Theoretical Solid State Physics and Statistical Mechanics Group

Secretaries	Masumi Shikano, Setsuko Sumino, and Yoko Wako
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Research Activities

III. SOLID STATE THEORY OF CARBON NANOTUBES AND NANOWIRES

(*R. Saito, W. Izumida, J. Jiang, J. S. Park, Y. Oyama, K. Sato*)

1. General information of members and visitors

Riichiro Saito was a visiting professor in 2005 in Department of Physics, University of Tokyo, for giving a lecture (2005.5.17-19) in the graduate course. He visited Delft Univ., The Netherlands,(2005.6.24-26), and Masachusette Institute of Technology, USA (2004.7.7-7.16), Stanford Univ. USA (2005.9.11-16) and Sungkyukwan Univ. Korea (2006.2.21-24). He gave general talks for highschool students twice at Heisei foundation of Science (2006.10.22, Prof. Koshiba), at Urawa High school (2006.12.16, Reiwa Seminar). He organized 2nd Korea-Japan symposium at Matsushima Taikanso (2005.11.27-30) with Prof. H. Shinohara and Prof. S. Iijima.

Wataru Izumida was a visitor in Kavli Institute of Nanoscience, Delft Univ. (2005.4-9), and have came back to Sendai on Sep. 31st 2005. Jiang Jie, continues to be a post doctoral fellow of CREST, JST (Japan Science Techonology Agency). Jiang Jie has got a daughter on 2006.2.24. (Jiang Zhuo Ling). Jin Sung Park entered to the graduate course (D1) as an IGPAS student from Oct. 1st 2005. Kentaro Sato (M2) has finished his master course on March 2005, and will enter the doctor course from April 2006. Yuji Oyama has finished his master course on March 2005, and will enter Bridgestone Corporation from April 2006.

We are happy to acknowledge the following short term, (more than one week) international visitors: Eduardo Cruz Silva (IPICyT Mexico, graduate

student 2005.4/9-20), Georgii Samsonidze (graduate student, Department of Electronic engineering, Masachusette Institute of Technology, graduate students, 2004.6.5-6.24). Prof. Marcos Pimenta (UFMG) (UFMG, Brazil, 2005.7.31-8.13).

2. Resonance Raman spectroscopy of carbon nanotubes

R. Saito *et al.* have investigated physical properties of cabon nanotube and nano-graphite nanotubes[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22]. This work is a project reseach of CREST, JST (Group leader: Prof. H. Shinohara of Nagoya Univ., Project leader: Prof. H. Fukuyama of IMR) started and supported by Grand-in-Aid, MEXT in 2003. We made an electron-phonon matrix element calculation which is used for resonance Raman and Photoluminescence intensity.

R. Saito, MIT and UFMG group found a phonon-assisted excitonic recombination channels observed in DNA-wrapped carbon nanotubesprocesses of single wall carbon nanotubes [1, 13]. J. Jiang and R. Saito calculated the intensity in the resonance Raman excitation spectra of single-wall carbon nanotubes with using the electron-phonon coupling matrix element[4]. Collaboration with Raman experimental group, we analyze the metal-semiconductor separation of single wall carbon nanotubes[5] and boron and nitrogen doped nanotube[15]. M. S. Dresselhaus, A. Jorio and R. Saito presented some review articles on carbon nanotubes[6]

Y. Oyama, K. Sato, J. Jiang and R. Saito made a photoluminecence intenisty and disorder induced Raman intensity (D-band) calculation by electron-photon and elastic scattering matrix elements[16, 17], which are combined with the experimental results for obtaining the population analysis of carbon nanotubes[18, 20].

3. Inelastic scattering process in single wall carbon nanotubes

S. Roche, J. Jiang and R. Saito considered inelastic scattering length of single wall carbon nanotube with use of Kubo's formula and electron-phonon coupling matrix elements[7]. They further considered the conductance and coherence lengths as a function of the Fermi energy in disordered carbon nanotubes[10, 21]

4. Some special Aharonov-Bohm effect in torus structure

K. Sasaki, Y. Kawazoe (IMR) and R. Saito discussed on local energy gap in deformed carbon nanotubes[2]. K. Sasaki, S. Murakami, R. Saito , Y. Kawazoe considered the edge state appeared in the zigzag edge of nanographite system[3, 8, 11, 13]. K. Sasaki, S. Murakami, and R. Saito show that the edge states has a small energy dispersion which comes from next nearest neighbor interaction which is compared with scanning tunneling spectroscopy experiment[20].

5. Electron transport through a quantum dot and a carbon nanotube

W. Izumida *et al.* have investigated the transport properties of a quantum dot and a carbon nanotube. Parts of these works were supported by Grant-in-Aid from the Ministry of Education, Culture, Sport, Science and Technology. Transport in suspended metallic single wall carbon nanotubes in the presence of strong electron-electron interaction was investigated[23]. A tube of finite length was considered and it was discussed that the effects of the coupling of the electrons to the deformation potential associated to the acoustic stretching and breathing modes. Treating the interacting electrons within the framework of the Luttinger liquid model, the low-energy spectrum of the coupled electron-phonon system was evaluated. The discreteness of the spectrum is reflected in the differential conductance which, as a function of the applied bias voltage, exhibits three distinct families of peaks. The height of the phonon-assisted peaks is very sensitive to the parameters. The phonon peaks are best observed when the system is close to the Wentzel-Bardeen singularity. The results were compared with the recent experiment.

References

[1] S. G. Chou, F. Plentz Filho, J. Jiang, R. Saito , D. Nezich, H. B. Ribeiro, A. Jorio, M. A. Pimenta, Ge. G. Samsonidze, A. P. Santos, M. Zheng, G. B. Onoa, E. D. Semke, G. Dresselhaus, M. S. Dresselhaