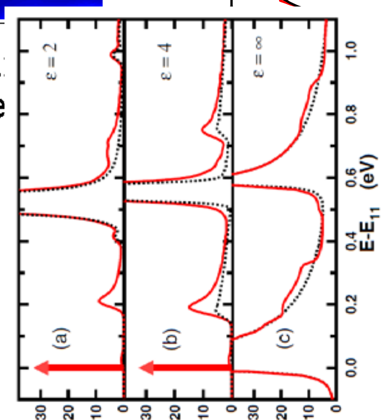
Shigeo Maruyama and Yuhei Miyauchi
Dept. of Mech. Eng., The University of Tokyo





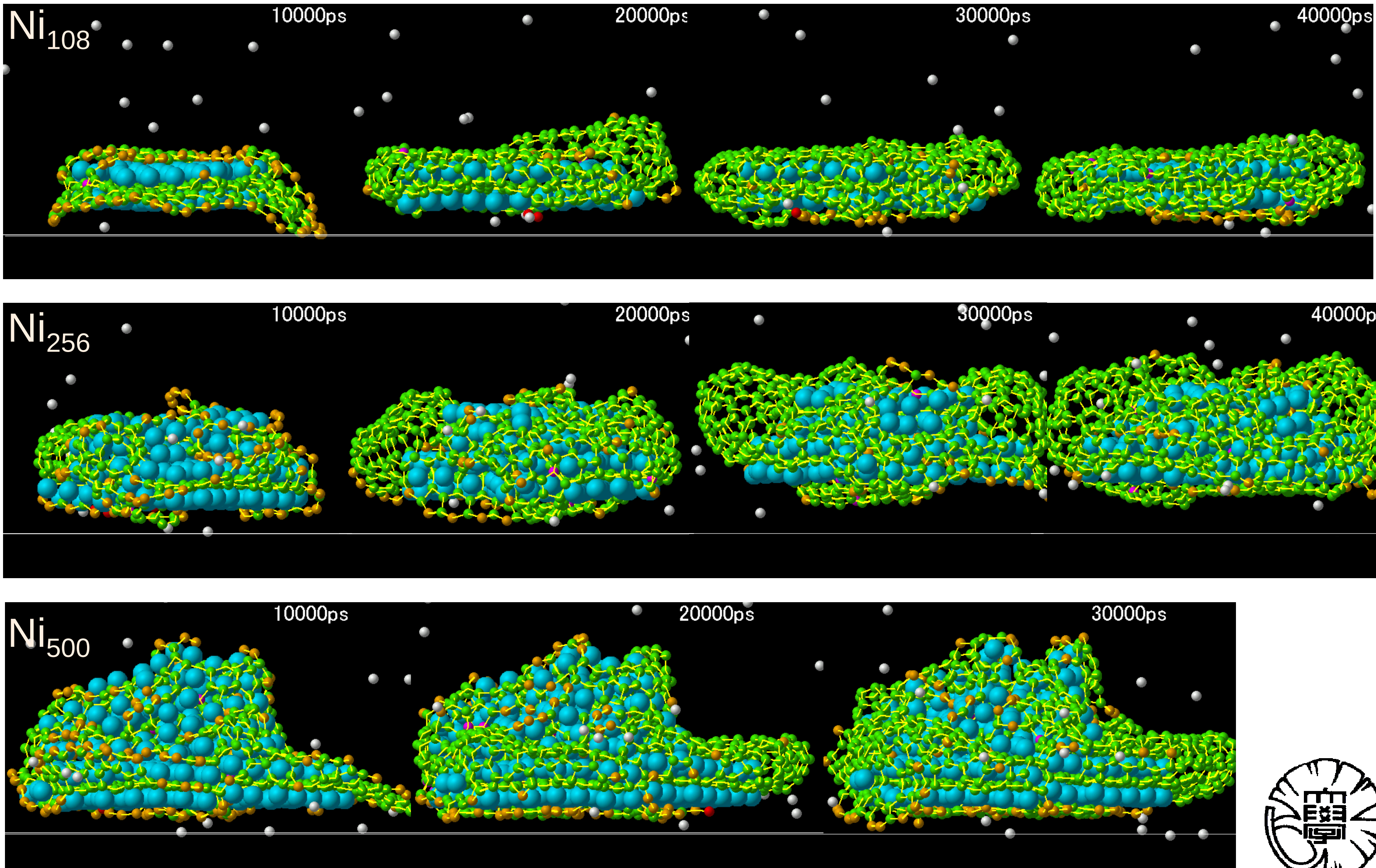
PLE Spectra of SW^{13}CNTs





V. Perebeinos, J. Tersoff, P. Avouris, PRL 94, 027402 (2005).

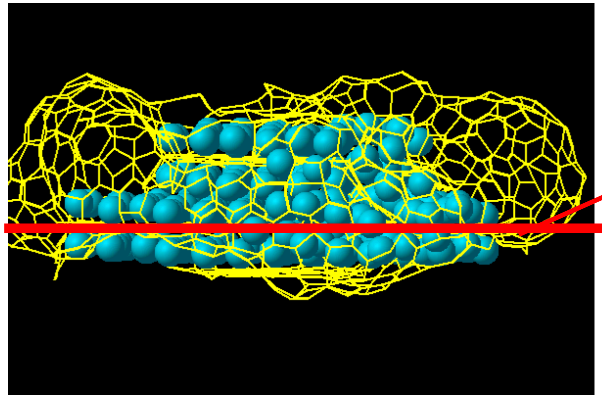
MD of Nucleation of SWNTs from a Cluster on a Substrate



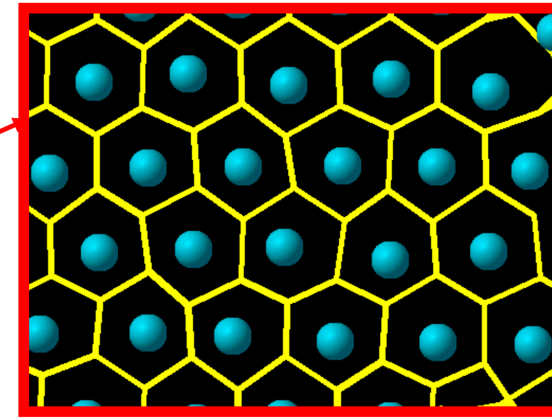
I.71 Shibuta & Maruyama @ The Univ. of Tokyo

Cross Sectional View of the Metal Cluster

Ni_{256}, D_e =0.98eV
40 ns, 2500K

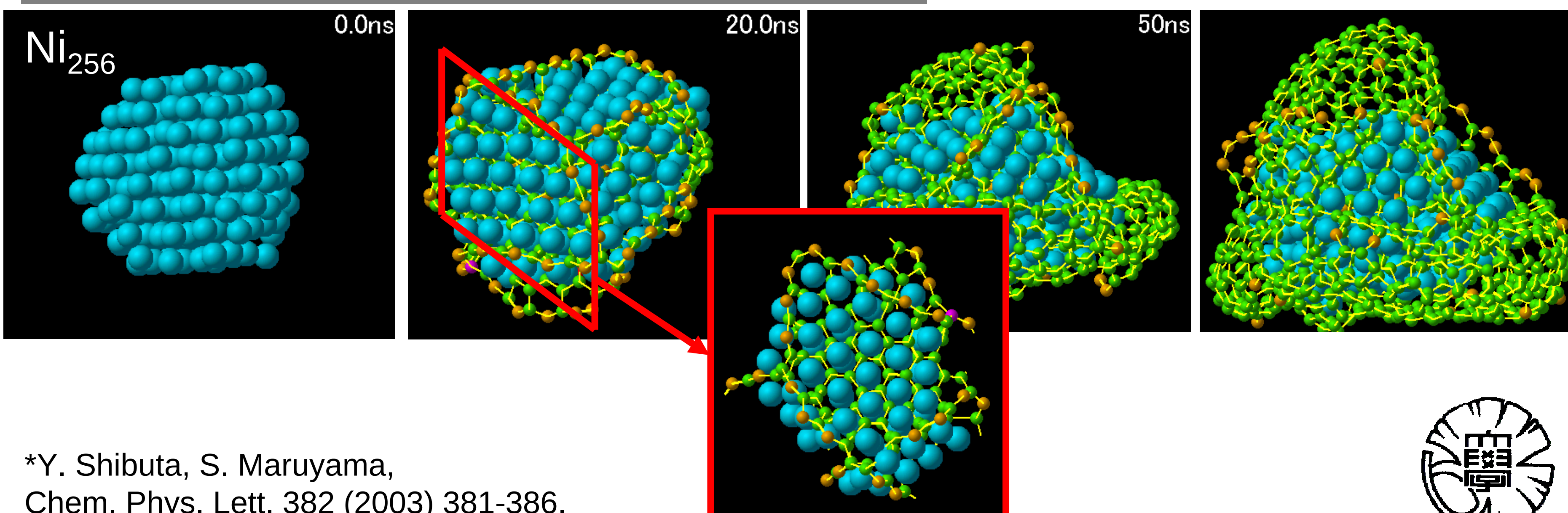


Carbon atoms are not shown for clarity.



Ni(111) structure

Comparison with the non-supported cluster*



*Y. Shibuta, S. Maruyama,
Chem. Phys. Lett. 382 (2003) 381-386.

Yet Open Issues

* Synthesis of (n,m) controlled SWCNT's

* Nucleation and growth mechanisms of SWCNT with given (n,m)

A.3 Marcos Pimenta Tuesday, June 28

Section II - Non-CVD nanotube synthesis

II-1 to II-8 downstairs, II-9 to II-20 in this level

Section III – Formation and characterization of unusual nanostructures

all posters in this level

Section IV – Raman characterization of nanotubes all

all posters in this level

Marcos A. Pimenta

Departamento de Física, UFMG

Belo Horizonte, Brasil

Section II - Non-CVD nanotube synthesis (16 posters)

• Chirality control – CNT chirality determined by the atomic structure of the SiC substrate (II-15)

• Isolated nanotubes made by arc-discharge (II-2)

Influence of catalyst, promoter and electrodes

• Ni and Y carbonates and oxides (II-6)

• Different transition and rare earth metals (II-16)

• Influence of sulfur promoter (II-14)

• Influence of graphite electrodes (II-8)

• Pre-formed catalyst: NT diameter determined by catalyst size (II-4)

• Real-time study: diameter does not depend on particle size (II-17)

New Methods

- Wet chemical synthesis: cyclacene (II-10)
- Spray pyrolisis of natural precursors (II-7)
- Radio frequency magnetron sputtering (C and BN) (II-5)

Formation Mechanisms

- Fluorescence experiments (laser vaporization method) (II-11)
- Arc discharge (II-9)
- BN bamboo-like nanostructures (II-20)

- Large scale production: DWNTs (II-12), MWNTs (II-18)

  carbon cones and carbon disks (II-18)
- Long amorphous carbon nanotube ropes (21 cm) (II-1)

Section III – Formation and characterization of unusual nanostructures (14 posters)

- Controlled assembling nanotubes on surfaces with atomic steps (III-12)

Things @ Nanotubes

- Fluid Ice (Neutron scattering) (III-3)
- Ice nanotube (X-ray diffraction) (III-14)
- Magnetic nanoparticles (III-11)

Nanohorns, Nanocapsules, Nanofibers, Nanoribbons

- Desorption of organic materials on nanohorns (III-7)
- Metal-encapsulated nanohorns and nanocapsules (III-5, III-8)
- Growth and characterization of nanofibers (III-4, III-10)
- Conversion of nanotubes into nanoribbons (III-9)
- Simulation of carbon deposit in zeolyte nanopores (III-2)

Section IV – Raman characterization of nanotubes (11 posters)

SWNTs (7), DWNTs (2), MWNTs (1)

<u>SWNTs</u>

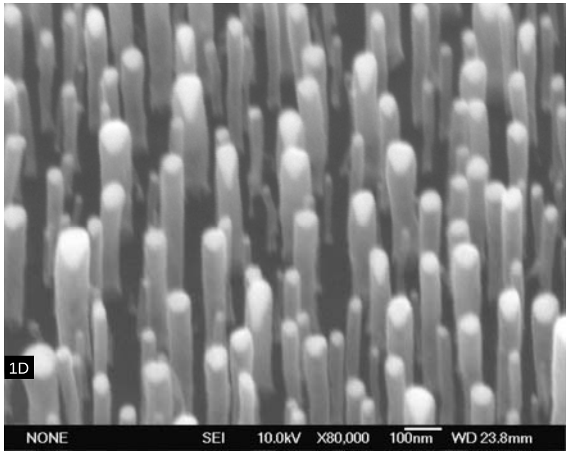
- Correlation between Raman and transport measurements (IV-3)
- UV Raman in SWNTs @ zeolytes (d_T = 0.3 nm) (IV-10)
- Comparison of NTs on Si/SiO_2 surfaces and in aqueous solution (IV-2)
- Raman and electrochemical doping (IV-8)
- Temperature dependence (4-1000K) of the Raman spectra (IV-12)
- Calculation of the RBM resonant profile for 300 SWNTs (IV-1)
- Infrared modes (purification and annealing of the sample) (IV-7)

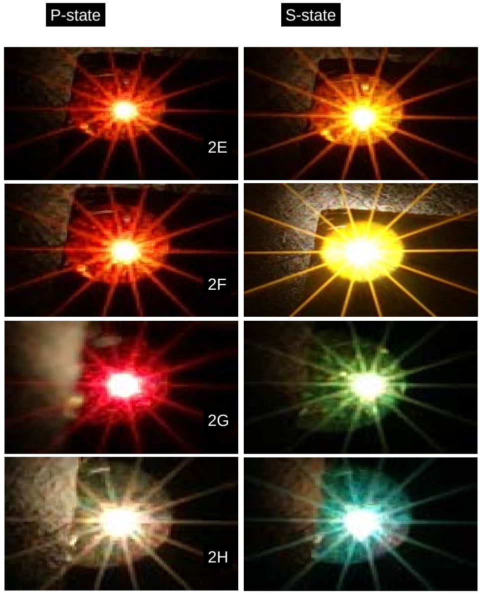
DWNTs

- Fine structure of RBM – inner tube inside different outer tubes (IV-5)
- Raman under pressure – inner tubes protected by outer tubes (IV-9)

MWNTs

- Vertcaly aligned – Ag coated for SERS (IV-6)





A.4 Jack Fischer Tuesday, June 28

Sixth International Conference on the Science and Application of Nanotubes

Göteborg University, Chalmers University of Technology and University College of Borås

June 26-July 1, 2005 (Gothenburg, Sweden)

"CHEMICAL" POSTERS

- **V . Characterization of Nanotubes (18)**
- **VI. Nanotube Dispersion and Purification (9)**
- **VII. Chemical Modification of Nanotubes (29!)**
- **VIII. Non-Carbon Nanotubes (12)**

V. Characterization of Nanotubes

- **Individuals**, ropes & bundles, **fibers, films**, suspensions/dispersions, composites
- **(n,m) determination and synthetic control**
- **density, porosity, preferred orientation**
- **Atomic-scale defects – more emphasis and new techniques needed!**

Technique mentioned most often: HRTEM, followed closely
by optical probes (absorption, PL)

"New" techniques: NEXAFS - chemically-specific orientation information
SAXS – structure of large aggregates

Popular "problems" in characterization:
purity determination/quantification
tuning and measuring chirality
nitrogen (sidewall) doping
gas sorption

New issues in characterization:
radiation effects on tubeFET behavior,
high pressure phenomena

VI. Nanotube Dispersion and Purification

- How pure is pure enough? Depends on application.
- Would it be easier/better to grow them pure in the first place? How? Catalyst tricks? MWNT easier to grow relatively pure.
- Dispersion: precursor to **i) rational or self-assembly into higher-order structures, e.g. fiber spinning, thin film deposition; ii) sorting by (n,m) and nanodevice engineering; iii) composite processing; ……….**
- Can it all be done without damaging tubes (sonication, sidewall adducts..) ?

9 ABSTRACTS

- Reference standards for "pure" SWNT.
- Drift of SWNT in DC electric field during growth – diagnostic of CVD yield
- Novel SWNT dispersants based on saccharide chemistry.
- Heat treatment and opening ends to facilitate peapod formation.
- Dispersing LONNNNNNNNNNNG MWNTs and composite synthesis.
- Bundle/rope dissociation by amides: "SWNT causes rearrangement of solvent" (theory and expt.). See also P23 (X.1) "partly ordered solvent around acid-swollen SWNT fibers" (WZ and JEF).
- Diameter-selective oxidation by hydrogen peroxide.
- Patterned SWNT deposits on the anode in DC electrophoresis using aqueous electrolyte.

VII. Chemical Modification of Nanotubes

- Functionalization: solubility, separation, tube-matrix adhesion (8)
- Doping/intercalation/filling (5)
- Control surface chemistry; curvature; adsorption sites (4)
- DNA hybrids (3)
- Fluorination (3)
- Sensor applications (2)
- Nitrogen doping (2)
- Purification, esp. removal of amorphous carbon (1)
- Cutting and sorting by length (1)
- Sidewall defects: measure and chemically modify (1)
- Nanotube/nanoparticle hybrids (1) (see also I.46)

$\Sigma(n)$ > # posters
Theory and experiment
Overlap with posters VI.

VIII. Non-Carbon Nanotubes

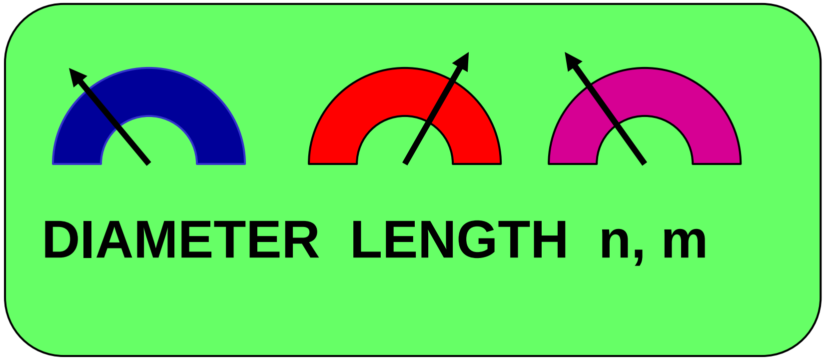
- Point and line defects in BN nanotubes (theory)
- Synthesis of BN nanotubes by *in-situ* nidriding
- BN SWNT synthesis & mechanism: EELS, optical properties
- Vertically-aligned BN tubes by PE-PLV @ 600C
- Boron sheets and tubes:structure, el.props., H2 sorption (thy)
- Si nanoparticles and nanowires: synthesis, low T transport
- TiO_2 nanotubes -> nanoparticles; chimie douce
- Bismuth sufide nanotubes @ 350C
- $Mo_6S_{4.5}I_{4.5}$ NW bundles: solubility, structure & mech.props.
- Aligned ZnO NW on patterned substrates; PL spectra

What's missing? What's next?

- **V . Characterization of Nanotubes (18)**
- ~~**VI. Nanotube Dispersion and Purification (9)**~~
- **VII. Chemical Modification of Nanotubes (29!)**
- **VIII. Non-Carbon Nanotubes (12)**

Continuous large-scale growth of isolated, perfect CNT's

"Designer" CNT synthesis



Single-tube ***in situ*** physical property measurements (ρ, κ, ε, α, …) concurrent with atomic-scale structural and defect diagnostics –

HRTEM appears to be the only option.

(limitations of Raman, scanned probe, …..)

NT05: Sixth International Conference on the

Science and Application of Nanotubes

Göteborg, Sweden

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http://nanotube.msu.edu/nt05/

B.1 Pavel Nikolaev Thursday, June 30

NT05: Sixth International Conference on the

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B.1 Pavel Nikolaev Thursday, June 30

Slides not yet received

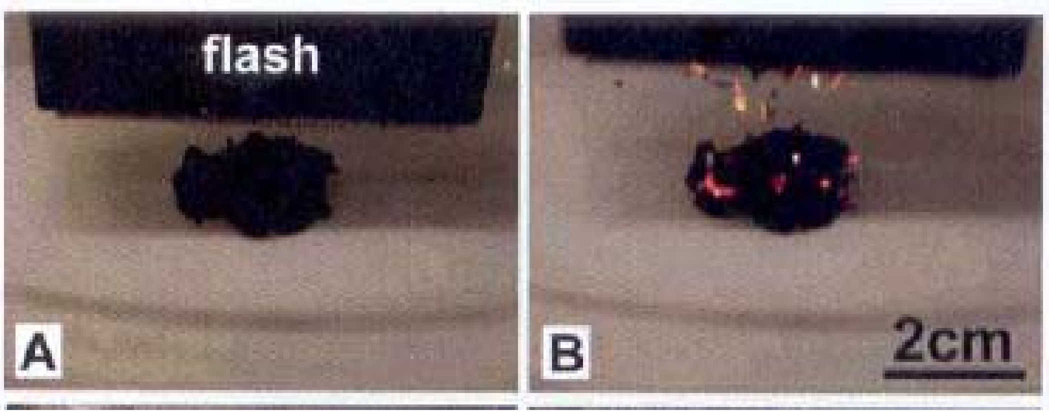
B.2 Apparao Rao Thursday, June 30

Poster Session XI

Poster Session XII

Poster Session XIII

Poster Session XI



Optical Ignition of CNT-doped Energetic Materials

-SWNTs when exposed to conventional photographic flash spontaneously ignite

Important practical benefits: **(XI. 1)**

(1) the optical signal is immune to electromagnetic interference, ambient conditions of pressure and temperature,

(2) pulse-delivery is not dependent on materials that might degrade over time.

Poster Session XII

(5 Computational, 12 Experimental)

Elastic properties of CNTs as a function of:

- length, outer / inner tube diameter (1), chirality (11), interaction with substrate (13)

- coiled NTs (14, 16)

- precursors used in the synthesis (4, 16)

- MoS_2 NTs (3), BN nanowires (10), polypryrrole NTs (12)

Poster Session XII

How mechanical properties influence electronic properties? (2)

Current induced bends, repairing structural defects (5,6)

Selective removal of individual CNTs from a high density CNT network (7)

Cantilevers – zeptogram (8), attogram (14) mass detection

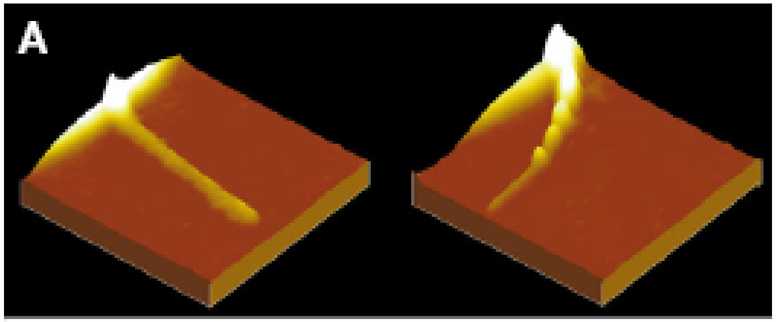
Suspended tubes

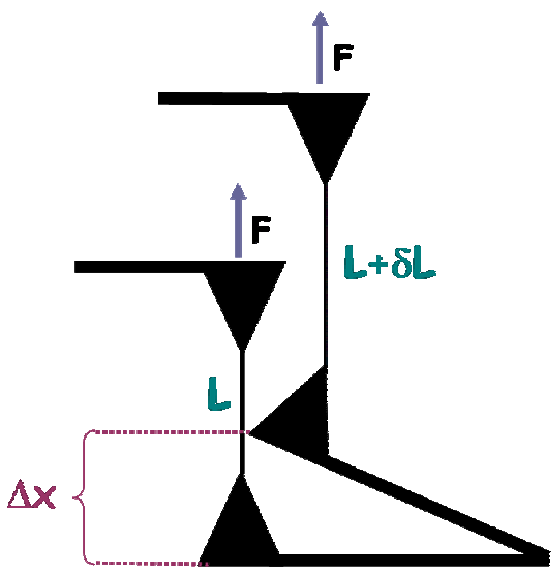
- evidence for phonon-assisted tunneling (15)
- thermal effects on optical transition energies E_{22} (17)

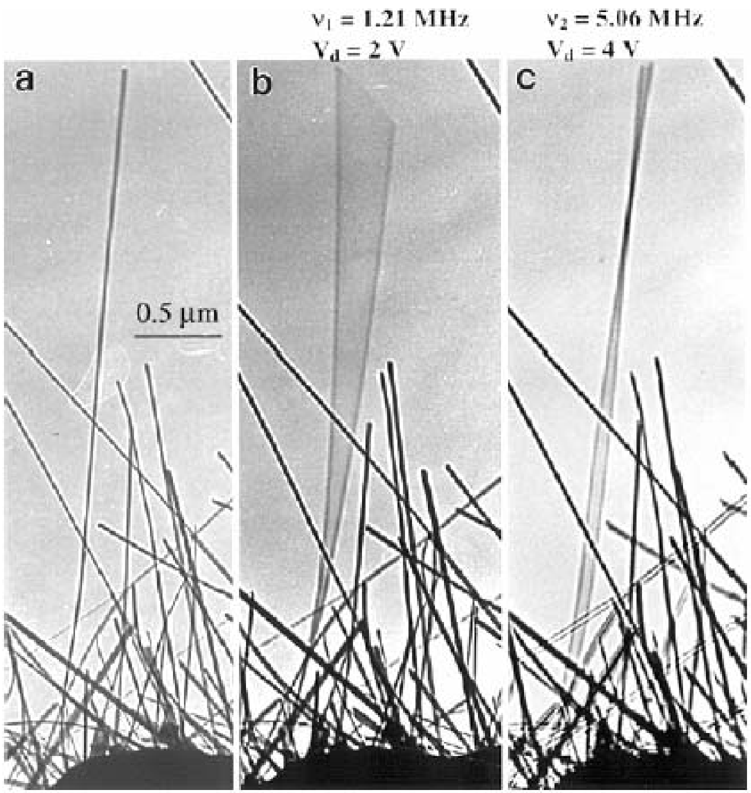
Anisotropic heat transfer by CNTs (9)

Methods for Measuring Bending Modulus

Wong et al. *Science* **277**, 1971 (1997).

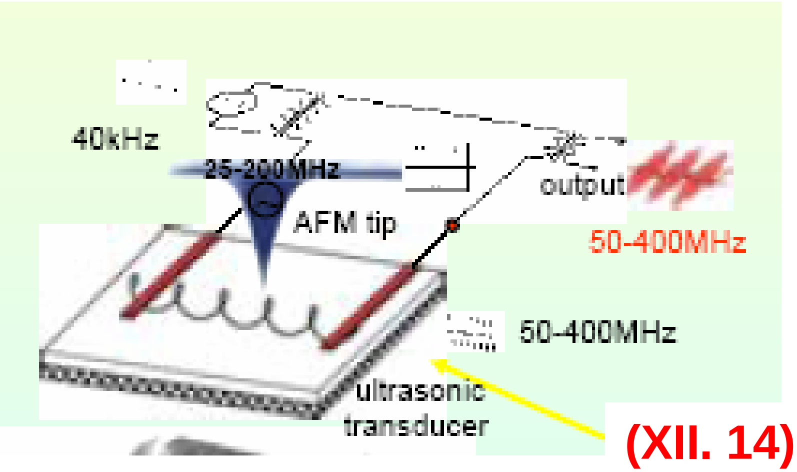




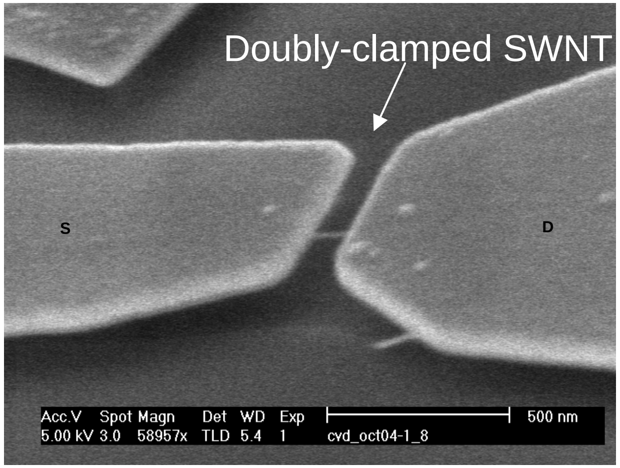


Wang et al. *Pure Appl. Chem*., Vol. 72, Nos. 1–2, pp. 209–219, 2000.

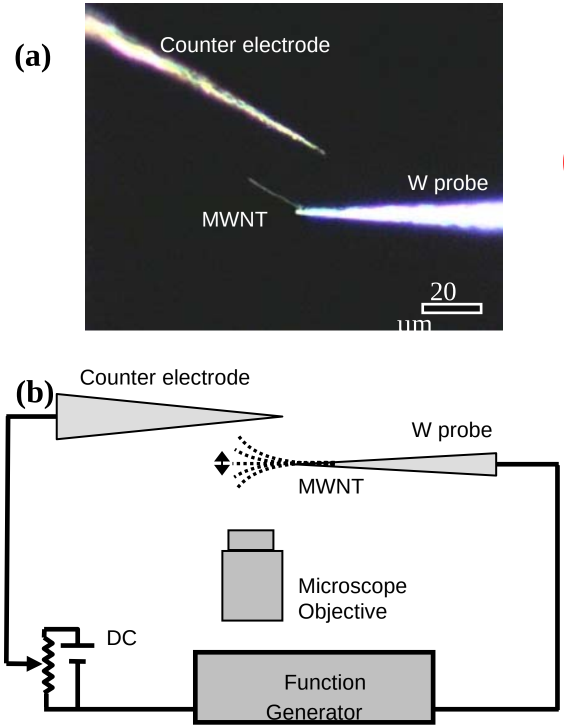
NEMS



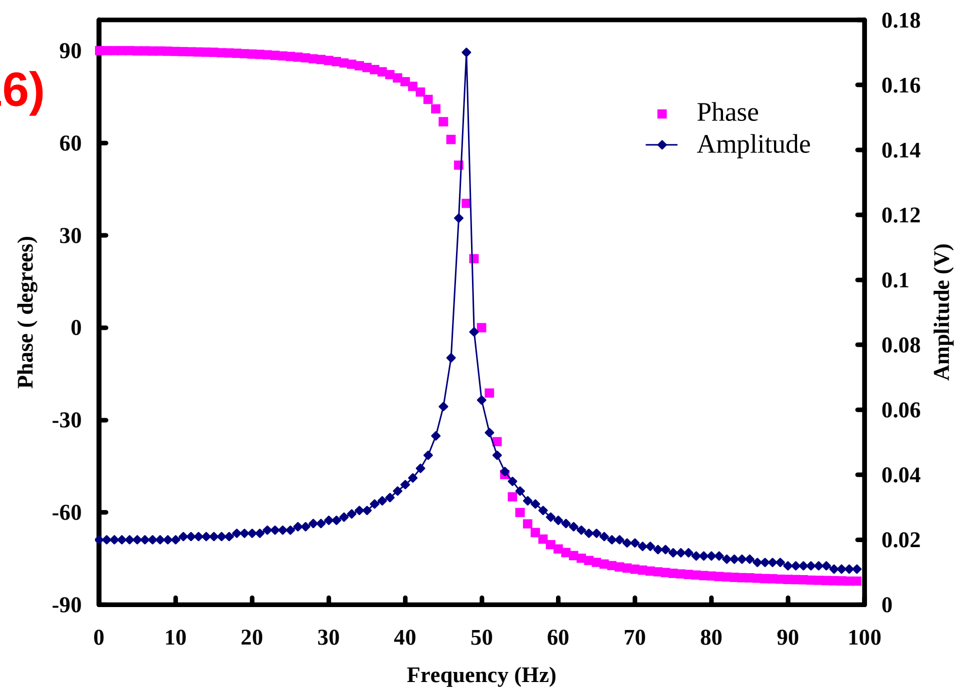
(XII. 14)



(XII. 15)

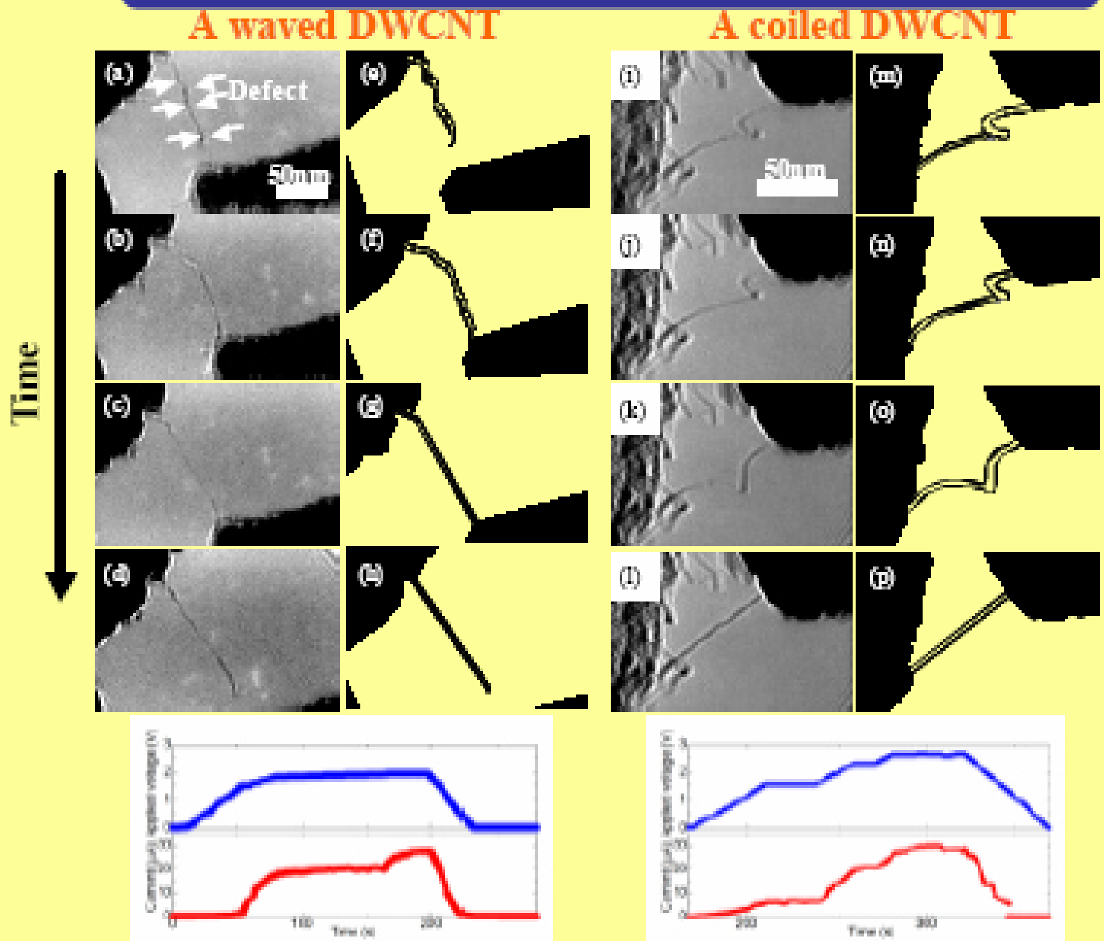


(XII. 16)

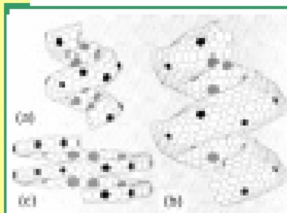


XII. 5

The generation and disappearance of the SW defects



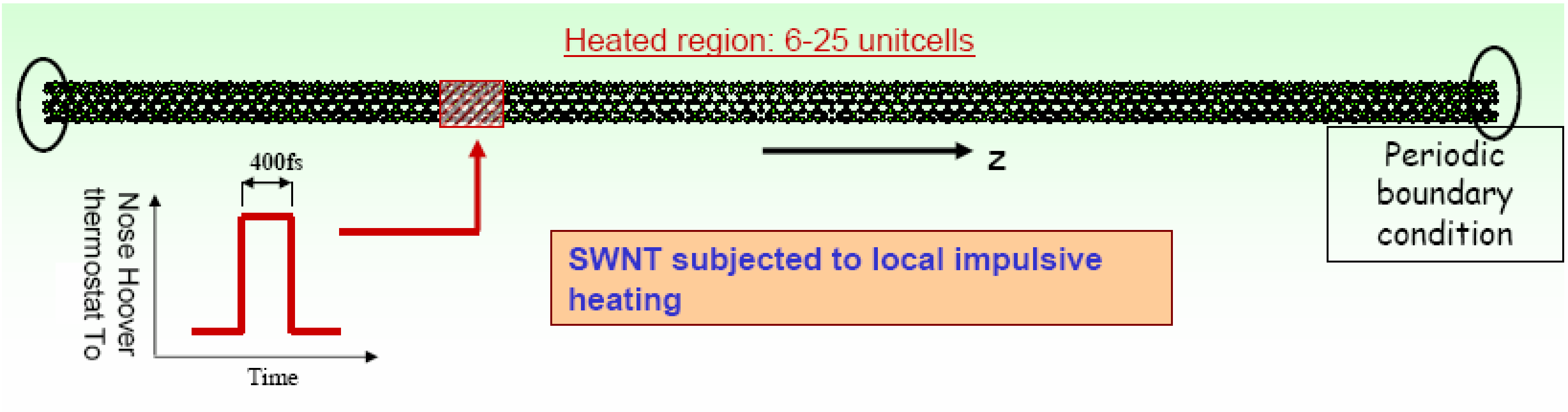
These results are proof for the restoration of defects on CNTs by heating due to flowing current.

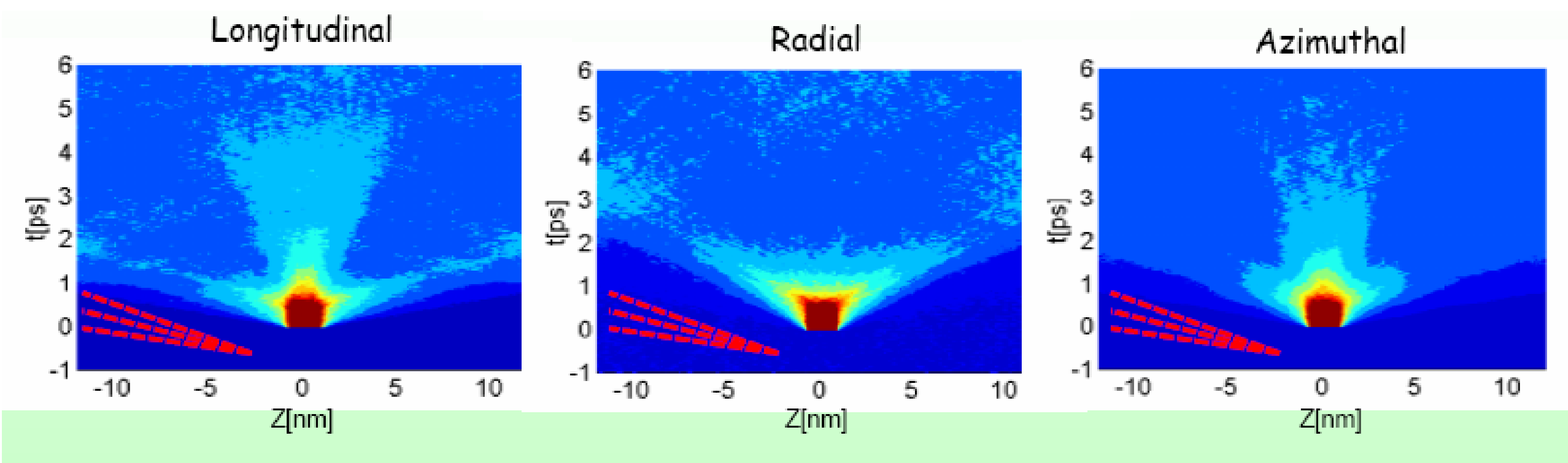


The coiled carbon nanotube has the pentagons and heptagons for the outer and inner ridge lines of a coil, respectively.

S. Ihara, S. Itoh and J. Kitakami, Phys. Rev. B 48, 5643 (1993).

XII.9


Heated region: 6-25 unitcells
400fs
Nose Hoover thermostat To
Time
z
SWNT subjected to local impulsive heating
Periodic boundary condition


Longitudinal
Radial
Azimuthal
t[ps]
Z[nm]
6
5
4
3
2
1
0
-1
-10
-5
0
5
10

Poster Session XIII

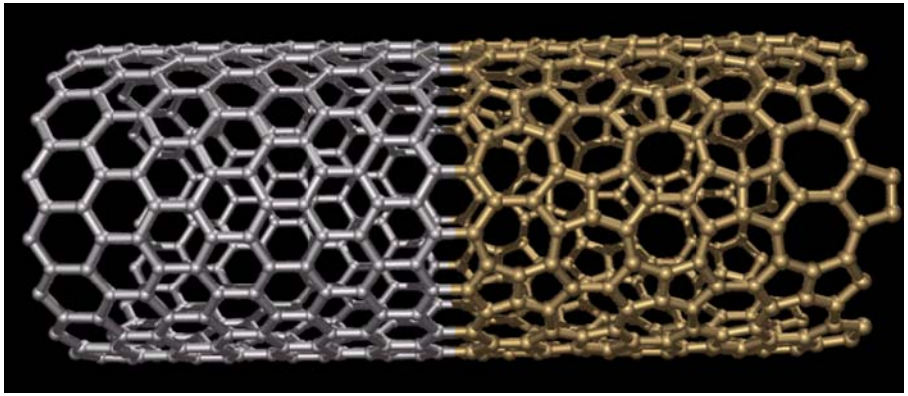
(6 Computational, 4 Experimental)

Atomic Structure of NTs

- Identical chiralities in a single DWNT inside a DWNT bundle (1)

- Effect of HTT on the interlayer spacing between adjacent graphene layers inside a MWNT (3)

- Computed powder diffraction pattern for Haekelelite CNTs (4,5)



Poster Session XIII

(6 Computational, 4 Experimental)

Atomic Structure of NTs

- Controlled point defects and its mobility (6)

- Correct description of molecular interactions in peapods (7)

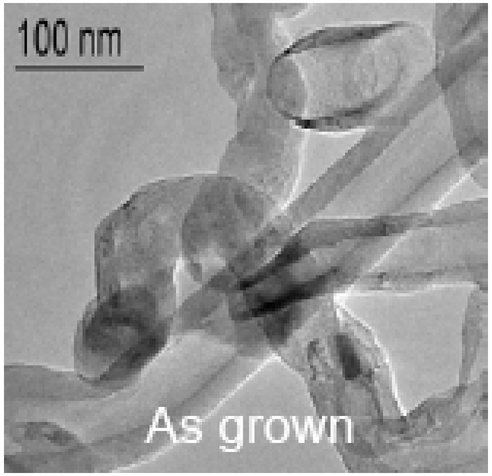
- Near Edge X-ray Absorption Fine Structure (NEXAFS) for determining the dopant concentration (9)

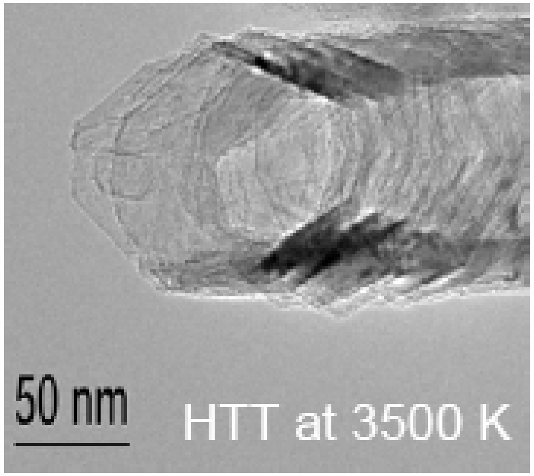
- Peierls distortion in small diameter tubes (2, 8, 10)

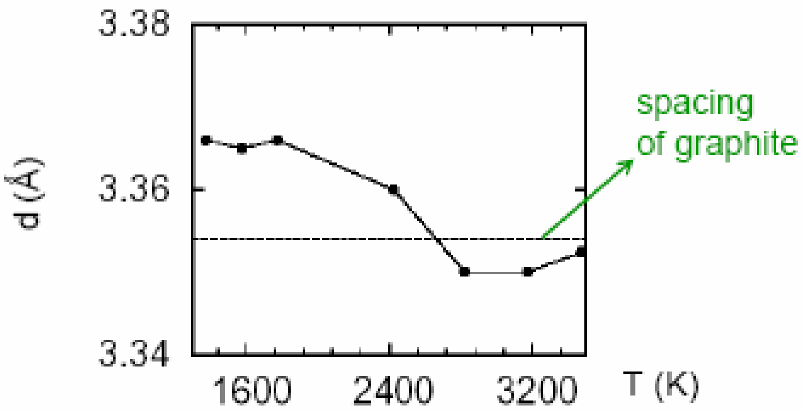
XIII.3

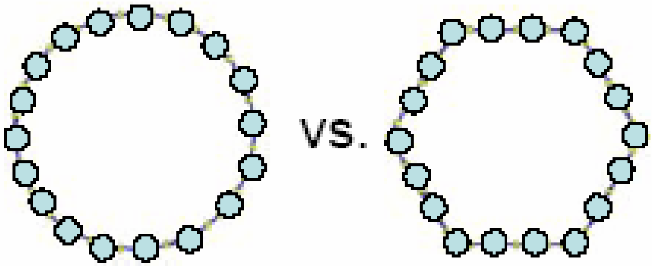
Experimental Confirmation

Transmission Electron Microscopy

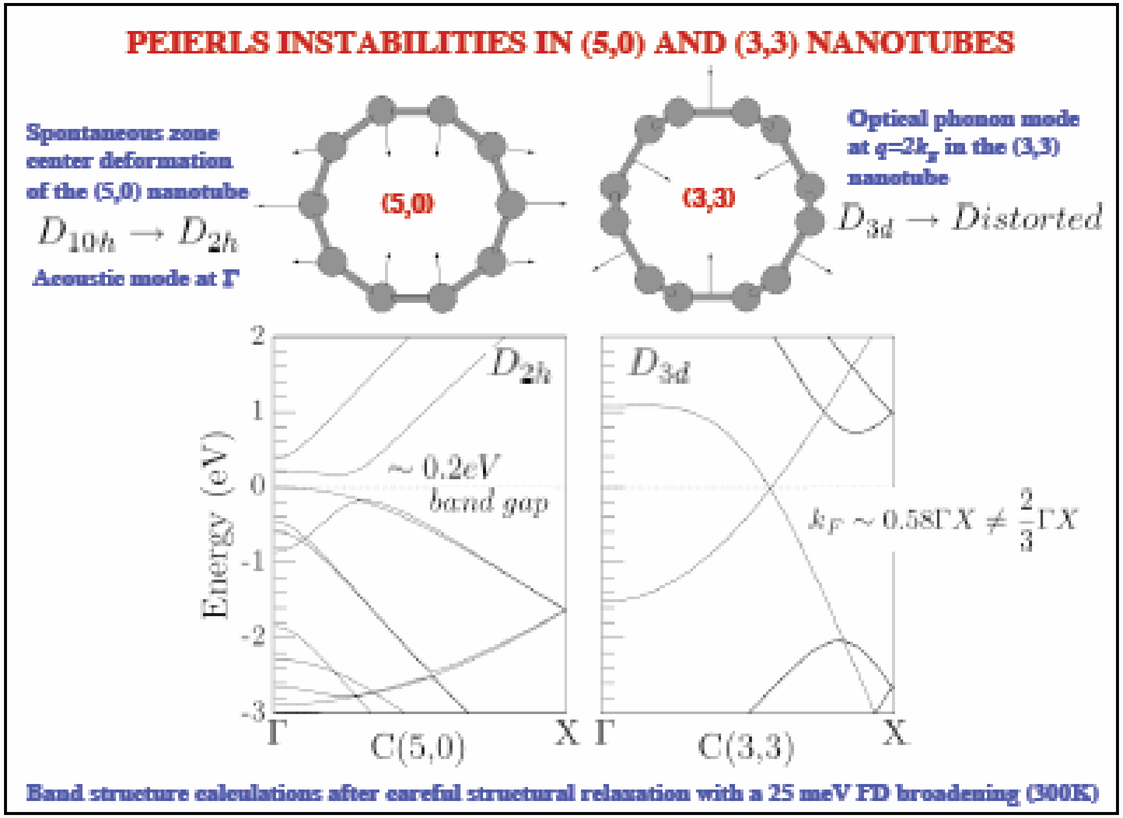






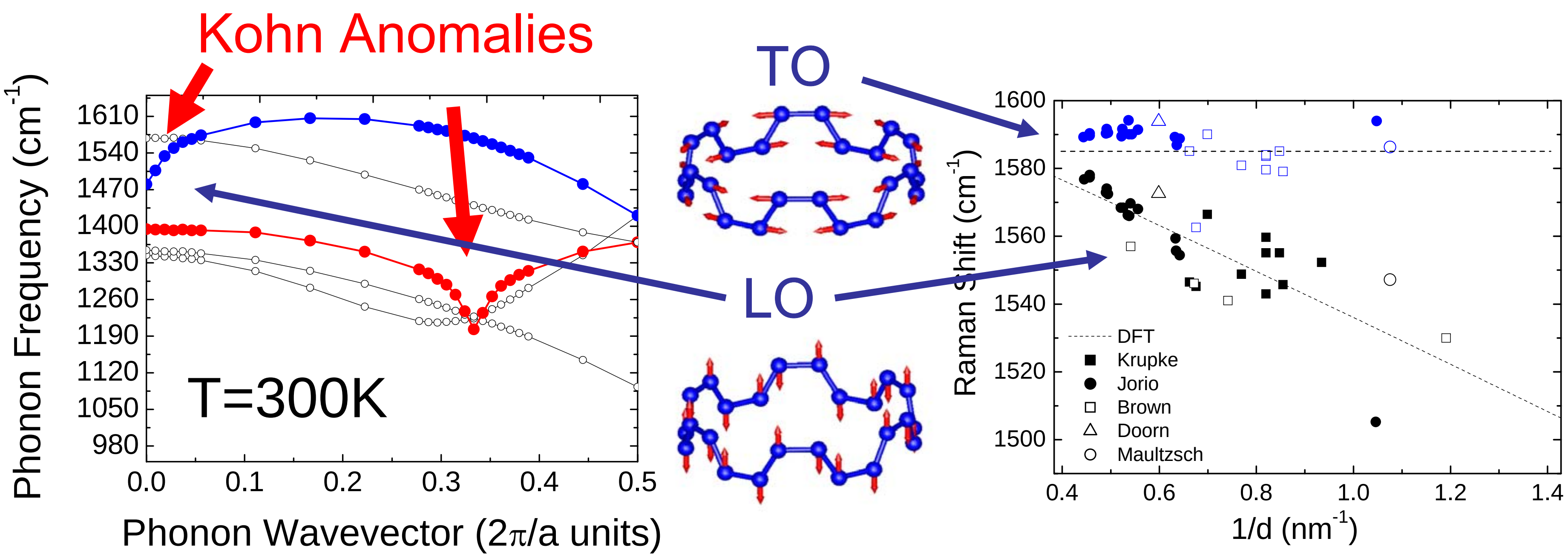


XIII. 2


PEIERLS INSTABILITIES IN (5,0) AND (3,3) NANOTUBES
Spontaneous zone center deformation of the (5,0) nanotube
$D_{10h} \rightarrow D_{2h}$
Acoustic mode at Γ
(5,0)
(3,3)
Optical phonon mode at $q=2k_F$ in the (3,3) nanotube
$D_{3d} \rightarrow Distorted$
D_{2h}
$\sim 0.2eV$ band gap
Energy (eV)
D_{3d}
$k_F \sim 0.58\Gamma X \neq \frac{2}{3}\Gamma X$
Γ C(5,0) X
Γ C(3,3) X
Band structure calculations after careful structural relaxation with a 25 meV FD broadening (300K)

XIII.10: Kohn Anomalies and Temperature Dependent Peierls Distortions in Nanotubes

S. Piscanec, M. Lazzeri, F. Mauri, A. C. Ferrari, J. Robertson



- Efficient DFT calculation of phonon dispersion of large diameter nanotubes
- Study of Kohn anomalies, Peierls distortion and LO-TO splitting in metallic tubes
- Peierls Distortion temperature exponentially depends on diameter, and is negligible for tubes normally used in experiments (<<1K)

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B.3 Tony Heinz Thursday, June 30

Overview of Poster Session XIV
Transport in Nanotubes

Tony Heinz
Columbia University

Desired Presentation

Realistic Presentation

Actual Presenter

Transport in Nanotubes: Session B3 / Poster in group XIV

- Electrical Transport: 28
- Mechanical and electro-mechanical: 5
- Thermal and thermoelectric: 2
- Material (atom transport): 1

Electrical Transport

- Ideal structures: Mechanisms, noise, as quantum dots
- Exotic regimes: Tomonaga-Luttinger liquids (TLL), superconductivity
- Perturbations: Defects, adsorbates, etc.
- Behavior of contacts
- New structures and materials

Electrical Transport: Ideal Structures

- XIV36E Transport in long suspended nanotubes; Influence of strain (straight/bent)
- XIV28T Role of hot phonons for transport in SWNTs
- XIV10E Shot noise in SW/MWNTs and spectral characteristics
- XIV18E Noise in SWNTs as random telegraph process
- XIV27T Quantum Dots of SWs under magnetic field
- XIV29E Photon assisted tunneling in SWNT QD
- XIV38T Two coupled QD defined by gates on SW

Poster XIV.28

Electron Transport and Hot Phonons in SWCNTs

M.Lazzeri, S.Piscanec, F.Mauri, A.C.Ferari, J.Robertson

Several transport masurements in metallic SWCNTs report a scattering length of l_{scatt}~15nm (at high bias).

We show that this length might be in contrast with other electron-phonon coupling measurements (IXS-phonon dispersion, phonon line-width, …)

Proposed Explanation:

During electron transport, phonons are very hot ! (T_{eff} ~ 6000 K)

Electrical Transport: Exotic Regimes

- XIV5E Superconductivity end-bonded MWNTs at 12K
- XIV25E SWNT contacted to superconductors (SMS)
- XIV6E Tomonaga-Luttinger liquid behavior in pea-pod (with C_{60}) SWNT
- XIV12E Photoemission of peapod SWNTs (with K and C60) to study TLL behavior
- XIV13T TLL behavior, diamagnetism in SWNTs
- XIV16T Conductivity in SWNT networks
- XIV30T SWNT conductivity for high B field, theory

Electrical Transport: Role of Pertubations from Defects and Adsorbates

- XIV1E Effect of annealing on MWNT transport
- XIV34E Influence of doping of metallic SWNTs
- XIV31T Conductance in zigzag/chiral metallic SWNTs with defects

- XIV21T SWNTs w/ many defects: Anderson localiz.
- XI26E Tunneling spectrosc. on disordered MWNTs

- XIV2T | Influence of adsorbates on electronic structure
- XIV17T | and charge transport characteristics

Breakdown of ballistic transport in zigzag and chiral metallic nanotubes

S. Povia[1], S. Reich[1], P. Ordejón[2], A. C. Ferrari[1] and J. Robertson[1]

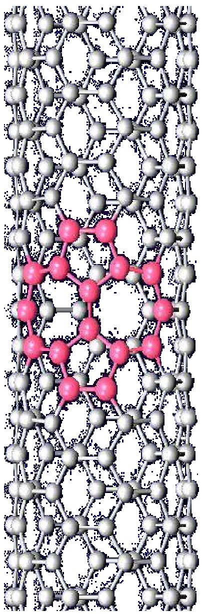
[1] University of Cambridge, UK [2] Institut de Ciència de Materials de Barcelona, Spain

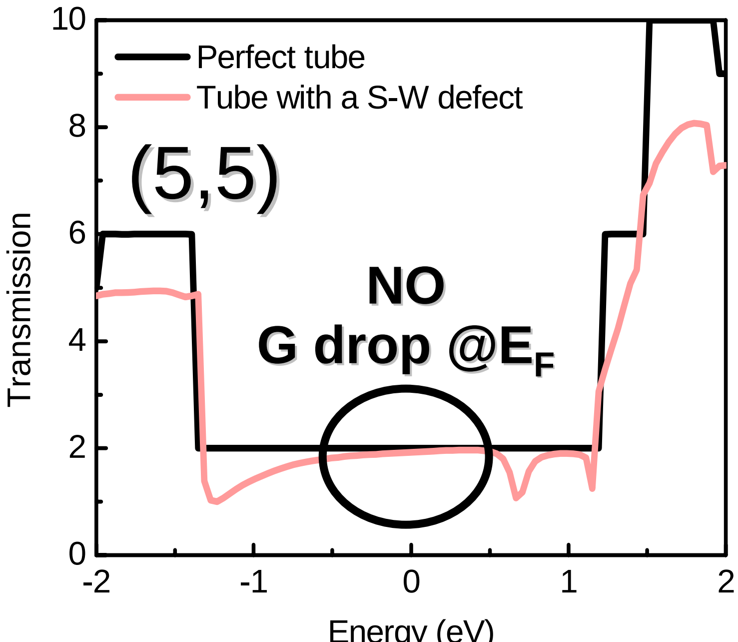
Poster XIV.31

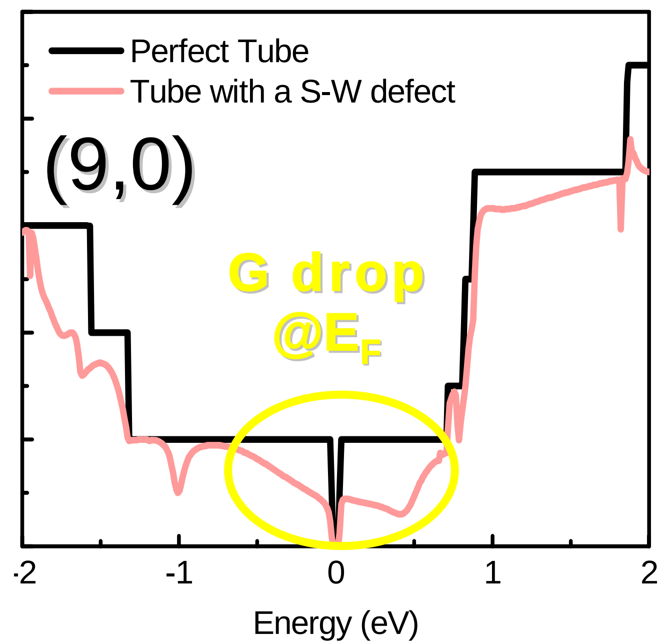
Insertion of a Stone-Wales defect: conductance @ E_F? *IV*?

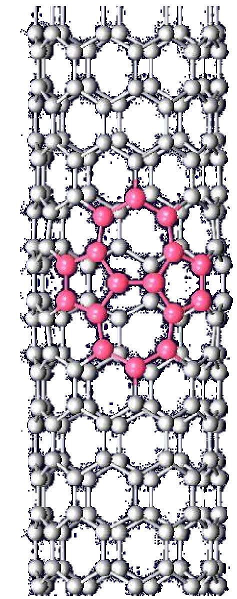
So far: armchair

This work:
zigzag and chiral conductance @ 0eV
+ calculated *IV*









H. J. Choi, et al. PRL **84**, 2917 (2000)

Electrical Transport: Contacts

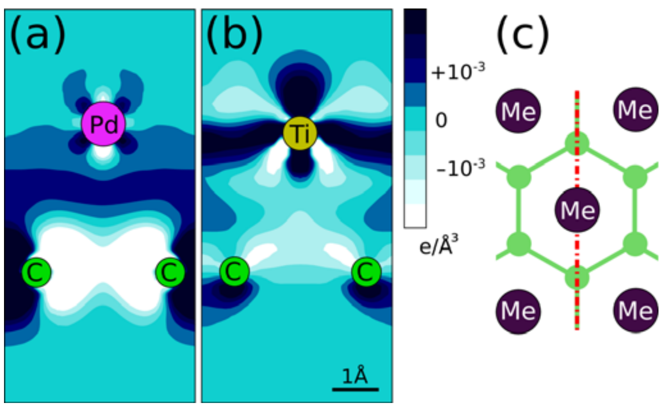
- XIV4E Contacts SWNTs by AC properties
- XIV35E Schottky barriers for high freq.;
  also high current field emission
- XIV15E SWNT length dependence; deduce contact resistance
- XIV39T Theory of metallic contacts

Contact dependence of carrier injection in carbon nanotubes: an *ab initio* study

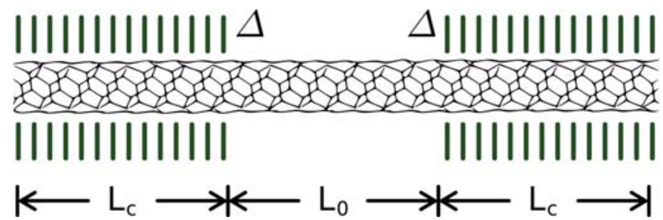
XIV.38

Norbert Nemec, David Tománek and Gianaurelio Cuniberti

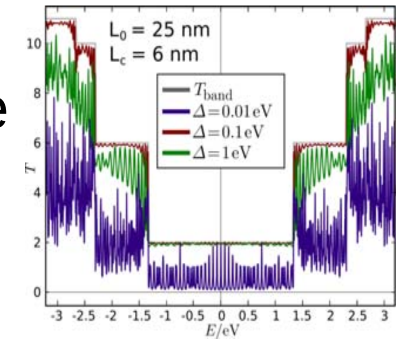
Microscopic *ab initio* study

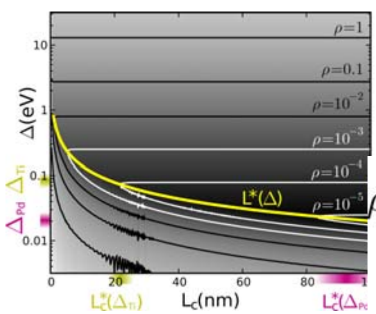


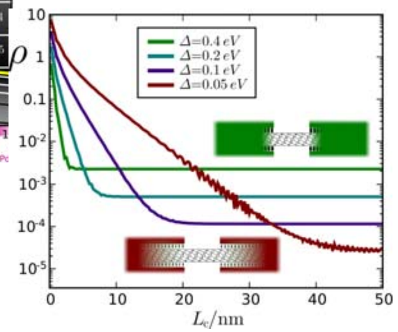
+



Large-scale model calculation







strong coupling = bad contact

weak coupling = transparent contact

Electrical Transport: New Structures and Materials

- XIV9T Transport properties of 3-terminal SWNT junctions (substitute for original poster)
- XIV19E Loop SWNT structures: charging behavior
- XIV32E Transverse electrical conductivity on MWNT
- XIV20E GaAs / CNT hybrids by MBE fabrication
- XIV14T Gold nanotubes formed from gold nanobridges: theory of structure, transport

Mechanical and Electromechanical Properties (Also many in other sessions)

- XIV7T Electromechanical instability of suspended SWNTs
- XIV17E Three terminal nanotube relay with MWNTs
- XIV24T/E Electrostatic deflection of MWNT
- XIV35E Mechanical switches with SWNTs
- XIV36T Stepper motor simulation using torroidal CNTs

Thermal and Thermoelectric Properties

- XIV3E Thermal transport in individual MWNTs/ bundles; correlation with electrical
- V19E Bolometers and electron cooling in S-I-Nanotube junctions

Mass Transport

- XIV33E Nanopipettes in MWNT: Electromigration in tubes filled with iron atoms

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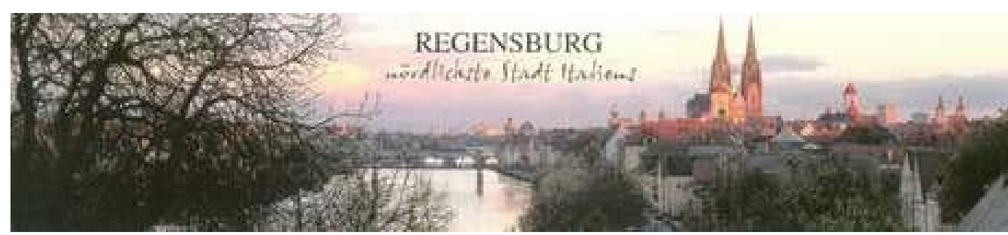
B.4 Gianaurelio Cuniberti Friday, July 1

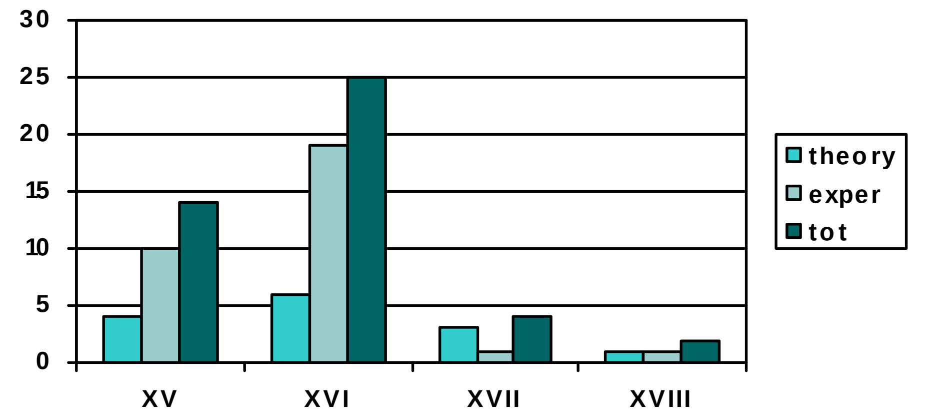
Overview on NT05 poster session B3 (categories: XV, XVI, XVII, XVIII)

G. Cuniberti
University of Regensburg (DE)




SUGGESTIONS

Categories



XV. Field Electron Emission (**14**)

XVI. Optical Properties and Optoelectronics (**24+1**)

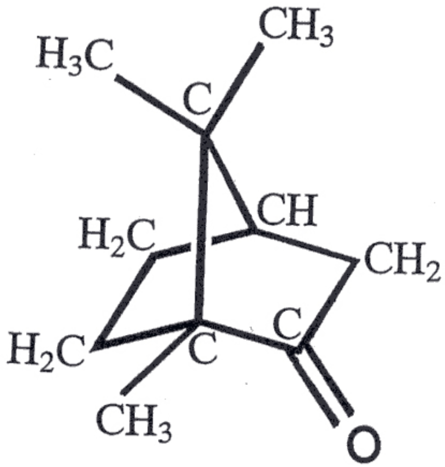
XVII. Transport in Complex Nanostructures (**4**)

XVIII. Electron-Phonon Coupling in Complex Nanostructures (**2**)

XV. Field Electron Emission (**14**) *1st floor*

- field emission of *individual* MWCNTs (.2)
- CNT FED (.3, .7, .13)
- growth of CNT (.4, .6: treeCNTs, .8)
- *in situ* characterization of coiled CNT (.11)
- theory (.5, .9, .12)

X V . 6 CNTs from tree !

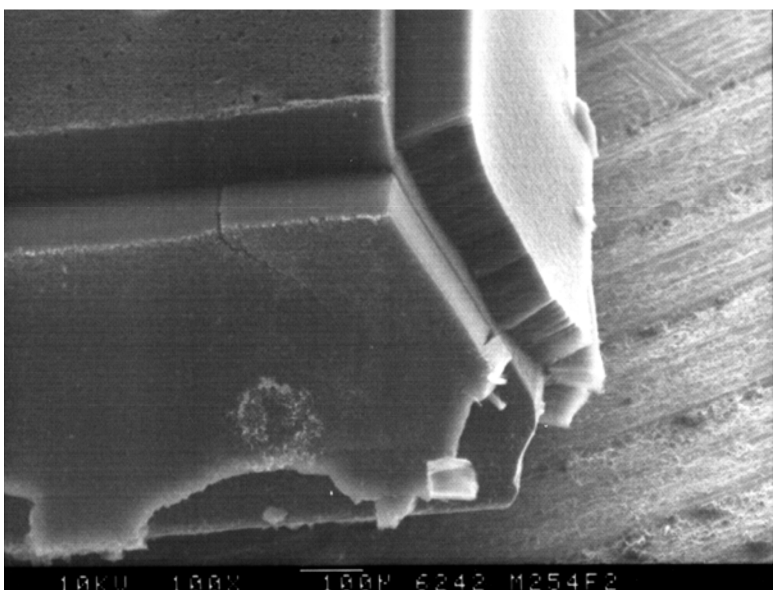


Prime Novelty:

CNTs are grown from a botanical hydrocarbon, Camphor.

Two special features:

1. Three dimensional growth of CNTs on various substrates



2. Camphor-grown CNTs are efficient field emitters

Low turn-on field:

1 V/um

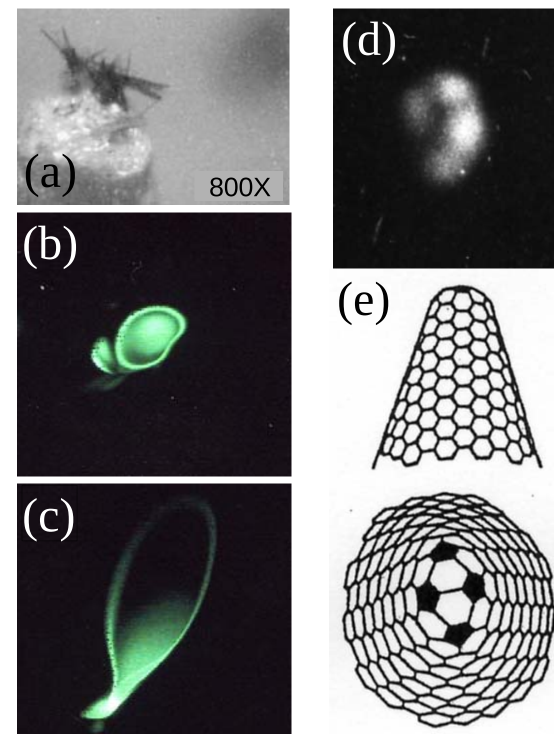
Low threshold field:

3-4 V/um

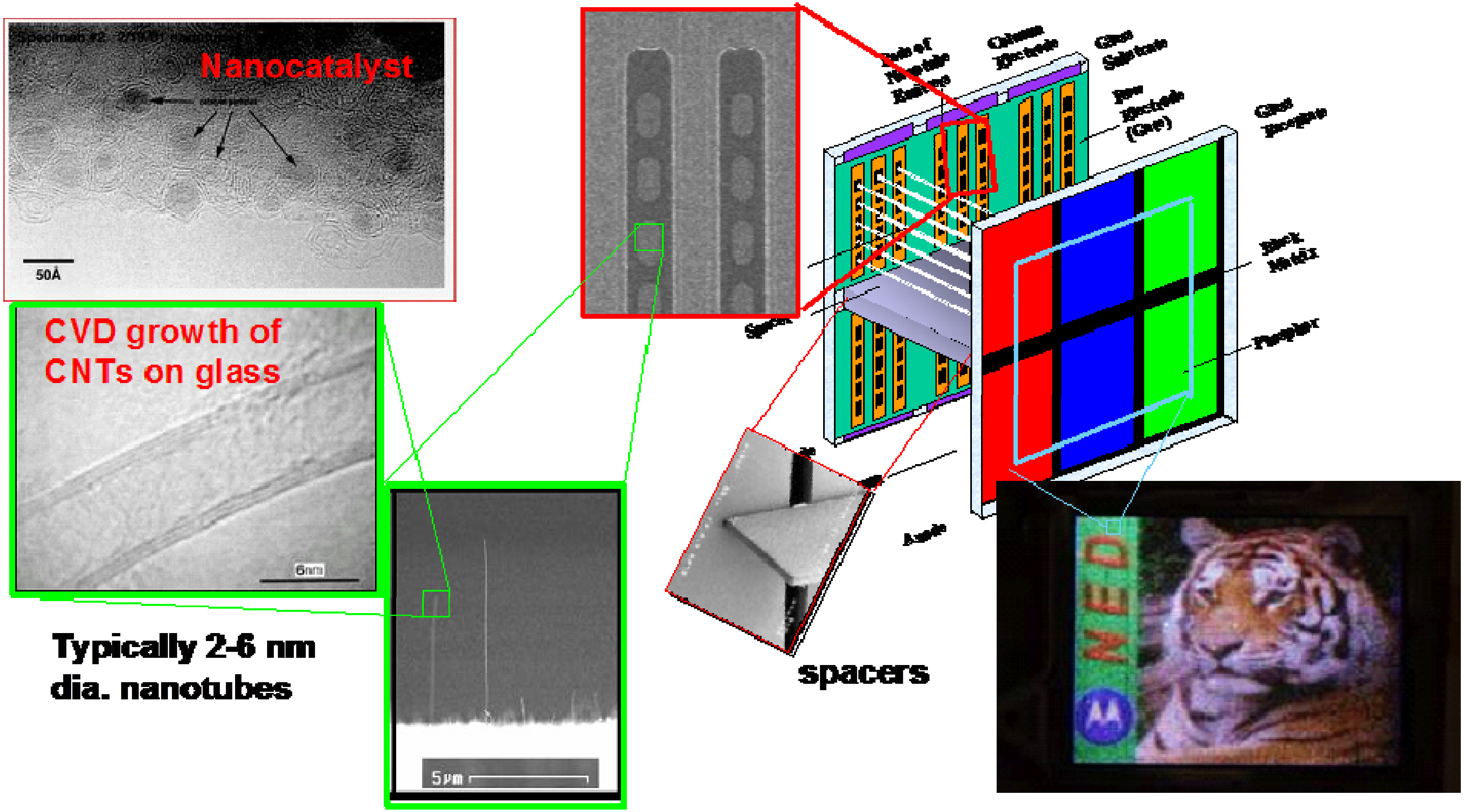
High current density:

28 mA/cm^2

Appreciable stability



Motorola's Nano Emissive Display (NED)



Selective Nanotube Growth on Glass Substrates + **Simple Field Emission Device Structure** = **Low Cost, High Quality Display**

Nano Emissive Displays for Large Area HDTV

NED Prototype Performances...

	4.6 '' NED Performances
Peak Current Density	> 5 mA/cm^2 @ V_g=90V 4V/um
Switching voltage	40V
Anode voltage	6KV
Brightness	> 1500 Cd/m^2 in Green
Lifetime	~ 10000 hours
Uniformity	> 92%

Video Image of a 4.6" diagonal NED prototype with 726 um pixel size which represent a piece of a 16:9 63" (1920x1080) diagonal HDTV.

Objectives...

Advanced HDTV with Specifications

- True HDTV (1920x1080) at Consumer Prices
- Brightness> 800 cd/m2
- Contrast Ratio 1000:1
- Enhanced Color Gamut >EBU; NTSC
- Video response time<2ms

High Performance

- CRT-like Color Quality
- High Brightness & Contrast
- High Grayscale Dynamic Range
- Fast Video Response
- Wide Viewing Angle
- Low Power Consumption
- Scalability in High-Definition Resolution
- Wide Temperature Range

Low Cost Planar Structure

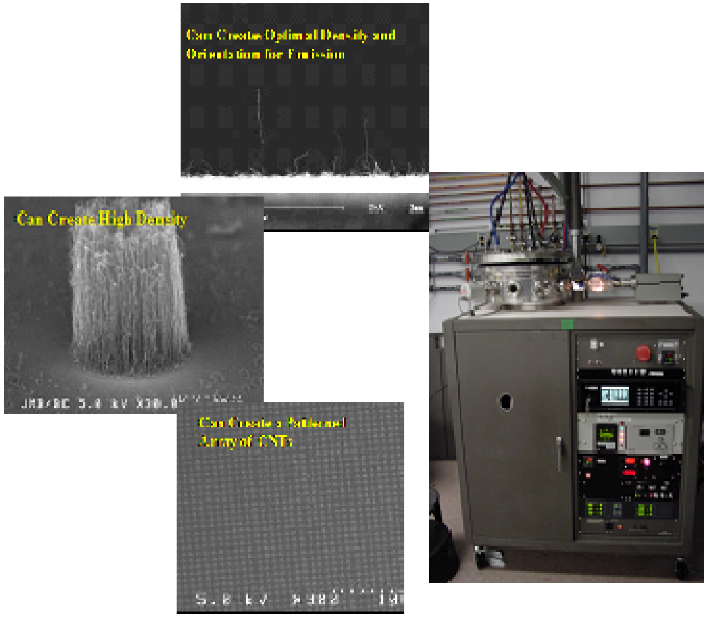
- Simple planar Structure
- Few processing Steps
- High Manufacturing Yield
- Simple Manufacturing Process
- Low Driver Electronic Cost

Nano Powered...

Proprietary Nano-catalyst and Chemical Vapor Deposition reactor developed and built in our Lab for growing CNTs allow:

- Selective growth
- Controlled morphology and structure (diameter, length, number of walls)
- Controlled density and special distribution......

at temperature compatible with glass substrate < 550C



Manufacturing of straight and aligned CNT with a scalable process compatible with volume production and large area displays

MOTOROLA

XVI. Optical Properties and Optoelectronics (**24+1**) *1st floor*

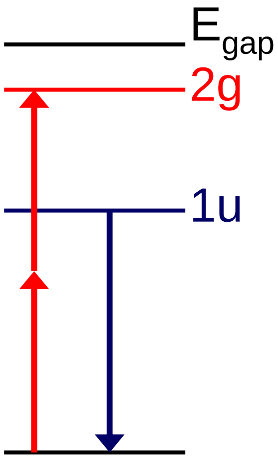
- photoluminescence studies
  - stress induced interband transistions (.5)
  - exciton binding energy (.16 ”+ 1”)
  - SWCNTs suspended in pillars (.15)
  - red shift in PL of metallocene encapsulation (.2)
  - DWCNTs (.21)
  - polarized PL with ^{13}C (.22)

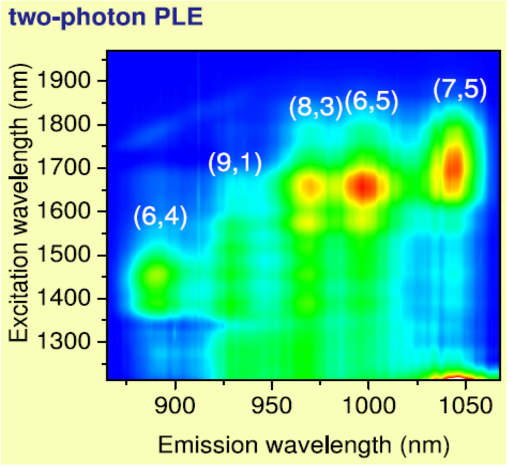
Exciton binding energy in carbon nanotubes

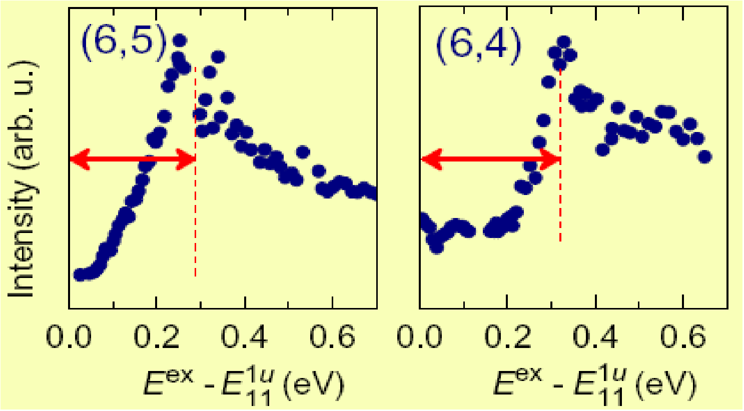
XVI.16

Janina Maultzsch *et al.*

observe exciton states with different wavefunction symmetry:
2-photon absorption (2g) & 1-photon emission (1u)







- direct proof of excitonic nature of absorption & emission in nanotubes
- binding energies 300-400 meV

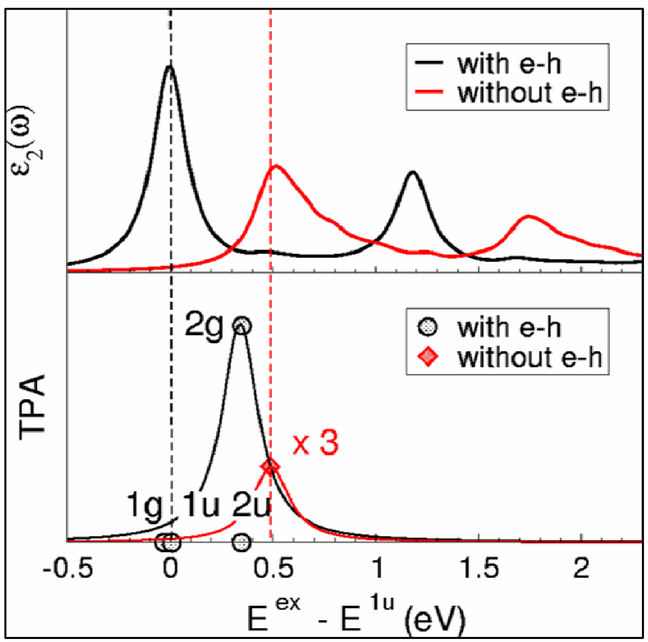
One- and two-photon absorption in carbon nanotubes: A first-principles study

"+1"

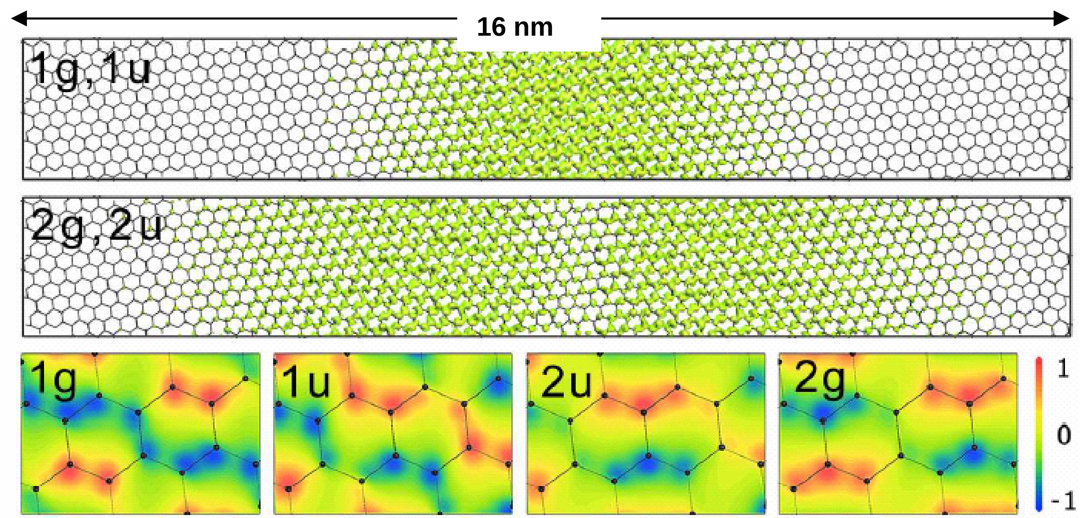
Eric Chang, Deborah Prezzi, Alice Ruini, Elisa Molinari
Dipartimento di Fisica, Università di Modena e Reggio Emilia and INFM-S3 National Research Center, Italy

- Bethe-Salpeter equation on a symmetrized Gaussian basis set
- (6,4) SWCNT: 152 atoms/cell & 0.7 nm diameter

One- and two-photon optical spectra



Exciton wavefunctions



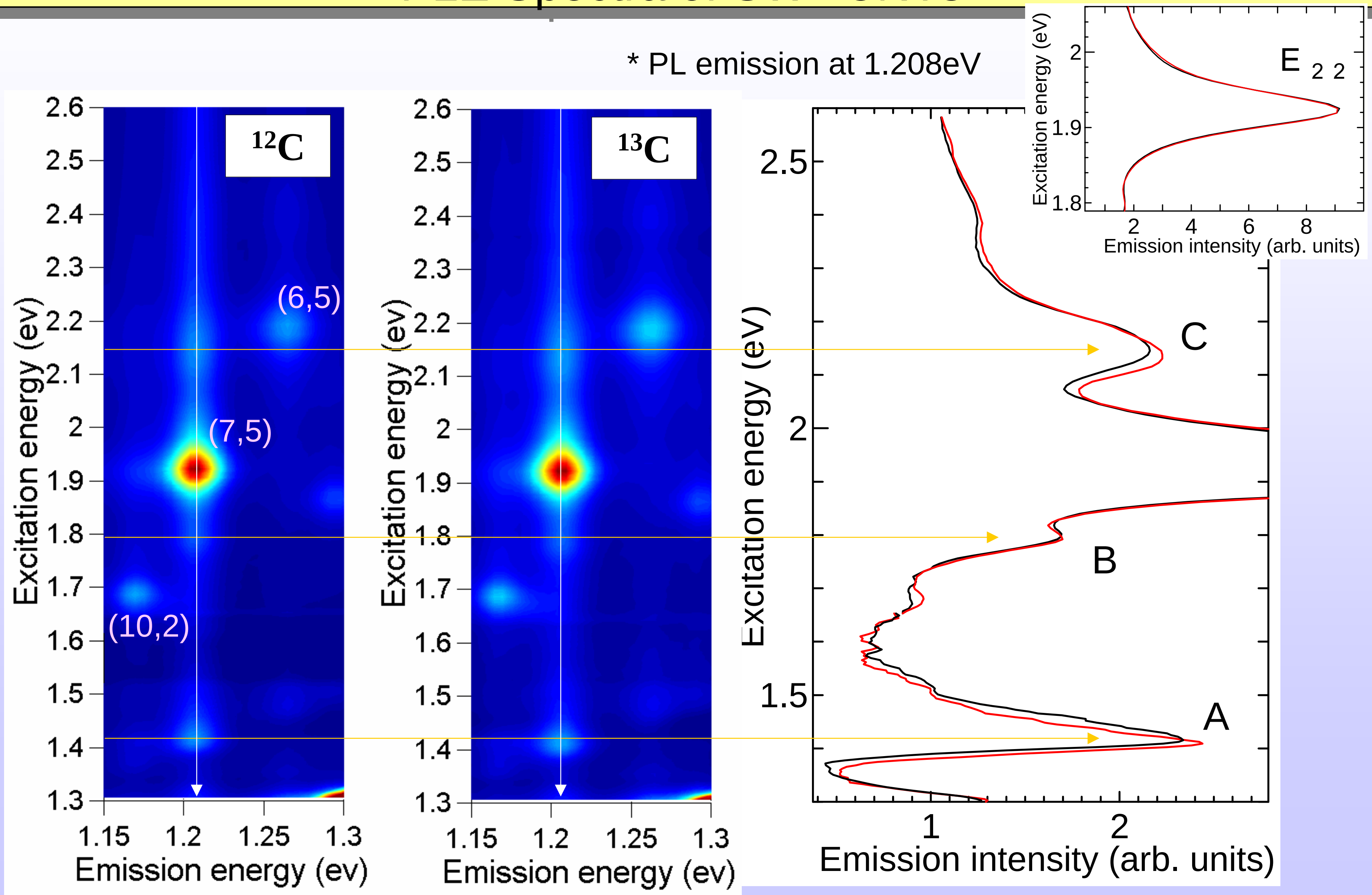
E_b (1g,1u) = 0.50 eV

E_b (2g,2u) = 0.22 eV

INFM
nanoStructures and bioSystems at Surfaces

XVI.22 Polarized-Photoluminescence Excitation Spectroscopy of Aligned Single-Walled Carbon Nanotubes by Y. Miyauchi, M. Oba, S. Chiashi, S. Maruyama

PLE Spectra of SW^{13}CNTs



XVI. Optical Properties and Optoelectronics (**24+1**), *1st floor*

- photonics
  - 3rd harmonic nonlinear optical calculations (.6)
  - CNT-based saturable absorbers (.17, .19, .23)
- photoconduction (.8)
- lifetime of photogenerated charges
  - slow (.10), fast (.14)
- optical transitions and phonons (.20)
- photoconduction (.8)

High Optical Quality Nanotube-Polymer Composites For Photonic Devices Applications

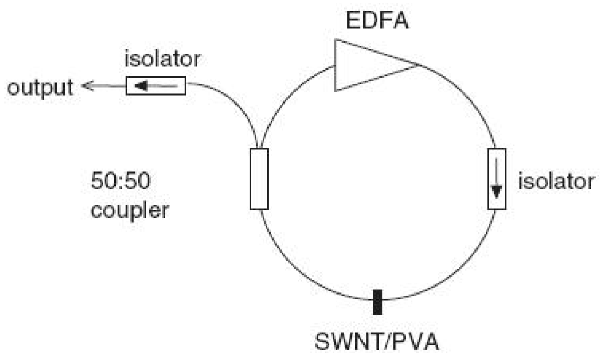
UNIVERSITY OF CAMBRIDGE

Imperial College London

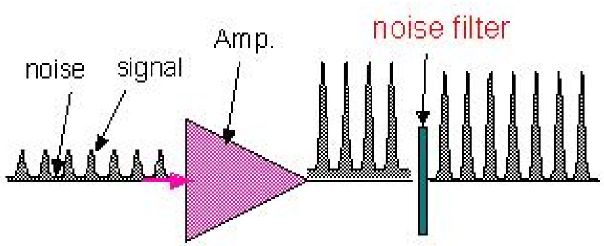
V. Scardaci, A. G. Rozhin, M. A. Reilly, M. Shaffer, A. C. Ferrari, S. Reich, I. H. White, J. Robertson, W. I. Milne

XVI
.17, .19, .23

Nanotubes: excellent materials for photonics



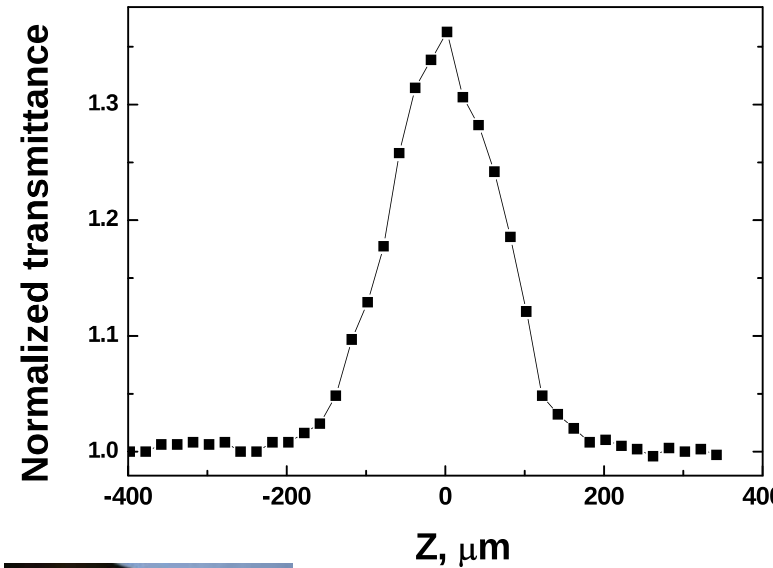
Mode Locked Lasers



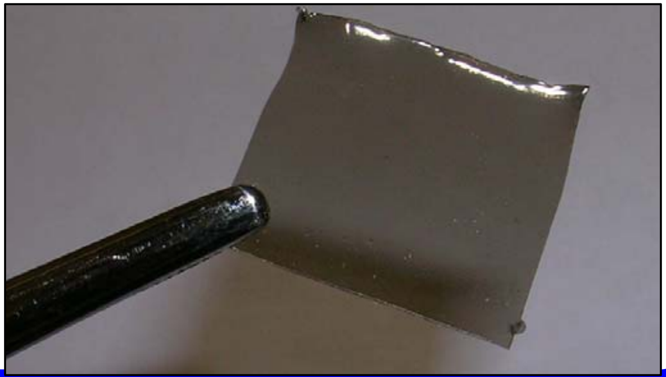
Noise Suppression Filters

A. G. Rozhin et al.

Saturable Absorbers



PVP composites with very high optical quality



Exciton Relaxation in Single Wall Carbon Nanotube by sub-20 fs Time Resolved Optical Spectroscopy

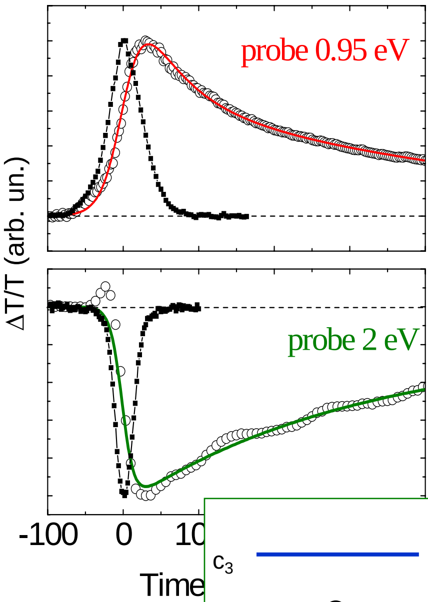
C. Manzoni, A. Gambetta, G. Lanzani, G. Cerullo

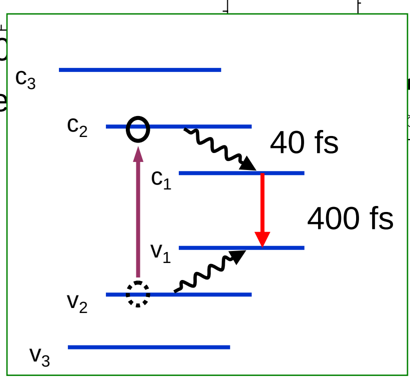
ULTRAS – INFM Dipartimento di Fisica, Politecnico, Milan (Italy)

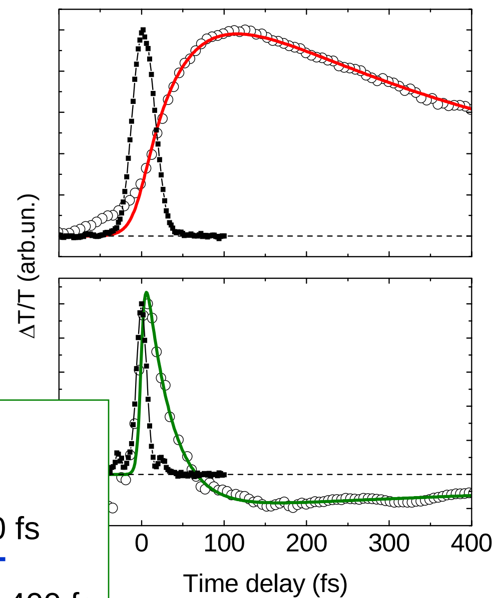
E. Menna, M. Meneghetti

Department of Chemical Sciences, University of Padova, Italy

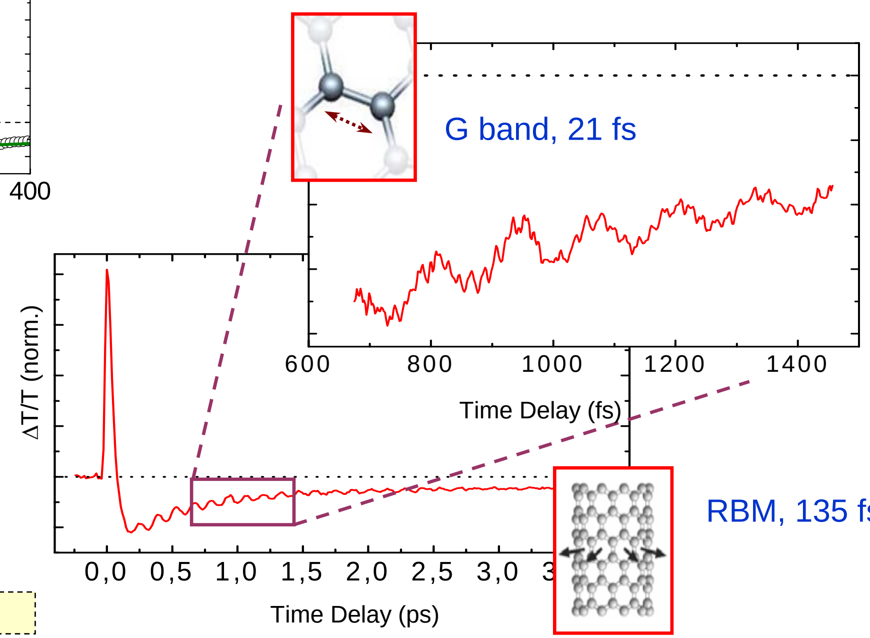
Poster XVI.14







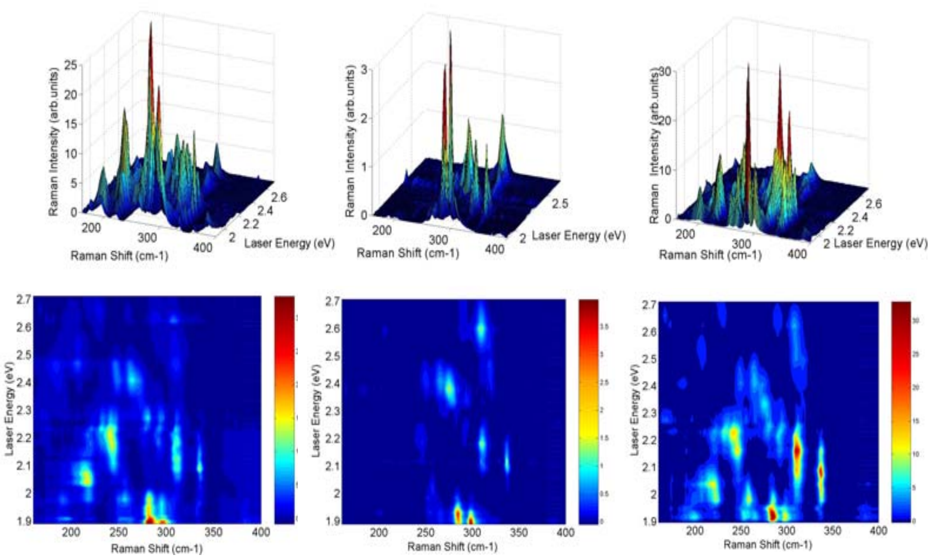
- Pump probe measurements withfemtosecond pulses
- Real time observation of dynamics and oscillations



C. Manzoni *et al.*, Phys. Rev. Lett. **94**, 207401 (2005).

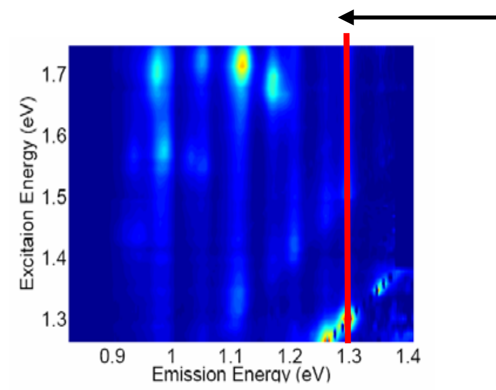
XVI-20 Optical transitions and phonon-related processes in different samples of carbon nanotubes using resonance Raman and photoluminescence excitation spectroscopies.

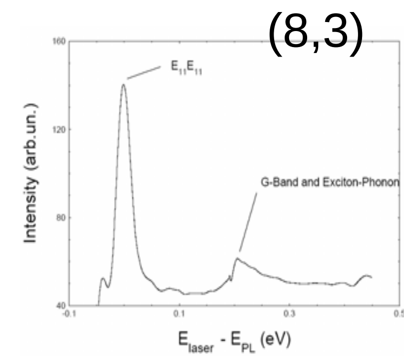
Resonant Raman spectra of CoMoCat samples

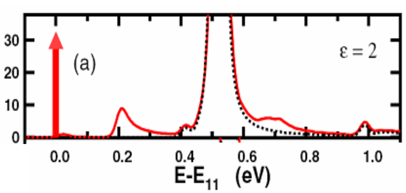


- (6,5) and (7,5) are the most abundant
- Sharp cut-off on dt < 0.7nm
- Strong peak for the metallic (7,4) NT

Photoluminscence excitation of dispersed nanotubes







Perebeinos et al, Phys. Rev. Lett. 94, 027402 (2005)

Exciton-phonon coupling in the optical absorption of carbon nanotubes

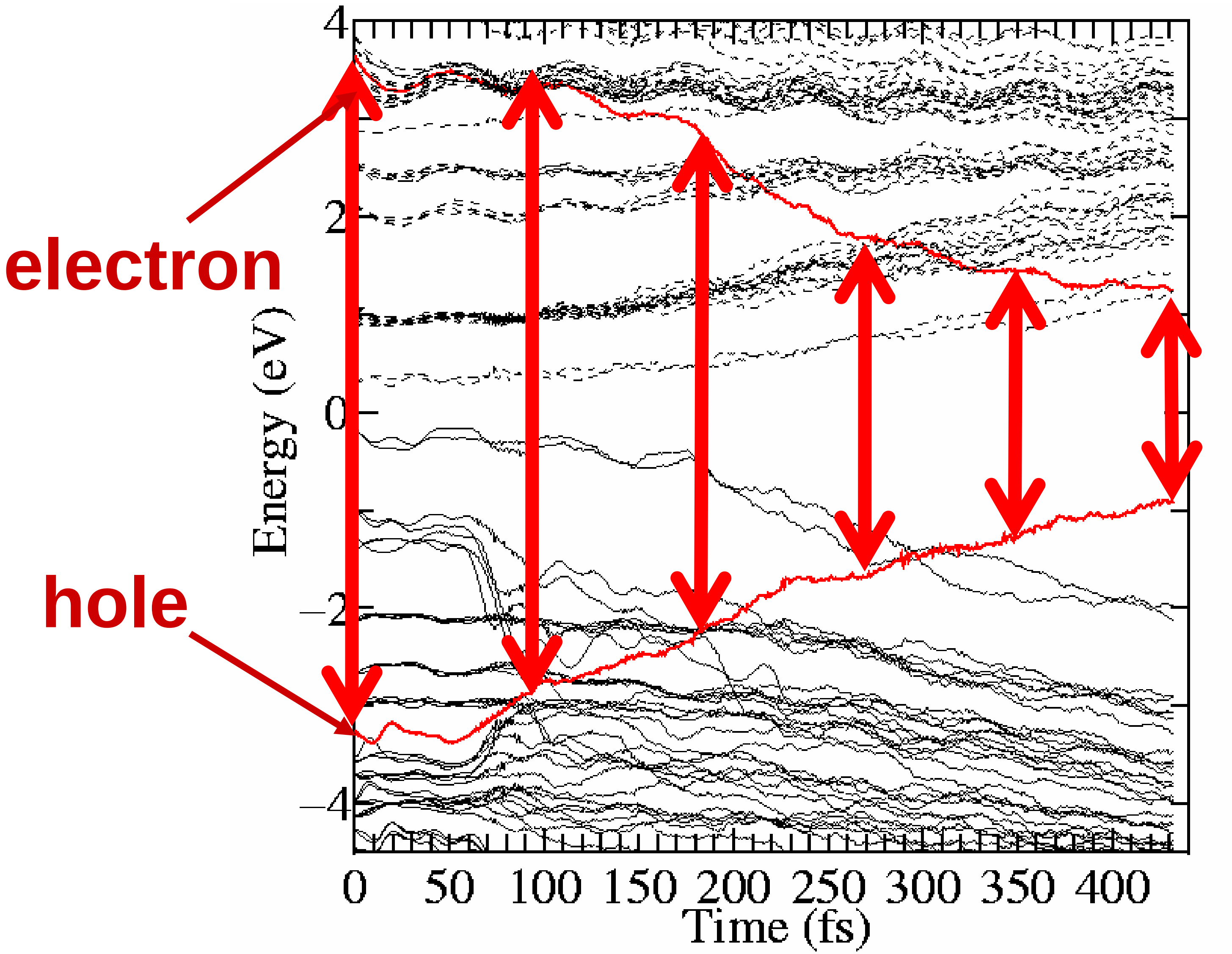
XVI. Optical Properties and Optoelectronics (**24+1**) *1st floor*

theory

- TDDFT for carrier decay (.1)
- band structure calculations (.3)
- non linear optical response (.6)
- e-ph coupling (.12)
- optical spectrum with E-field (.24)

XVI.1 TDDFT-MD simulation for ultra-fast carrier decay in nanotubes: Dependence on lattice temperature

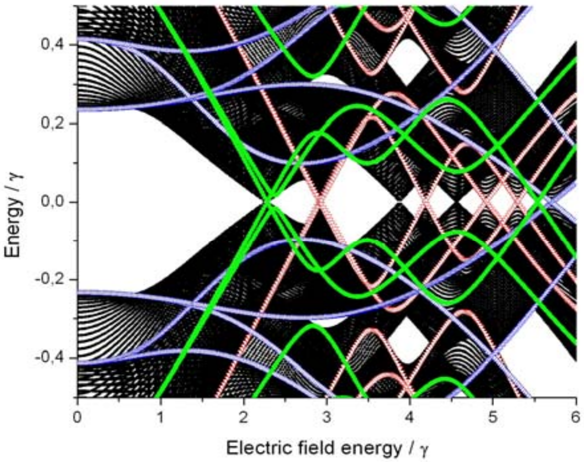
Yoshiyuki Miyamoto, Angel Rubio, and David Tománek

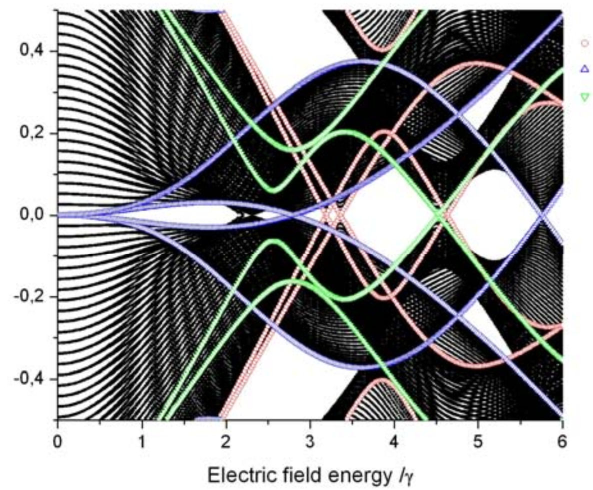


POSTER XVI 24

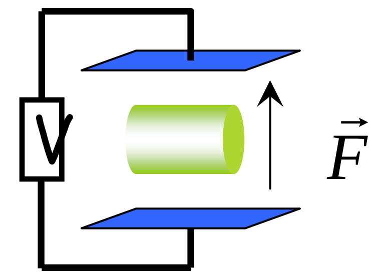
Optical properties on carbon nanotubes under external fields

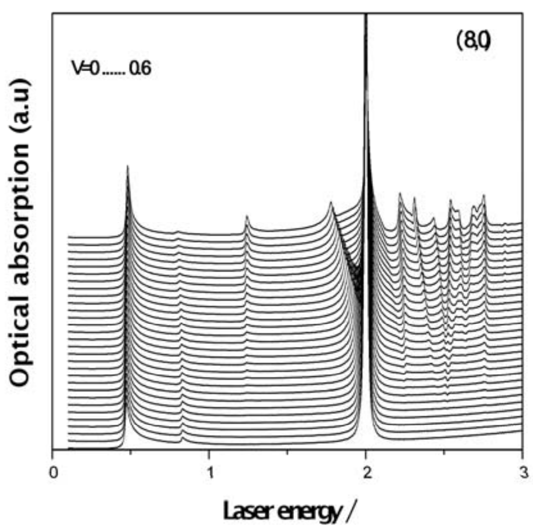
M. Pacheco*, C. G. Rocha† Latgé†, Z. Barticevic*

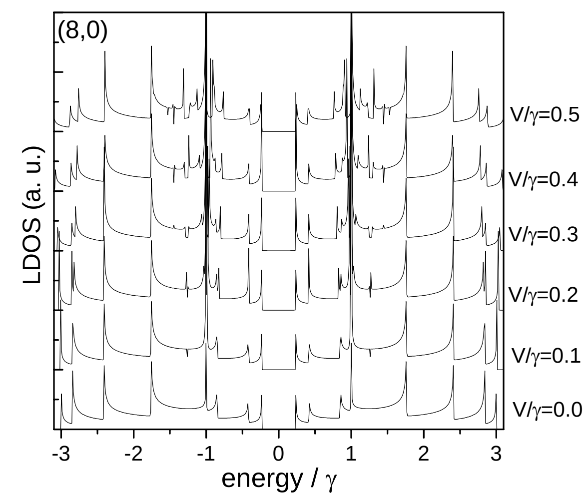




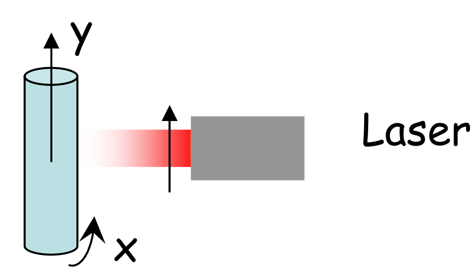
Energy spectra for ZZ CNT as a function of an Electric field







Optical absorption and DOS for different EF values



XVII. Transport in Complex Nanostructures (**4**), *2nd floor*

- molecular mechanics (.1T)
- e-transport of CNTs embedded in polymer macrotubes (.2)
- STM response of a Luttinger liquid (w/ Kondo) (.3T) [**the only on!**]
- *chemical* diffusion through flower-like bundle of manganese oxide nanofibers (.4)

XVIII. Electron-Phonon Coupling in Complex Nanostructures (**2**), *2^{nd} floor*

- Family pattern in electron-phonon matrix elements and relaxation time in carbon nanotubes (.1)
- Experimental electron phonon coupling in graphite and nanotubes (.2)

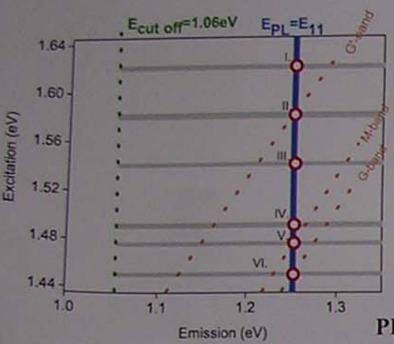
T. Shimada et al., Carbon 43 5, 1049 (2005)

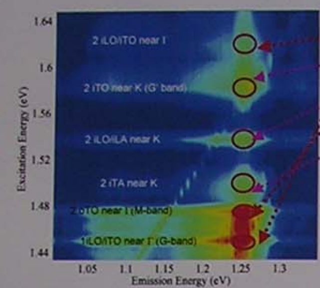
K. Sato et al., unpublished

R. Saito et al., unpublished

XVII. 12 + XVIII.1

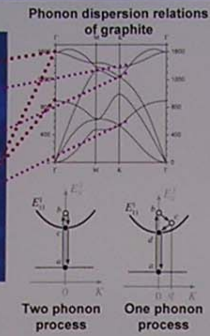
Relaxation process in semiconducting tubes

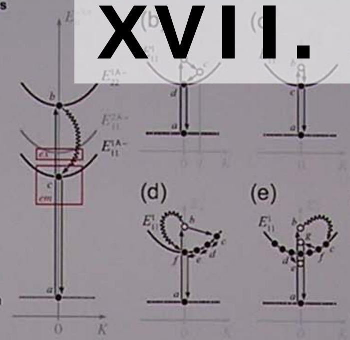




PL spectra of (6,5) tubes

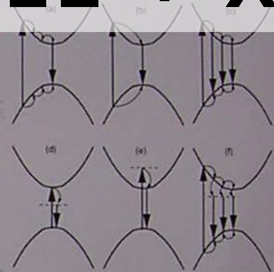
S. G. Chou, *et al PRL* **94**, 127402 (2005)

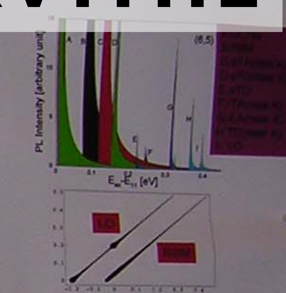




Exciton picture

S. G. Chou, *et al PRL* **94**, 127402 (2005)

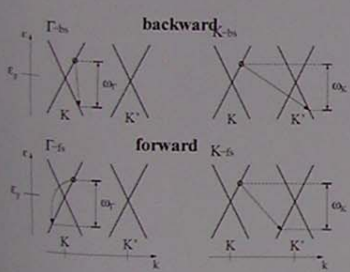




Band-band picture

J. Jiang, *et al PRB* **71**, 045417 (2005)

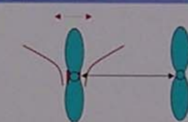
Inelastic scattering in metallic tubes: transport properties



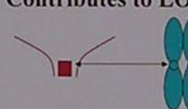
Forward and backward scattering processes

mode	Forward			Backward		
	g (eV/Å)	τ (ps)	l (nm)	g (eV/Å)	τ (ps)	l(nm)
LA	0	0		0	0	
TW	0	0		0.163	6.944	5694.08
RBM	0.567	3.300	2706.00	0	0	0
oTO	0	0		1.119	12.391	10160.62
iTO	8.088	0.434	355.88	0	0	0
LO	0	0		6.805	0.757	620.74
$E_2'(1)$	0	0		0	0	0
$E_2'(2)$	0	0		2.959	1.072	879.04
A_2'	0.177			0	0	
$E_1'(1)$	11.031	0.1926	157.93	0	0	
$E_1'(2)$	0	0		11.658	0.159	130.38
A_1'	0	0		9.828	0.281	230.42

Relaxation time by Fermi Golden rule



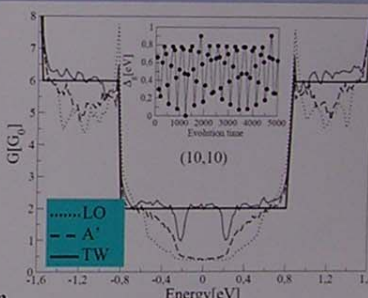
Contributes to LO and A'_1



Contributes to E'_1

Backscattering mean free path: 67 nm

Jiang *et al.*, unpublished



"Baboo dancing effect"

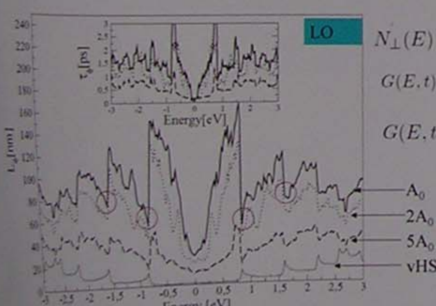
$D_E(t) = \frac{1}{t} < \{X(t) - X(0)\}^2 >_E$

$X(t)$: position operator

$G(E) = \frac{2e^2}{L} \lim_{t \to \tau_i} Tr[\delta(E - H) D_E(t)]$

S. Roche et al. unpublished.

This work is recently submitted by S. Roche, J. Jiang, F. Triozon, R. Saito



$N_\perp(E)$: number of conducting channel

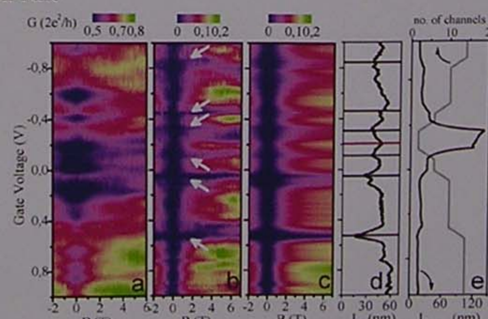
$G(E,t) = \frac{2e^2}{L} Tr[\delta(E - H) D_E(t)]$

$G(E,t) = \frac{2e^2}{h} \frac{N_\perp(E) L_\phi(E)}{L(E,t)}$

A_0 :Phonon amplitude At T=300K

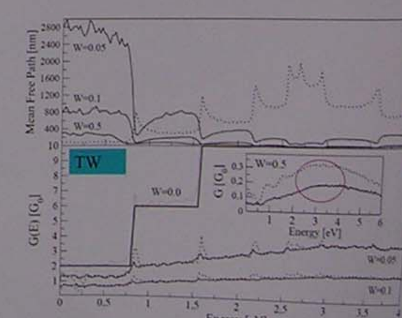
L decreases much at vHSs

S. Roche *et al.* unpublished.



L decreases much at vHSs due to e-e scattering

B. Stojetz, et al *PRL* **94**, 186802 (2005)



Delocalization by inelastic scattering

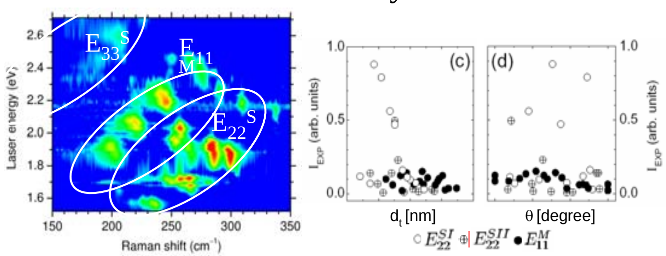
S. Roche *et al.* unpublished.

Family patterns in the electron-phonon matrix elements and relaxation time in carbon nanotubes

J. Jiang[1], R. Saito[1], Y. Oyama[1], K. Sato[1], A. Grueis[2], S. G. Chou[3], Ge. G. Samsonidze[3], A. Jorio[4], F. Triozon[5], S. Roche[5] , G. Dresselhasu[3], M. S. Dresselhaus[3]
[1]Tohoku University and CREST JST, Sendai Japan, [2]IFW, Dresden, German
[3]MIT, Cambridge, MA USA, [4]Univ. Fed. Minas Gerais, MG, Brazil, [5]CEA/DSM/DRFMC/SPSMS, France
E-mail : jiang@flex.phys.tohoku.ac.jp Web: http://flex.phys.tohoku.ac.jp

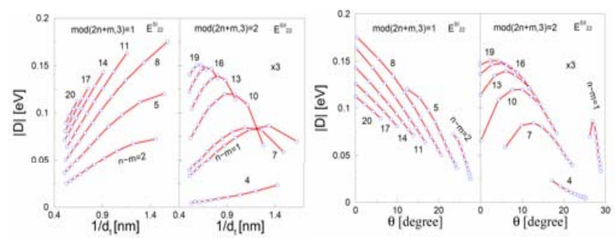
Family patterns and quantum interference in RBM Raman intensity

Measured RBM Raman intensity

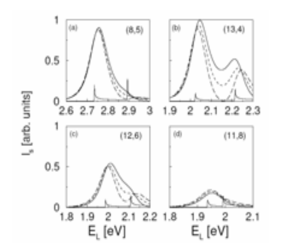


Jorio et al., **71**, 075401, 2005

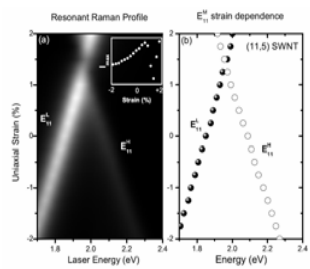
Calculated electron-phonon matrix lements.



Quantum interference predicted by theory



Quantum interference observed by experime

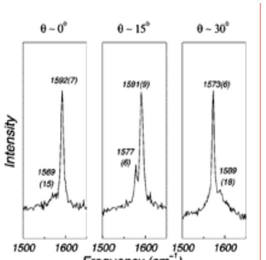


Both gives same family patterns

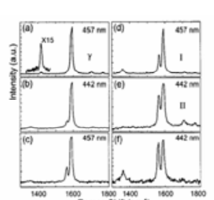
J. Jiang et al, **71**, 205420 (2005) A. G. Souza Filho et al, unpublish

Family patterns in Raman intensity of G band

Measured G-band Raman intensity

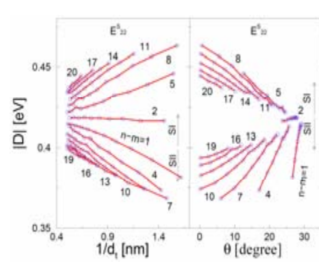


R. Saito etal, Phys. Rev. B 64, 085312 (2001)

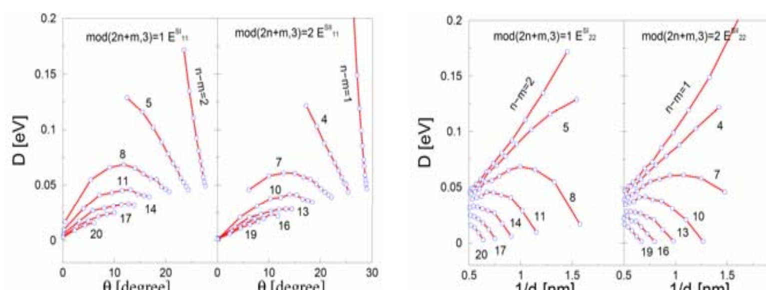


Z. Yu et al., J. Phys. Chem. B 105, 1123 (2001))

Calculated electron-phonon matrix elments for LO mode



Calculated electron-phonon matrix lements for TO mode



Family patterns in the matrix elements explain well the measurements

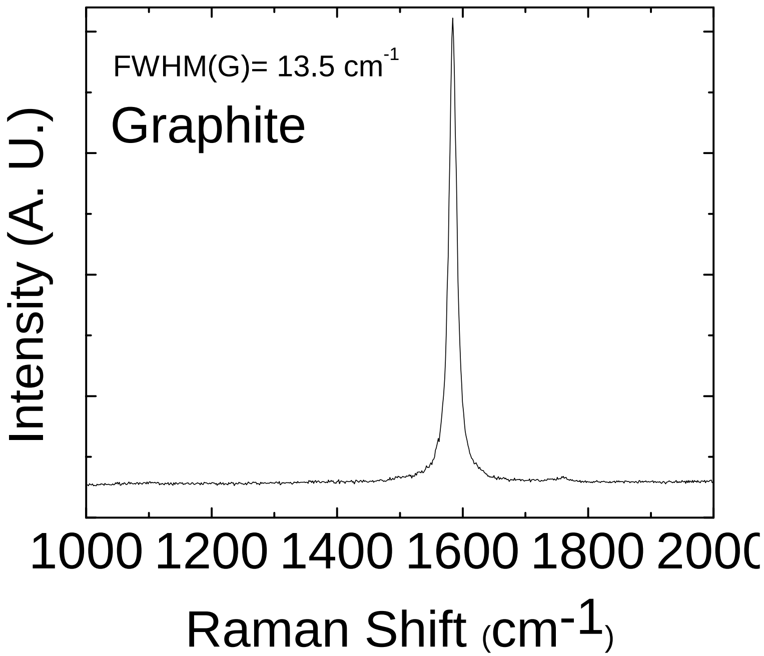
Experimental

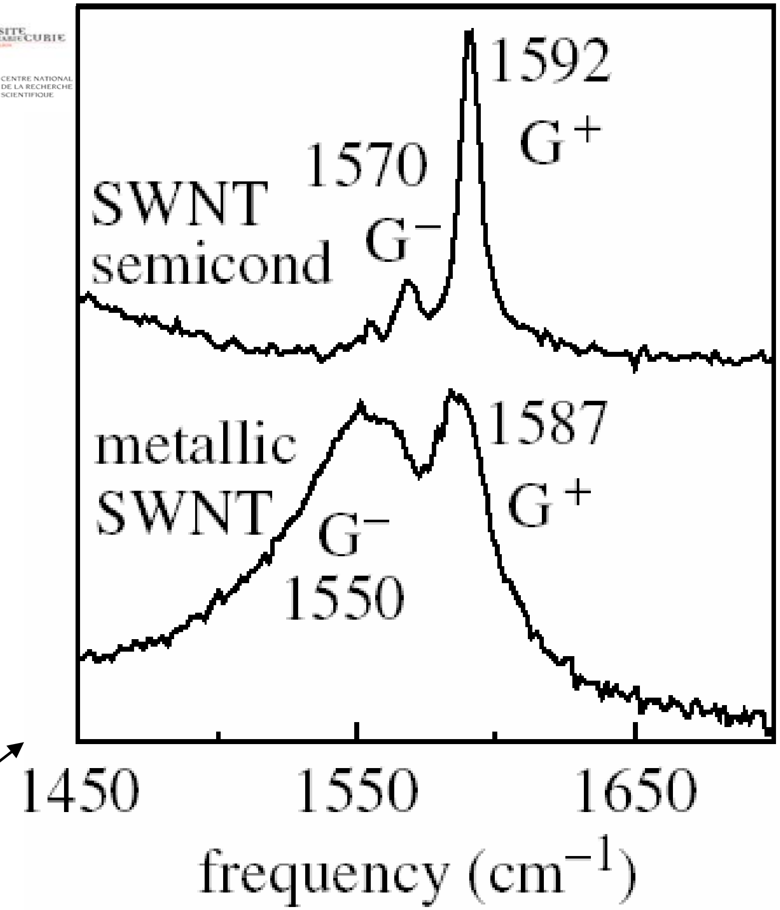
Electron-Phonon-Coupling in Graphite and Nanotubes

A. C. Ferrari, M. Lazzeri, S. Piscanec, F. Mauri, J. Robertson

UNIVERSITY OF CAMBRIDGE

$$FWHM(G) \propto EPC^2(\Gamma)$$





$$FWHM(G^-) \propto \frac{EPC^2(\Gamma)}{d}$$

- Kohn anomaly → down shift
- EPC → broader peak

NO PLASMON FANO RESONANCE

wish list (… for transport)

- transport with non equilibrium e+ph
- FM contacts: spin injection
- phase coherence length and e-mean free path in (2+)WCNTs
- limits for Luttinger / non-Luttinger
- superconducting contacts
- ...

NT05

B.5 Yoshiyuki Miyamoto Friday, July 1

Poster session B.5

47 presentations

(Third floor)

Poster chair

Yoshiyuki Miyamoto, NEC

Poster XIX.1-10

Challenge to nanotube electronic devices

Poster XX.1-7

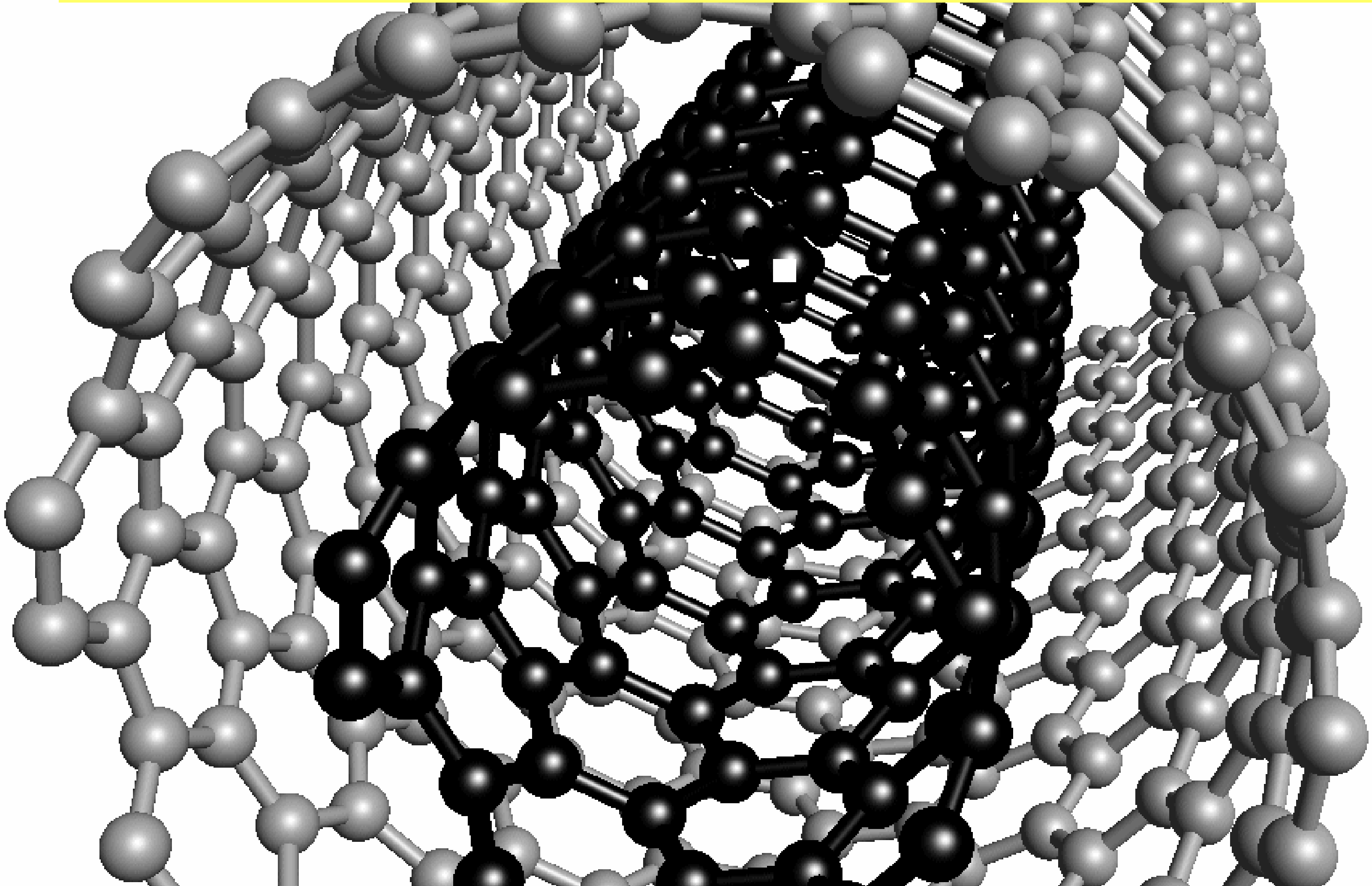
Magnetic property of nanotubes

Poster XXI.2-31

Others (the most challenging part for chairing)

Every Poster seems to be quite new for me.
Many new approaches are going
otherwise
the poster chair doesn’t know anything about nanotubes.

Poster XIX.1-10
Challenge to nanotube electronic devices (Transistors)



XIX.1 *Field emitting transistor*

XIX.2, XIX.6 ***e-irradiated Metal-semiconductor transition in FET***
Chirality change? Maybe not?

XIX.3,XIX.10 ***Stable n-type FET*** ***(XIX.3 Alkali atoms are inside, XIX.10 PMMA passivaton)***

XIX.4, XIX.5 ***FET as biochemical sensors***

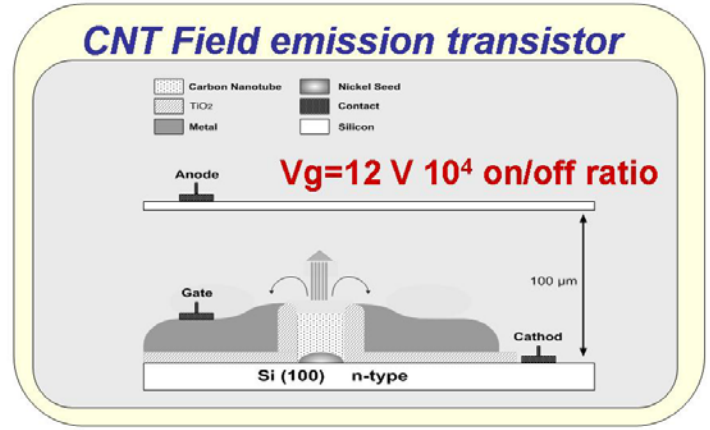
XIX.7 ***CNT-gated CNT-FET! (World smallest CNT transistor!)***

XIX.8 ***Standing CNTs on magnetic semiconductor substrate (spintronics)***

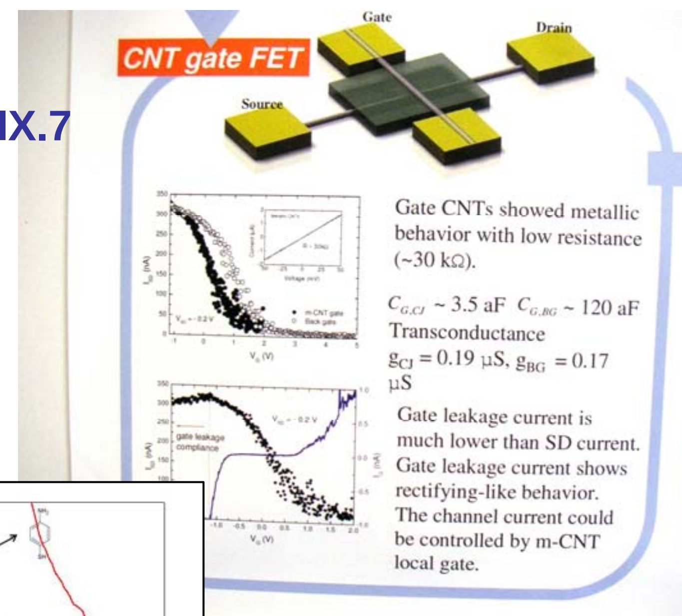
XIX.9 ***Barrier control with use of chromophore functionalization***

XXI.28 **Contact Resistance of CNT Coated Surfaces**

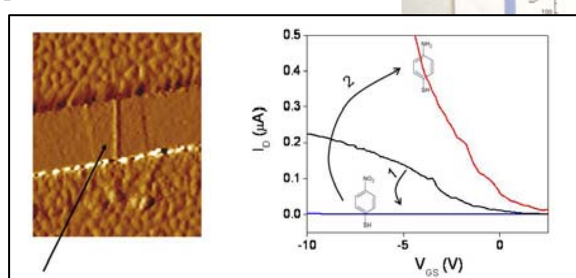
XIX.1



XIX.7



XIX.9



Modify work-function of metal electrode to get rid off the Schottkey barrier

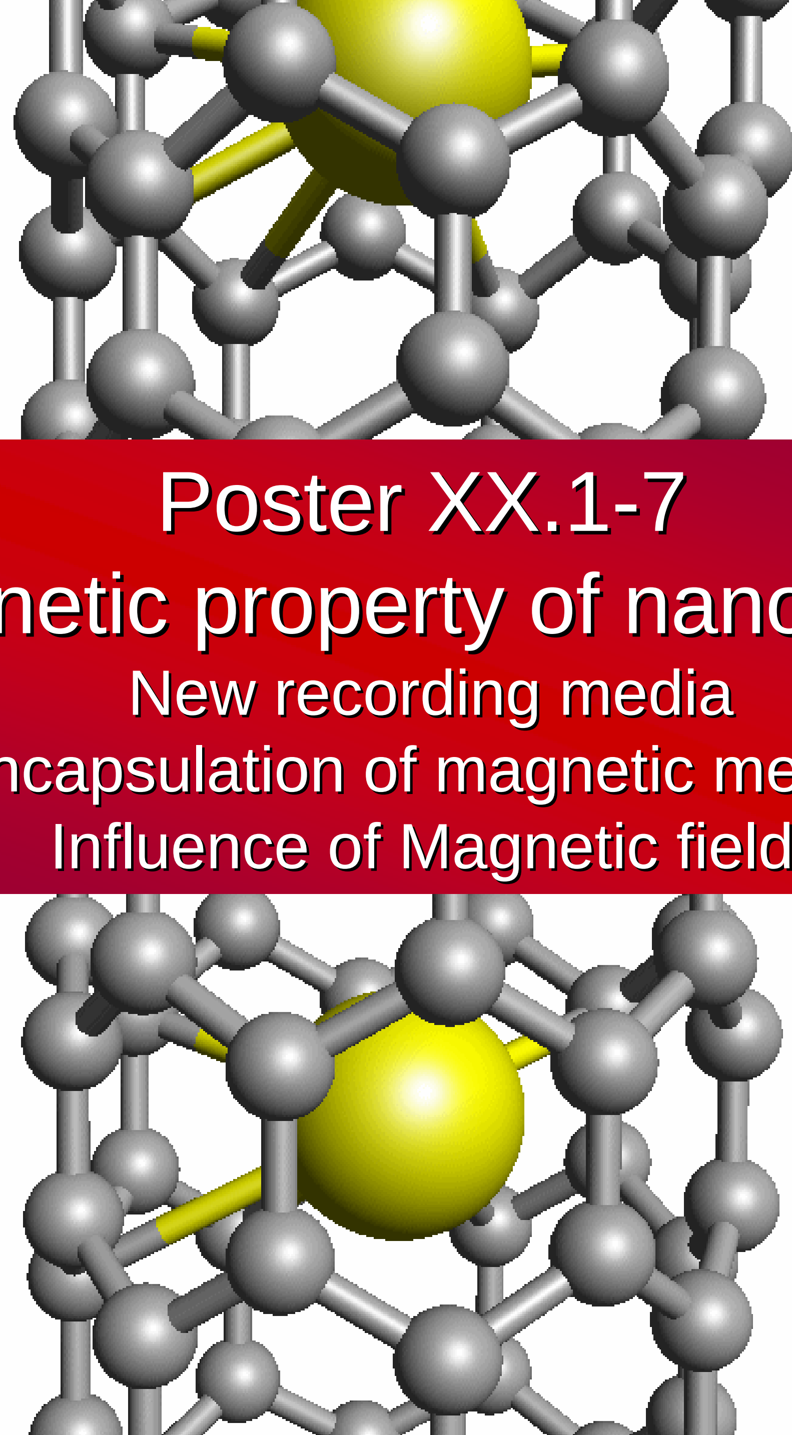
Poster XX.1-7

Magnetic property of nanotubes

New recording media

Encapsulation of magnetic metals

Influence of Magnetic field



XX.1 Realization of αFe inside CNT
-> strong magnetization!

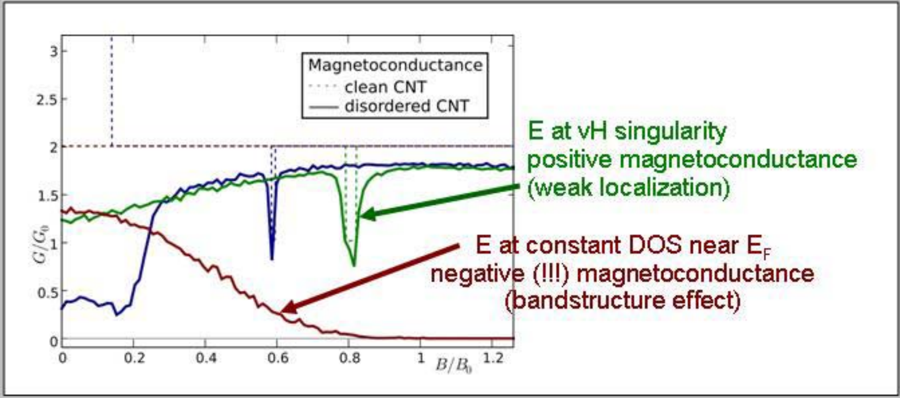
XX.2 ***CNT under magnetic field (Theory)***

XX.3 ***M@SWNTs targeting spintronics***

XX.4 ***under magnetic field and Vg control***

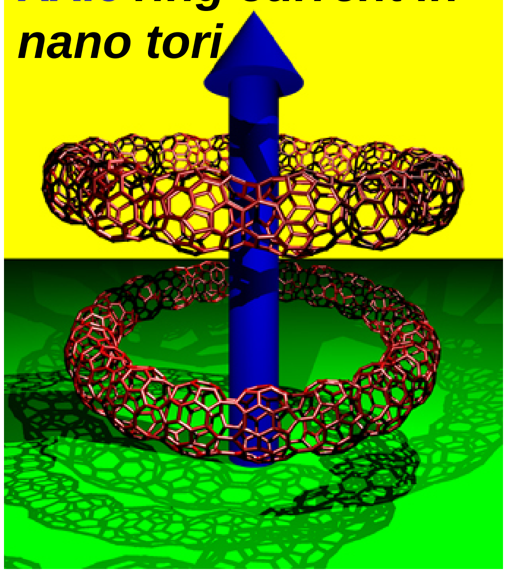
-> weak localization, AAS oscillations

XX.2

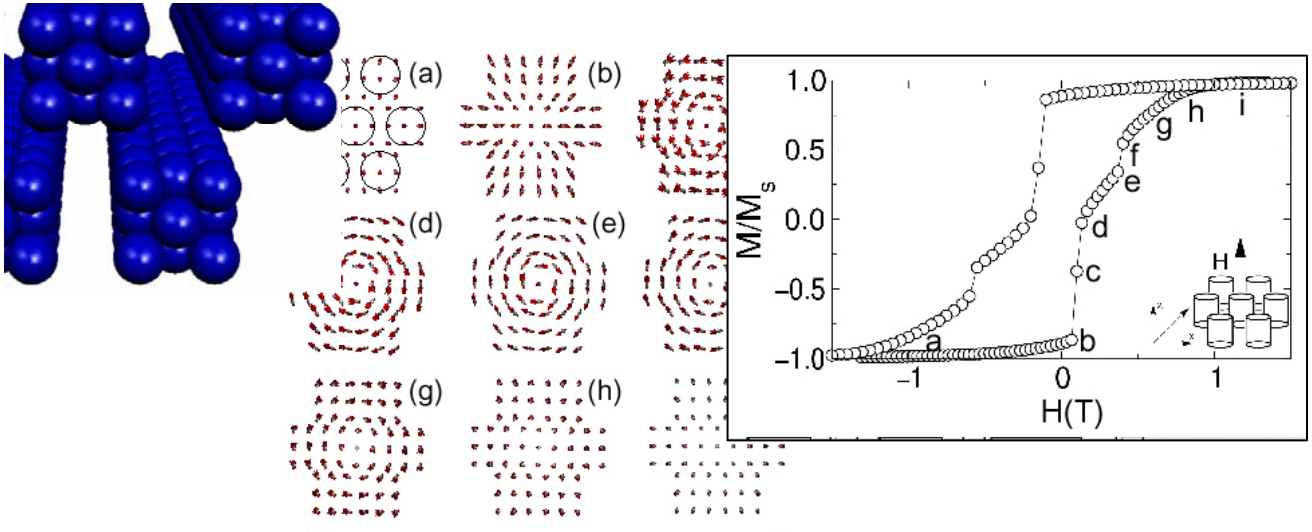


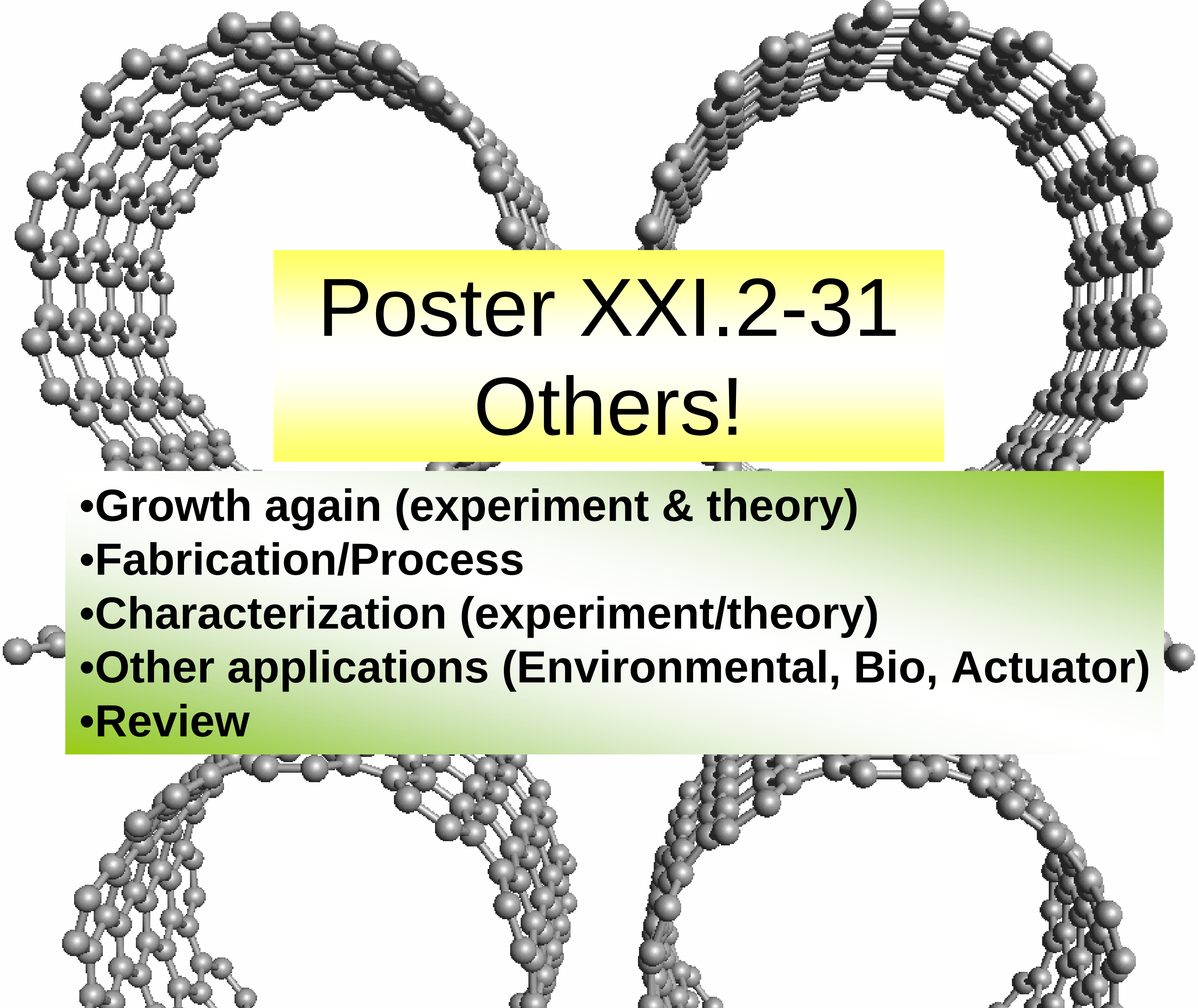
XX.5 ***aligned particle in top/end of CNT targeting high-density memory***

XX.6 ***ring current in nano tori***



XX.7 ***Magnetization Studies of Fe NWs***





Poster XXI.2-31
Others!

- Growth again (experiment & theory)
- Fabrication/Process
- Characterization (experiment/theory)
- Other applications (Environmental, Bio, Actuator)
- Review

Growth (experiment)

XXI.18 withdrawn

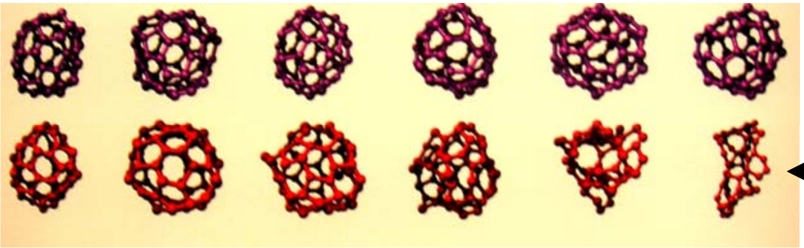
XXI.23 withdrawn

Growth (Theory/Simulation)

XXI.4 **growth on (100)(111) surface**

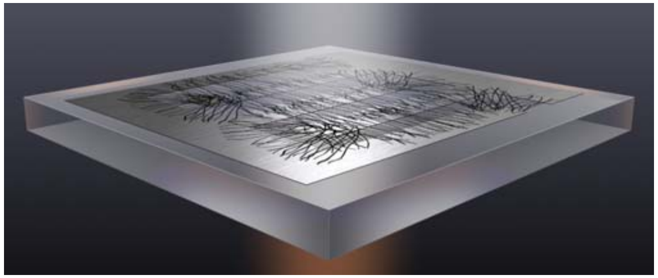
XXI.9 Influence of monoatomic steps of nickel during the nucleation of C-SWNTs

XXI.15 MD Test of heat bath->NG!: for each atom, Good!: for the system



Over melting with heat bath for each atom

Fabrication/processes



XXI.3 **Sort metallic tube by high-frequency field: for any diameters!**

XXI.6 **Direct structuring of SWNT free standing thin films**

XXI.10 **MD-examination for successful substitution of B/N as 30%/40%, sharp difference of diffusion barrier B(0.1eV)/N(1.1eV)**

XXI.12 **Location Control of CNT** **Etched pattern on SiO_2 and growth**

XXI.17 **LPCVD** **Apply E in order to separate SWNT, MWNT, M-particle, α-C from product.**

XXI.26 **H-impact induced structural change -> electronic structure change**

Characterization (Experiment)

XXI.8 First-time measurement of micro-X-ray diffraction : Nature of catalytic particles from root to top of CNT.

XXI.14 fullerene-like structures' metal derivatives

Structural magnetic properties by Mass, EPR, NMR, X-ray, Raman…

XXI.19 ^{13}C NMR study of alkali-CNT N(E_F) and preferential site

XXI.20 Electrostatics of individual SWNTs investigated by EFM

XXI.22 SWNT Light-Assisted Oxidation -> appeared in change of FL

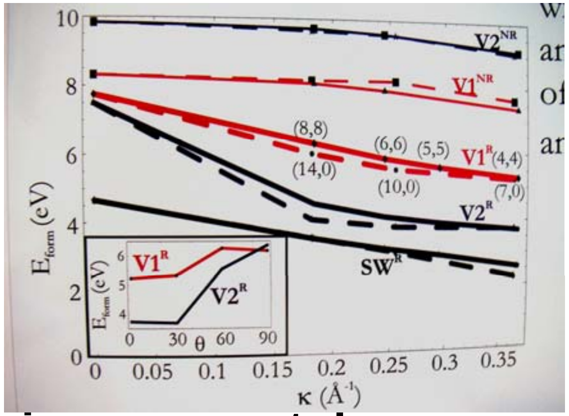
Light-induced selective burning/removal of CNT with H_2O_2

XXI.27 Determination of Nanotube Density by Gradient Sedimentation

Mass/Volume wrt bundle size vs. geometrical simple model.

XXI.29 Mechanisms of electromigration of inner Fe atoms is addressed from cross-sectional structure by TEM

Characterization (Theory)

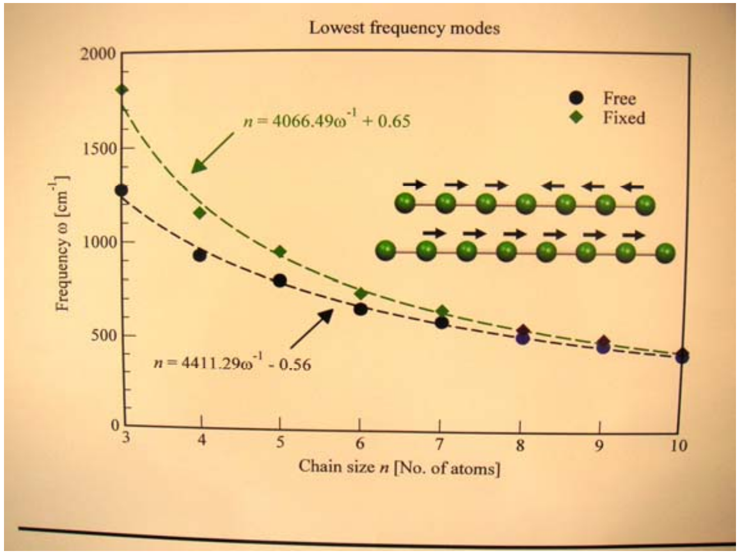


XXI.7 **Curvature assisted defects in nanotubes**

XXI.24 **Low energy instabilities of small-radius zig-zag nanotubes**

e-e Coulomb-repulsion vs e-phonon-mediated e-e attraction

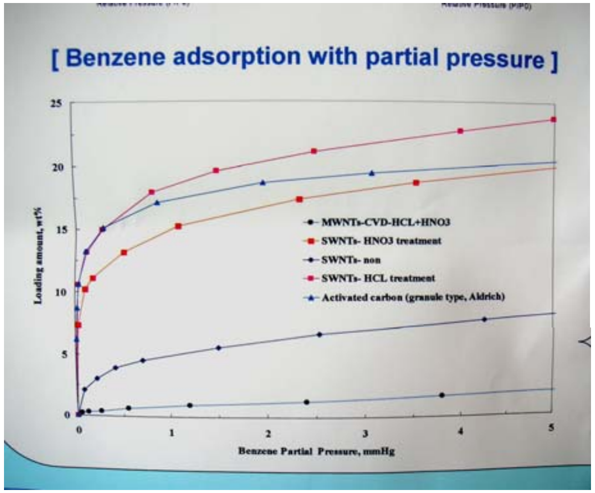
XXI.31 **virbational and electronic structure of 1D C-chains (even/odd # of C atoms)**



Other applications

XXI.11 The Adsorption of Hazardous Organic Compounds

SWNT shows better performance than activated carbon

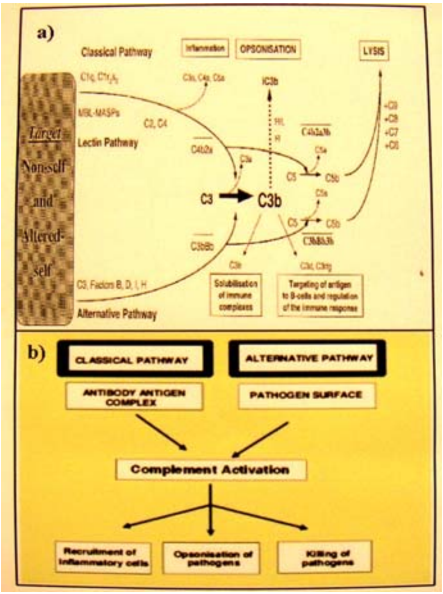


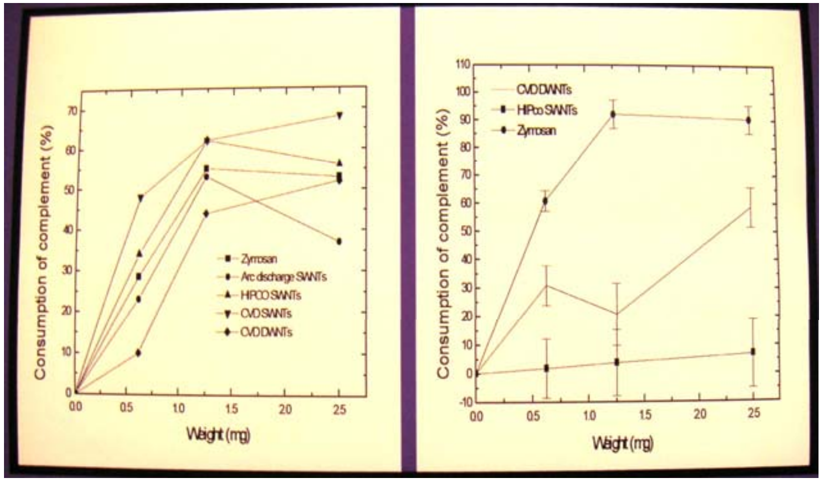
XXI.13 Novel actuator with SWNT (Theory)

Charge-induced forces on 10^{13} aligned SWNTS! (Theoretical-patent pended)

XXI.21

'We report for the first time that carbon nanotubes activate human complement via both classical and alternative pathways.'





Review

XXI.2 withdrawn

Thanks for supports from presenters!

Good fortune often comes from remaining things!

Poster XIX.1 ***Carbon Nano-tubes for the fabrication of high on-off ratio field-emission transistors*** **Surrounding gate on cathode tube->Vg=12 V 10^4 on/off ratio**

Y. Abdi, J. Koohsorkhi, A. Miri, and S. Mohajerzadeh

Poster XIX.2 ***Metal-semiconductor transition in single-wall carbon nanotubes induced by low energy electron irradiation***

A. Vijayaraghavan, K. Kanzaki, S. Suzuki, Y. Kobayashi, S. Kar, P. M. Ajayan

Poster XIX.3 ***Air-stable n-type single-walled carbon nanotubes with alkali-metal encapsulation performed by plasma ion irradiation***

T. Izumida, T. Hirata, R. Hatakeyama, Y. Neo, H. Mimura, K. Omote, and Y. Kasama

Poster XIX.4 ***Ult… …on Carbon Nano…***

…nd

Bio-applications!!

Pos… ***…ors***

Brian Hunt, A… …Willis

Poster XIX.6 ***Conductivity control of single-walled carbon nanotubes by electron beam exposure***

K.Kanzaki, A.Vijayaraghavan, S.Suzuki, Y.Kobayashi, H.Inokawa, Y.Ono

Poster XIX.7 ***Fabricatin of Crossed Semiconducting and Metallic Nanotubes: CNT-gated CNT-FET***
D.S. Lee, J. Svensson, S.W. Lee, Y.W. Park, E.E.B. Campbell

Poster XIX.8 ***1D-Carbon nanotubes on 2D-semiconductor***
Yun-Hi Lee, Je-Min Yoo, Jung-Ah Lee, B. K. Ju

Good electron emitter
Magnetisms in CNT-S junction

Poster XIX.9 ***Selective replacement on SiO_2, chromophore functionalization -> photo-transistors***

Poster XIX.10 ***Surface passivation of carbon nanotube field-effect transistors***
Hideki Shimauchi, Yutaka Ohno, Shigeru Kishimoto, and Takashi Mizutani

SiO_2/PMMA passivation -> reduction of hysteresis more than a month!!

CNT device is also seen in Poster XXI. 28, A contact/resistance issue.

Poster XXI.28 **Electrical Resistance and Contact Properties of Carbon Nanotube Coated Surfaces**
Onnik Yaglioglu, Anastasios John Hart, Alexander H. Slocum

Poster XXI.2 **THEORETICAL AND EXPERIMENTAL STUDIES OF CARBON NANOTUBES: A REVIEW**
Katya M. Simeonova, Ganka M. Milanova

Poster XXI.3 **Sorting carbon nanotubes via dielectrophoresis**
R. Krupke, F. Hennrich

Sort metallic tube only by high-frequency field

Poster XXI.4 **Atomic scale modelization of the nucleation of C-SWNT towards atomic**

TB-MD and MC grand canonical->growth on (100)(111) surface

H. Amara,C. Bichara, J.-P. Gaspard and F. Ducastelle

Poster XXI.5 **An alternate mathematical model for single-wall carbon nano**

New insight on nanotube structures and higher-symmetry representation

Nicol

Poster XXI.6 **Direct structuring of single-walled carbon nanotube (SWNT) free standing thin films using e-beam and focused ion-beam (FIB).**
S. Malik, C. A. Volkert, H. Rösner, O. Kraft ,

No intermediate steps of fabrication

Poster XXI.7 **A theoretical study of curvature effects in defective nanotubes**

Curvature assisted defect formation and reactivation

Johan M. Carlsson and Matthias Scheffler

Poster XXI.8 **STRUCTURAL INVESTIGATION OF NANOTUBE CARPETS AND FIBERS AT THE MICROMETER SCALE USING SYNCHROTRON MICROFOCUS X-RAY DIFFRACTION**
V. Pichot, M

Analysis of catalytic particle from the root to top of the nanotubes

Burghammer, C. Riekel and P. Launois

Poster XXI.9 Influence of monoatomic steps of nickel during the nucleation of C-SWNTs

TB-MD and Monte Carlo-grand canonical approach

H. Amara, C. Bichara and F. Ducastelle

Poster XXI.10 Ion irradiation induced B/N implantation onto carbon nanotubes

Substitution of C with N/B atom: effect of later annealing: MD!

J. Kotakoski, A. V. Krasheninnikov, Y. Ma, A. S. Foster, K. Nordlund, and R. M. Nieminen

Poster XXI.11 The Adsorption of Hazardous Organic Compounds onto Carbon Nanotubes Synthesized by Thermal Pyrolysis

Performance of MWNTs prepared by the thermal phyrolysis method!

N. J. Jeon

Poster XXI.12 Location Control of the Growth of Carbon Nanotubes using Focused Ion Beam Selective Milling

Etched pattern on SiO_2 and growth

E. S. Sadki, S. Ooi, and K. Hirata

Poster XXI.13 Novel actuator with single-wall carbon nanotubes as actuating material

Charge-induced forces on 10^{13} aligned SWNTS!

T. Koker, U. Gengenbach, G. Bretthauer

Poster XXI.14 Production and investigation of composition, structure and properties of fullerene-like structures' metal derivatives

K.B.Zhogova, B. S.Kaverin, A.G.Zvenigiridskii, A. M.Ob`edkov, G.A.Domrachev, S. N.Titova, A.I.Kirillov, M.A.Lopatin, M.V.Tatsenko, Yu.V.Ignat'ev, C.N.Kartanov

Structural analysis by Mass, EPR, NMR, X-ray, Raman…

Poster XXI.15 **Molecular Dynamic Simulations of Single-Wall Carbon Nanotube CVD Grow**

Refined parameter for GROMOS-> T, catalysis-size dep.

Ali Izadi-Najafabadi, Walter R. P. Scott, and John D. Madden

Poster XXI.16 **In situ characterization of field emission from individual carbon nanotubes in the scanning electron microscopy**

Do-Hyung Kim, Chang

Alignment under applied E-> non-FN to FN emission

Hyeong-Rag Lee

Poster XXI.17 **Gas Phase Electrophoresis of Carbon Nanotubes grown in Low Pressure CVD process.**

Apply E in order to separate SWNT, MWNT, M-particle, α-C from product.

D.V. Smovzh, V.A. Maltsev, O.

Poster XXI.18 **Synthesis of silicon carbide nanomaterials using multi-walled carbon nanotubes as te**

Start from MWNT + S powder-> graphite heater 2000K!

V.G. Sevastyanov, A.V. Ar

A.M. Ob`edkov , B.S. Kaverin, A.A.Zaitsev, K.B.Zhogova

Poster XXI.19 **NMR INVESTIGATIONS ON ALKALI INTERCALATED CARBON NANOTUBES**

Pure metallization and preferential alkali sites!

M. Schmid, C. Goze-Bac, T. Wagberg, M. Mehring, S. Roth

Poster XXI.20 **Electrostatics of individual SWNTs investigated by EFM**

M. Paillet, P. Poncharal and A. Zahab

Static charge distribution on INDIVIDUAL CNT on SiO_2/Si

Poster XXI.21 **Complement activation and protein adsorption by carbon nanotubes**

First-time report of actication of human complement!

Carolina Salvador-Morales, Emmanuel Flahaut, Edith Sim, Jeremy Sloan, Malcolm L.H.Green, Robert B.Sim

Poster XXI.22 **SWNT Fluorescence Spectrum Changes Induced by Light-Assisted Oxidation**

Light-induced burning/removal of CNT with H_2O_2

Minfang Zhang, Masako Yudasaka, Sumio Iijima

Poster XXI.23 **LCVD of Carbon Nanotubes, Catalytically Grown on Iron-Based Nanostructures Prepared by Laser Pyrolysis**

I. Morjan, R. Al [illegible] Scarisoreanu, [illegible] R. E. Morjan

Laser induced CVD on catalysis/Si-sub. Checked by SEM,TEM,,,

Poster XXI.24 **Low energy instabilities of small-radius zig-zag nanotubes**

E. Perfetto and J. Gonzalez

Coulomb-repulsion vs e-phonon-mediated attraction

Poster XXI.25 **Photoemission of insulator-coated carbon nanotubes**

SeGi Yu, Jungna Heo, [illegible] Kim

Optimization of insulator layer for high-emission (local E assisted enhancement)

Poster XXI.26 **Local Modification and Characterization of the Electronic Structure of Carbon Nanotubes**

H-impact induced structural change

Gilles Buchs

Poster XXI.27 **Determination of Nanotube Density by Gradient Sedimentation**

Qi Lu, Ga

Mass/Volume of bundles tends to match a geometrical simple model.

Poster XXI.28 **Electrical Resistance and Contact Properties of Carbon**

(CNT film)/(Au contact) has been tested-> reduction of ρ by annealing and press

Onnik Yaglioglu, Anastasios John Hart, Alexander H. Slocum

Poster X

L. de Kn

Mechanisms of electromigration of inner Fe atoms is addressed from cross-sectional structure by TEM

Poster XXI.30 **Fractal Analysis of Carbon Nanotubes by Means of Electrochemical Methods**

Ali Eftekhari, Fathollah Moztarzadeh, Parvaneh Jafarkhani

Poster XXI.31 **Structural, Electronic and vibrational properties of atomic carbon nanowires.**

E. Cruz-Silva, M. Terrones, F. López-Uría, E. Muñoz-Sandoval1, H. Terrones, R. Saito, M. Dresselhaus, M. Endo.

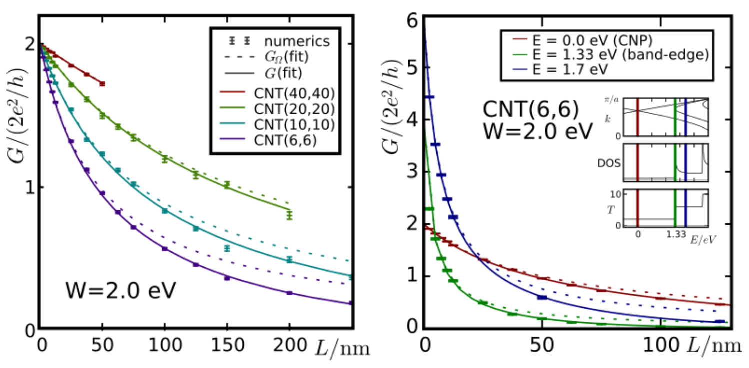
XX.2

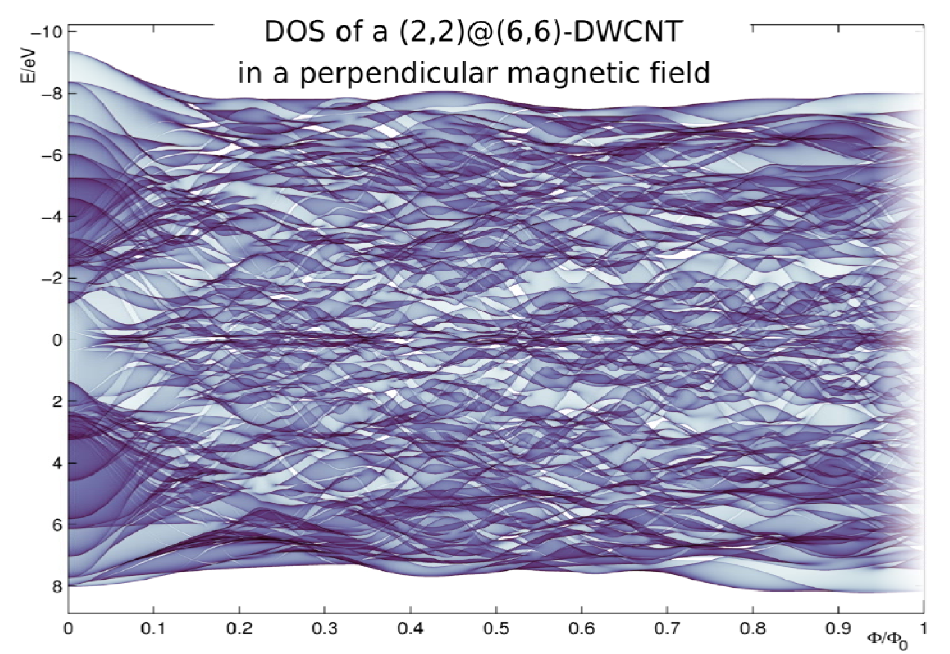
Magnetoconductance in Disordered Carbon Nanotubes

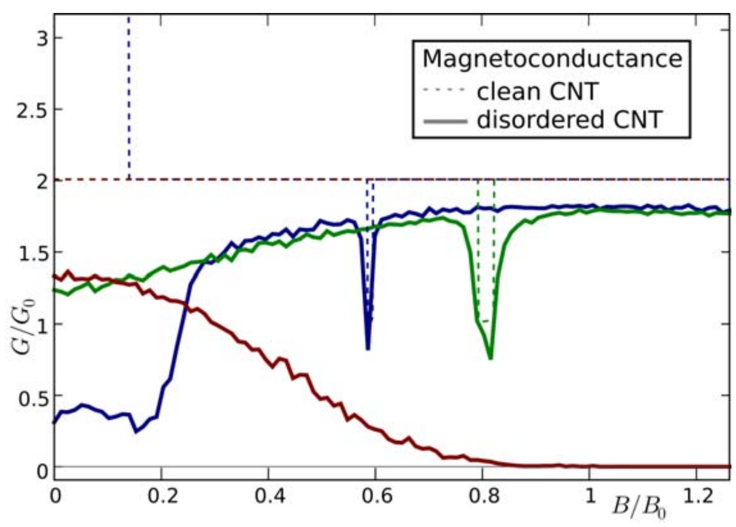
Norbert Nemec and Gianaurelio Cuniberti

TB& disordering

Length dependence of conductance



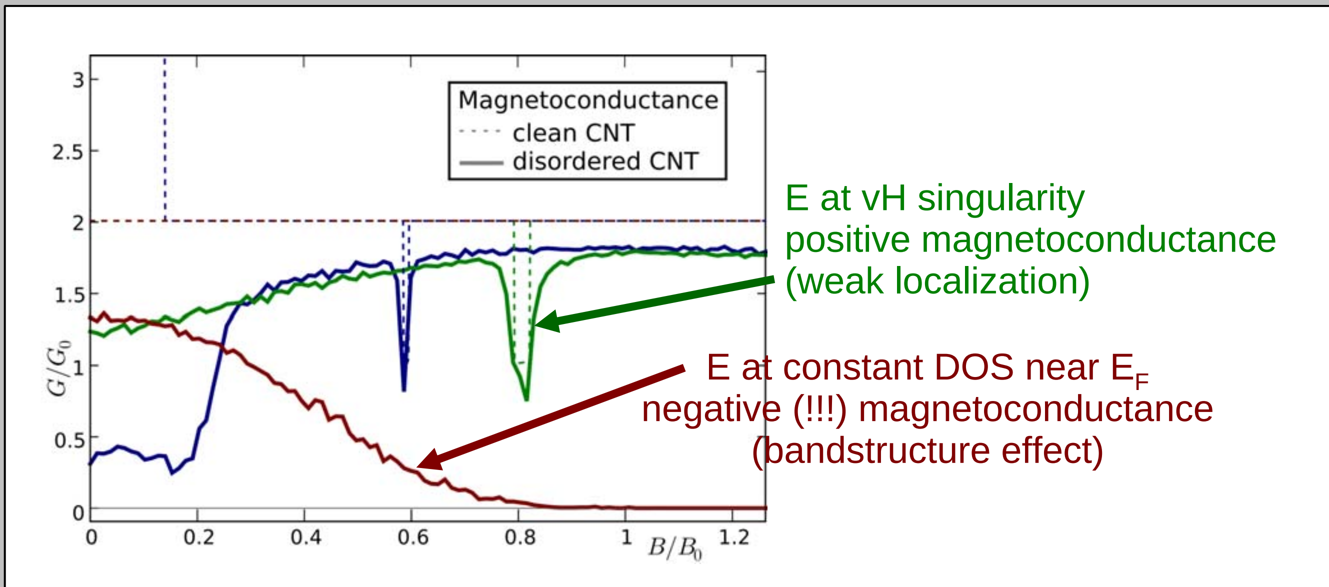




positive magnetoconductance (weak localization)

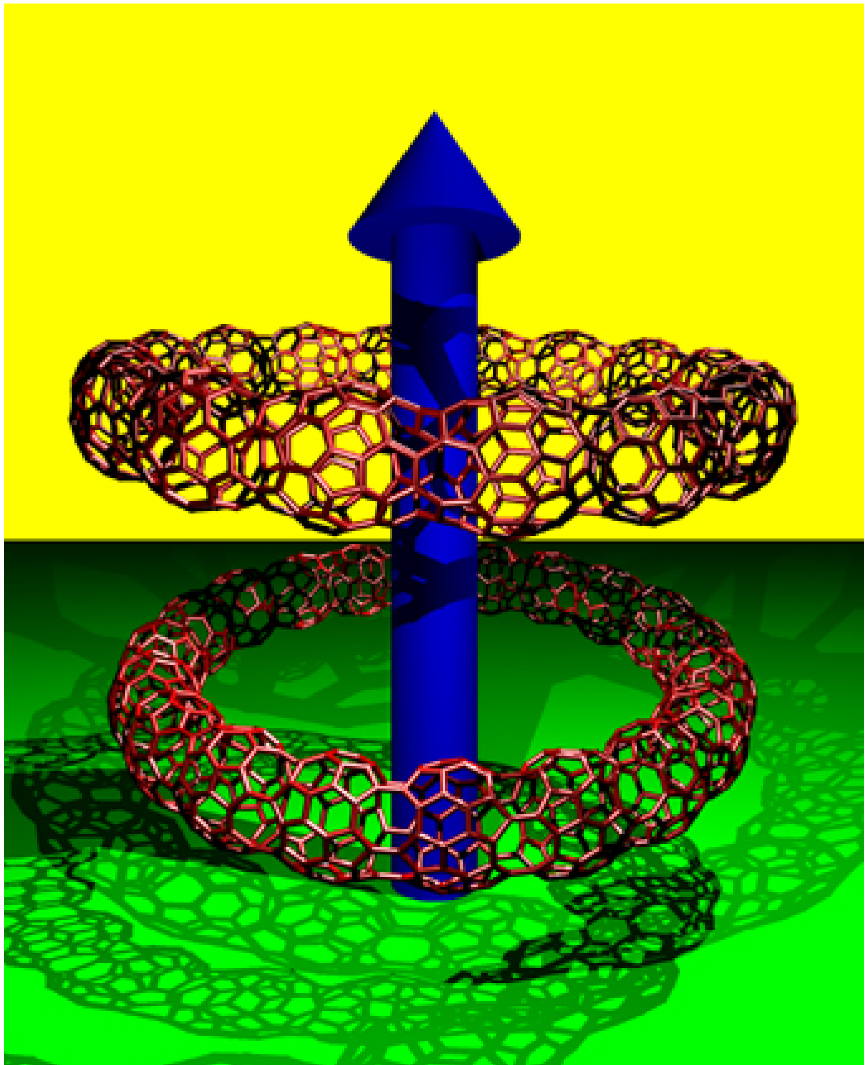
negative (!!!) magnetoconductance (bandstructure effect)

XX.2


Magnetoconductance
clean CNT
disordered CNT
G/G0
B/B0
0
0.5
1
1.5
2
2.5
3
0
0.2
0.4
0.6
0.8
1
1.2
E at vH singularity
positive magnetoconductance
(weak localization)
E at constant DOS near E_F
negative (!!!) magnetoconductance
(bandstructure effect)

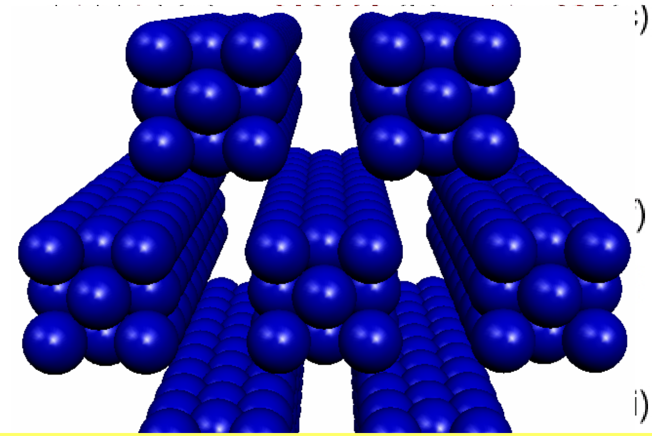
Magnetism in Carbon and Metal Nanowires

Ring Currents in Carbon Toroids

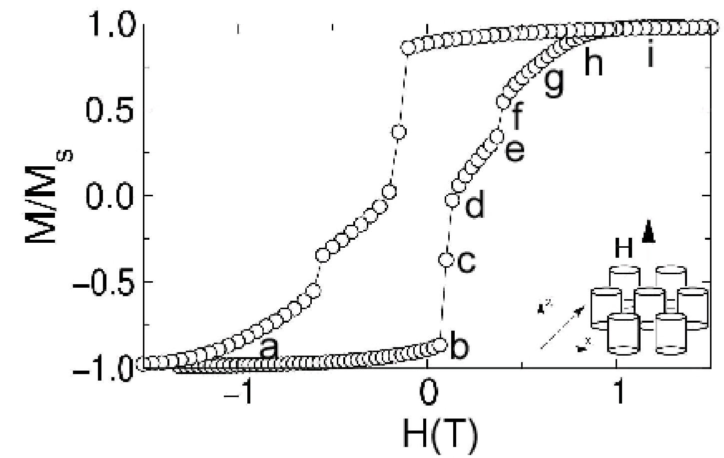


Poster XX.6

Magnetization Studies of Fe NWs



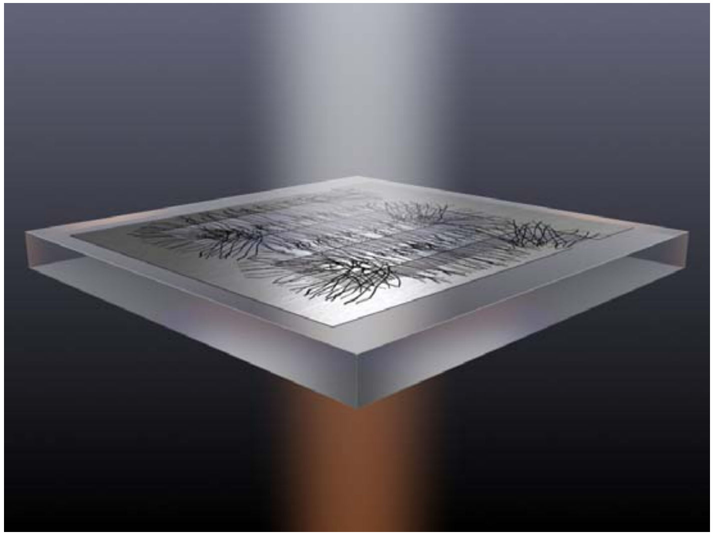
Helical alignment of spin inside NT?!
Checked by Exp. And Theory

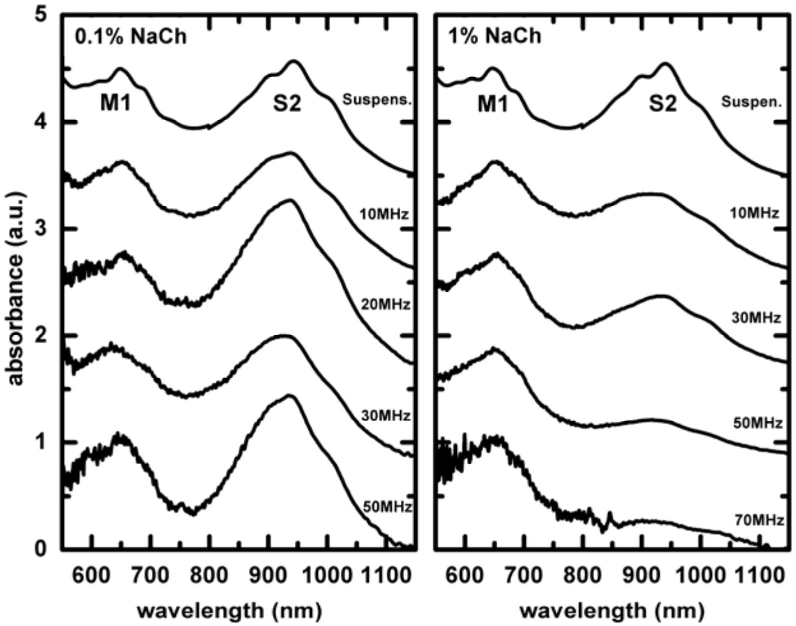


Poster XX.7

Sorting carbon nanotubes via dielectrophoresis

R. Krupke, F. Hennrich





Optical absorption spectra confirm our previous Raman data:

Metallic tubes are separated from semiconducting tubes by high-frequency, high-field dielectrophoresis – for all diameters !

NT05: Sixth International Conference on the

Science and Application of Nanotubes

Göteborg, Sweden

June 26 - July 1, 2005

http://nanotube.msu.edu/nt05/

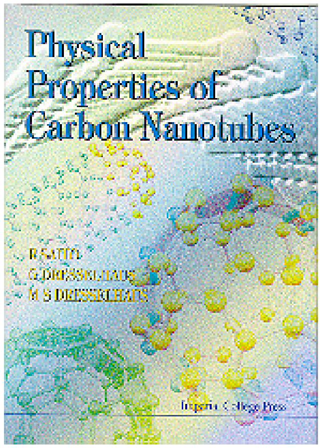
CR Mildred Dresselhaus Friday, July 1

Concluding Remarks

Outline

M. Terrones & M.S. Dresselhaus

- **Conference Overview**
- **What we learned at NT05**
- **Achievements and Trends**
- **Challenges & Future Work**

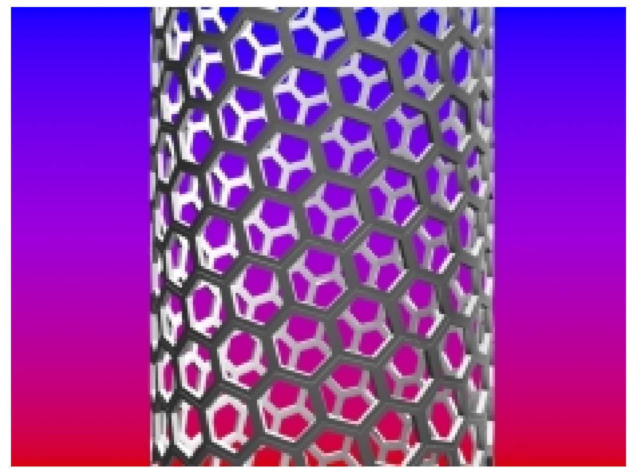


"*Physical Properties of Carbon Nanotubes*",

by R. Saito, G. Dresselhaus and M.S. Dresselhaus,
Imperial College Press (1998) ISBN 1-86094-093-5

Conference Overview

Time	Sun 26	Mon 27	Tues 28	Wed 29	Thurs 30	Fri 1
08:30-09:00		Registration	Registration			
09:00-09:45			Maurizio Prato	Morinobu Endo	David Tomanek	Paul McEuen
09:45-10:15		Welcoming address (09:30-10)	Alan Windle	Susumu Katagiri	Jean-Louis Sauvajol	Nadine Kam
10:15-10:45		Sumio Iijima (10-10:45)	Jerry Tersoff	Jean Dijon	Junichiro Kono	Cheol Jin Lee
10:45-11:15		Steven Louie	Coffee	Coffee	Coffee	Coffee
11:15-11:45		Coffee	Young Hee Lee	Jong-Min Kim	Tony Heinz	Brian LeRoy
11:45-12:05		Humberto Terrones (11.45-12.15)	Yoshinori Sato	Atsuko Nagataki	Arkady Krasheninnikov	SangWook Lee
12:05-12:25		Lars Samuelson (12.15-12.45)	Lunch	Anna Swan	Lunch	Lunch
12:25-14:00		Lunch (12.45-14.20)		Lunch		
14:00-14:20			Pavel Nikolaev	Boat trip and conference dinner	Gotthard Seifert	Pertti Hakonen
14:20-14:40		Feng Ding	Vincent Jourdain		Bo Gao	Andrew Wall
14:40-16:00		Masahiko Ishida (14.40-15)	Poster session A Chair A.2 14:40-14:45 Chair A.3 16:30-16:35 Chair A.4 18:30-18:35		Poster session B Chair B.1 14:40:14:45 Chair B.2 16:30-16:35 Chair B.3 18:30-18:35	Poster session B Chair B.4 14:40-14:45 Chair B.5 17:00-17:05
16:00-18:00	Registration	Poster session A (15:00-18:30) Chair A.1 15:00-15:05				
18:00-19:00	Welcome party					Snacks 19:00
19:00-21:00		Göteborg city reception				Concluding remarks 20.00



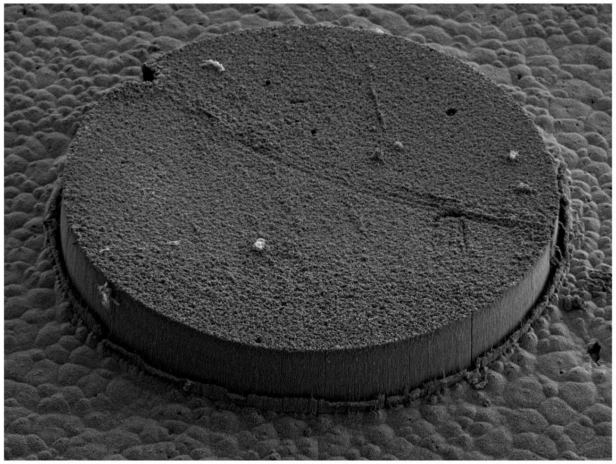
NT05 Conference Overview

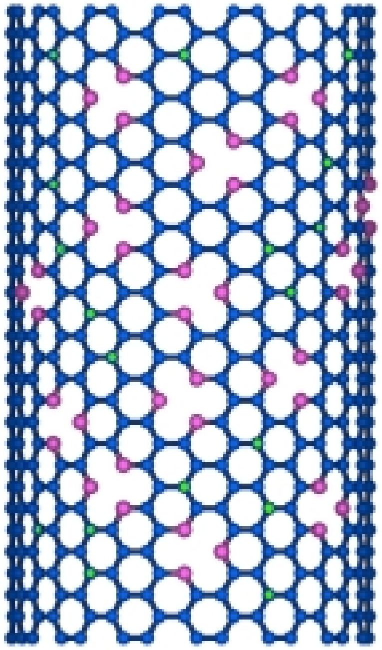
CVD Synthesis of Carbon Nanotubes (81)
Non-CVD Synthesis of Nanotubes (17)
Formation and Characterization of Unusual Nanostructures (14)
Raman Characterization of Nanotubes (12)
Other Characterization of Nanotubes (18)
Nanotube Dispersion and Purification (9)
Chemical Modification of Nanotubes (29)
Non-Carbon Nanotubes (12)
Nanotube-Based Composites (26)
Morphology and Application of Modified Nanotubes (13)
Photo-Induced Reactions in Nanotubes (1)
Thermal and Mechanical Properties of Nanotubes (16)
Atomic Structure of Carbon Nanotubes (10)
Transport in Nanotubes (37)
Field Electron Emission (14)
Optical Properties and Optoelectronics (24)
Transport in Complex Nanostructures (4)
Electron-Phonon Coupling in Complex Nanostructures (2)
Nanotube-Based Transistors (10)
Magneto-Transport and Magnetism (5)
General Studies of Carbon Nanostructures (31)

(402 contributed abstracts received in total)

CVD and Non-CVD Techniques

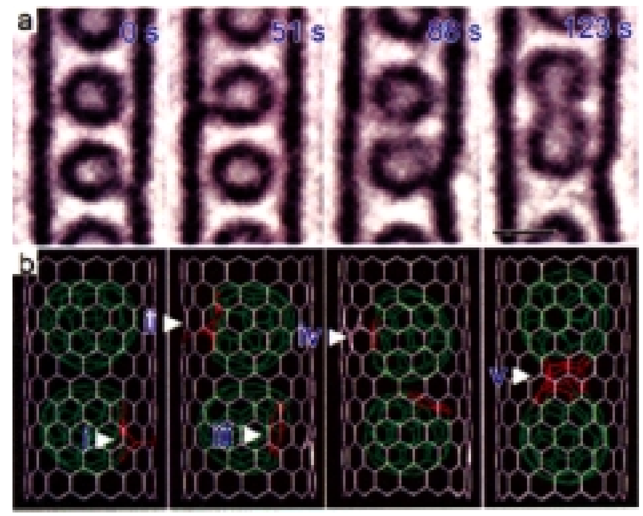
- CVD method is developing fast
  - **Bulk Production** and Scalable Process (companies developing).
  - **Alcohol** based CVD is powerful
  - **Continuous spinning** of Nanotube Fibers
  - **More active & controlled effort on DWNTs**
  - Starting Effort on **triple-walled NTs**
  - **Alignment** of nanotube arrays MWNTs (multi-layers)
  - **Supergrowth** Mechanism with H_2O (SWNTs)
  - **Doped Nanotubes**
- Plasma-enhanced CVD → Now making SWNTs
- No chirality Control yet!! But beginning!!
- More emphasis on **Small Diameter Tubes**
- Non-CVD (Arc, Magnetron Sputtering, Chemical, Laser, Ball-Milling)

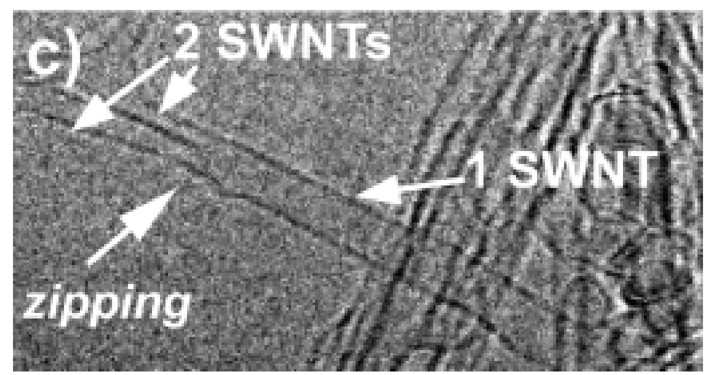




Characterization

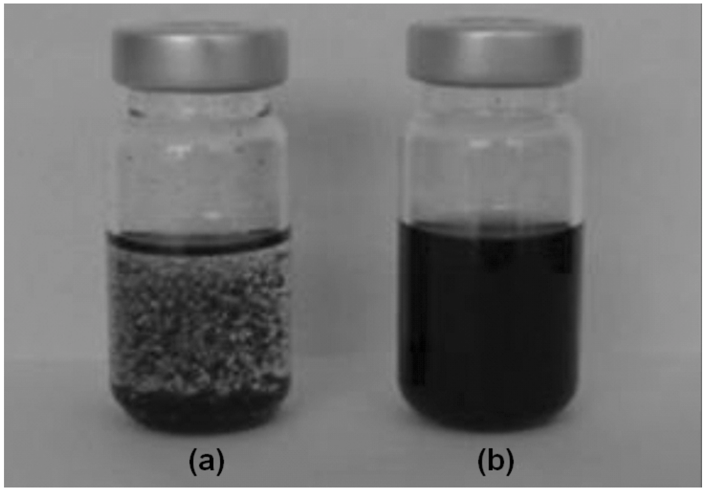
- HRTEM is improving (useful and powerful)
  - **Defects (individual atoms, vacancies)**
  - **Chirality (n,m) by imaging and ED**
  - **In-situ experiments (growth, kinetics)**
- Catalyst-NT Membranes under HRTEM →growth process
- MD simulations of NT growth
- Raman Spectroscopy
- STM and STS
- Photo-luminescence
- Magnetic Force Microscopy Developing Fast

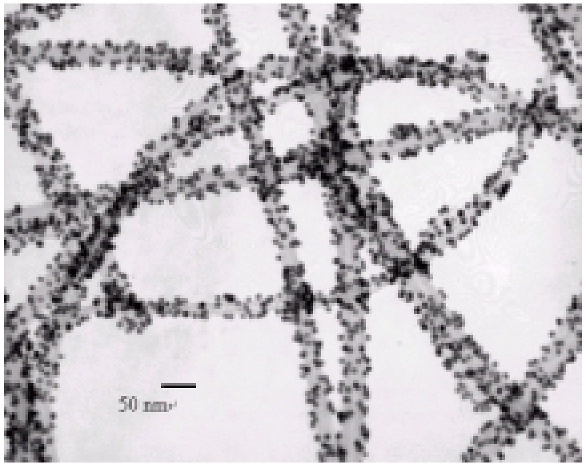




Chemistry of Nanotubes

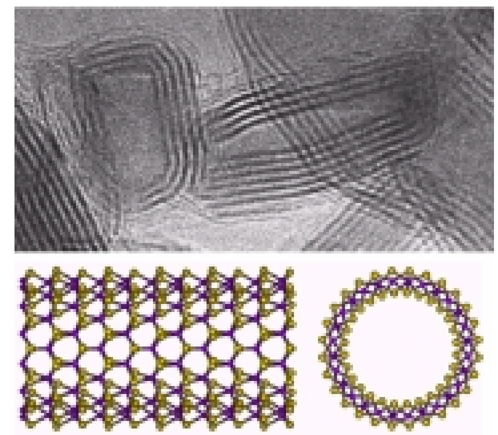
- Graphite and large diameter NTs are inert
- Introducing activity →Defects
- How to quantify and identify defects (Novel Electrochemical Methods)
- Functionalization & Dispersion Methods
- Separating, Cutting and positioning NTs.
- Doped Nanotubes
- Sensors and Biosensors
- Patterned growth of SWNTs on sapphire step surfaces
- DNA-wrapped tubes, Fluorination
- Removing amorphous carbon, and metal particles, adsorbates

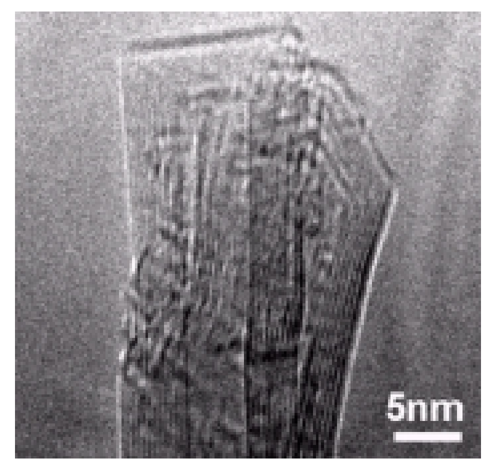




Non-Carbon Nanotubes, Nanowires & Related Materials

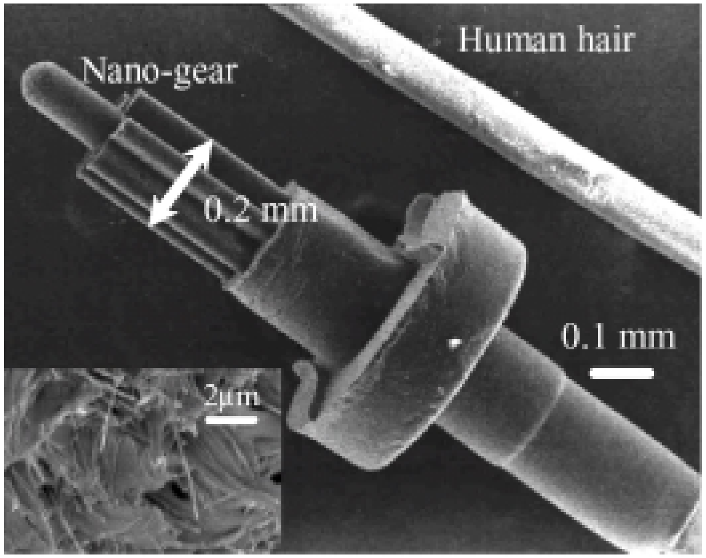
- BN, BCN Nanotubes
- Defects in BN tubes
- Nanotubes (layered Materials)
  - TiO_2, MoS_2, WS_2, CdS, etc.
- Need Calculations
- More Synthesis methods of layered nanotubes.
- More Property Measurements
- Nanowires of CdSe, ZnSe, ZnO, Si, BiSb, etc.
- *Future Trends: More Nano-Bio & Nano-graphite*

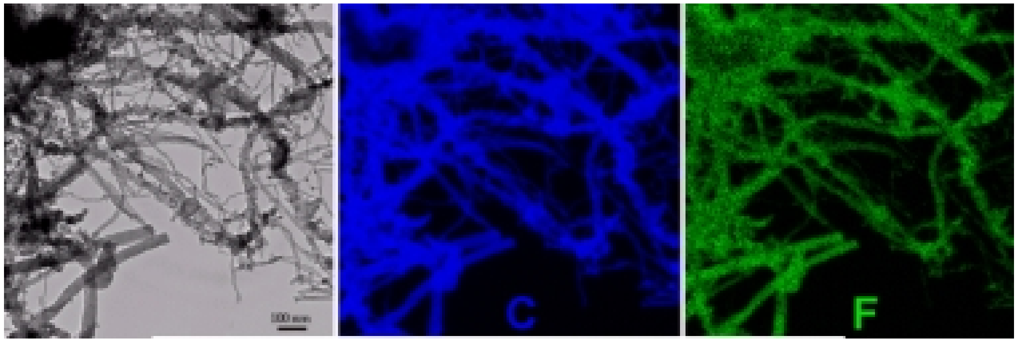




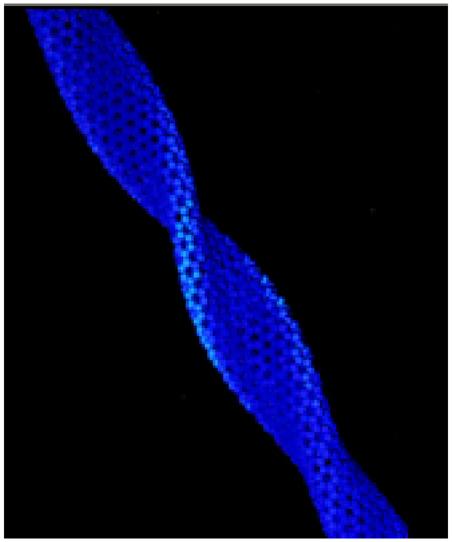
Composites and Modified Tubes

- Polymer Composites (we need standards)
- Conducting Polymers (transparent films)
- Electro-spinning of fibers
- In-situ polymerization from NT wall
- Novel Composites:
  Liquid Crystal,
  Ceramic-NT
  Metal-NT

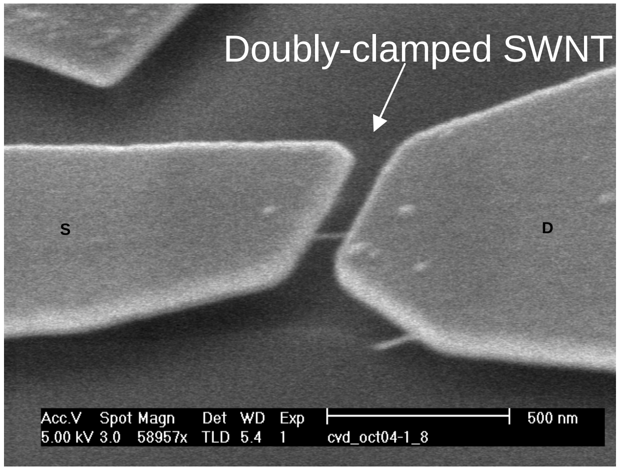




Mechanical and Structural Properties

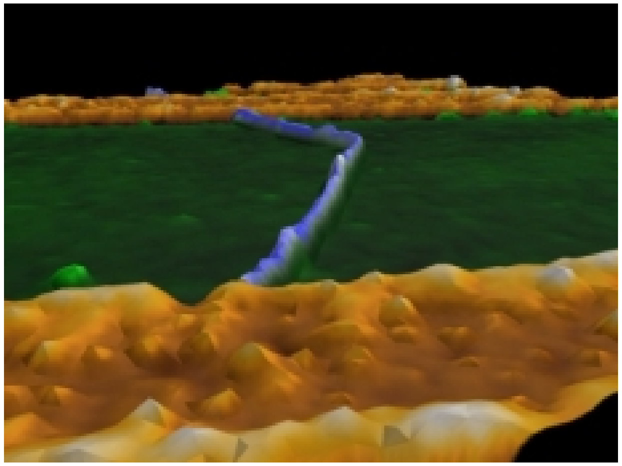


- Confinement effects of any filler within tubes (liquid, gas, solid)
- Current induced bends, repairing structural defects
- Generation & Disappearance of Stone-Wales type defects.
- Controlled point defects and their mobility
- Starting to do more NEMS with NTs
- Faceting MWNTs with Temperature
- Kohn Anomalies (Theory & Exp.)



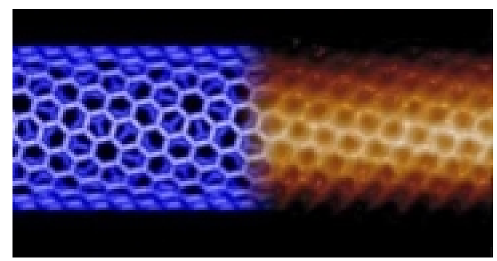
Transport in Nanotubes

- Devices from using long tubes provide better values for carrier scattering and mobility
- Firm evidence for phonon scattering effects in transport, and separation of acoustic and optical phonon contributions
- Measurements on suspended NTs (eliminate some extrinsic behaviors)
- Detailed understanding of SET and Kondo effects
- Combining Transport with Raman, etc
- Studies of Noise starting…
- *Still to come: Detailed understanding of Disorder & Defects in Transport*
- *Transport of DWNTs*



Photophysics

- Two-photon absorption experiments (Columbia & Berlin groups) demonstrated the need for excitons.
- Details of the exciton picture to describe the photophysics of SWNTs are emerging rapidly, including optically active and dark states.
- Correspondence principle between the usual Kataura plot and exciton model has been introduced.
- Femtosecond optics reveals lifetime of selected excited states, clarifying exciton picture.
- Coherent phonon generation in nanotubes has been demonstrated
- Rayleigh scattering for (n,m) determination

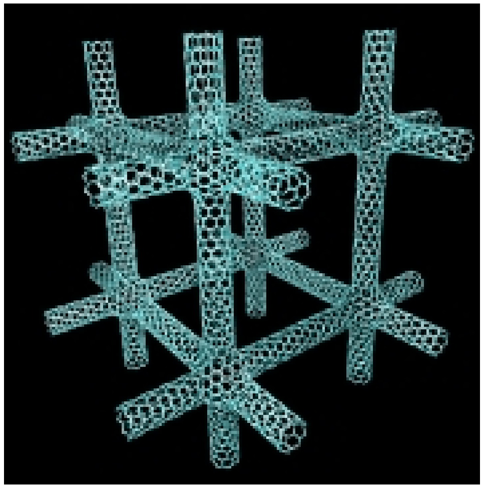


Applications

- Polymer Composites
  High Thermal Conducting Plastics
  Conducting Paints for automobiles
  Micro-gears
- Li-ion batteries & Lead acid batteries
- Field Emission Devices & Displays
- Nanotube-based Transistors
- Biological Applications
  Micro-catheters, protein immobilizers, Drug Delivery, Cancer treatment
- We need more COMMERCIAL APPLICATIONS

Overall Challenges

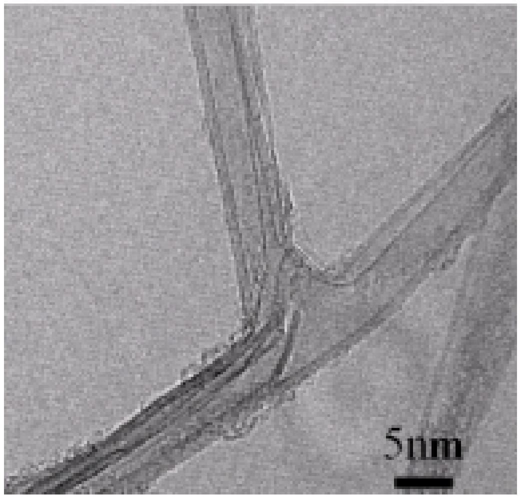
- **Standards**
  - On materials Characterization
  - How good are SWNTs, DWNTs, MWNTs?
    - Mean Diameter and distribution
    - Mean length and distribution
    - amorphous carbon content
    - Other materials content
    - Determine Metal/Semiconductor ratio
    - Determine (n.m) distribution
    - Identify Defect contents
    - Determine Functional groups
    - Estimate Doping
    - Bundles? Size of bundles?



  - How to BEST determine these parameters?
    - Combination of HRTEM, Raman, PL, TGA, SPM, etc.
  - Establish parameters for best qualities, set minimum standards for applications, what accuracy is needed?

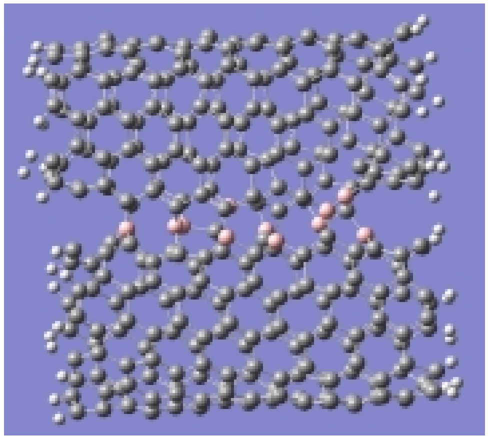
Overall Challenges

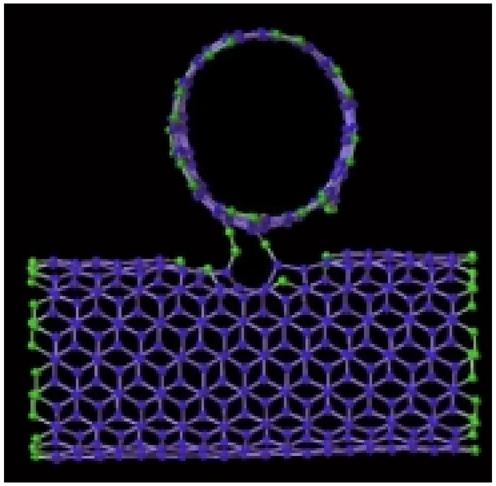
- **Health Effects**
  - Present status and knowledge
  - Best handling practices
  - Effects on skin, lungs, etc.
  - Carcinogenic effects?
  - What studies need to be done?
  - New special issue on Toxicity (Carbon Journal)



Theoretical Challenges

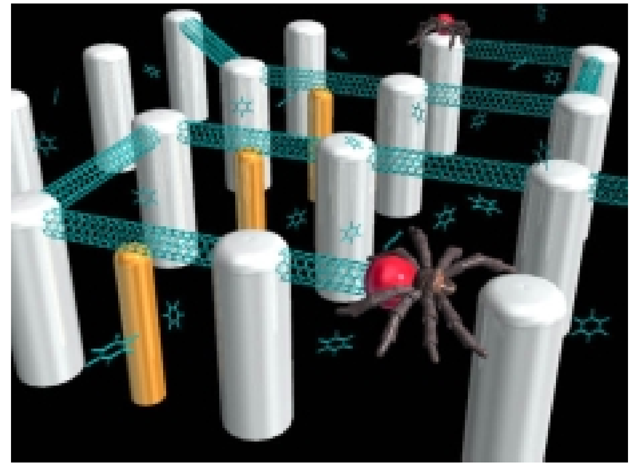
- Need accurate Calculations for NT growth (large scale in space and time)
- Theory on Chemistry of NTs
  - Effect of Functionalization on electronic & transport properties
  - Doping Effects
- Effect of Specific Defects on electronic properties & structural stability
- Electronic and Geometric Structure of DWNTs (treating incommensurability)
- Exciton Calculations for Photophysical Properties
- Predicting New Materials for Functionality & New Physics





We need to work on…

- **Real control of nanotube growth (catalyst dimensions and chirality selectivity)**
- **Improve Characterization** Techniques
- **In-situ experiments and at the individual NT level**
- **Easy NT manipulation**
- **Thermal Transport on individual NTs**
- **More experiments that are definitive of exciton phenomena including identification of dark states**
- **Applications**



Future NTxx Conferences

- NT06 in Japan
- NT07 in Brazil
- NT08 ??? – please post advert on Forum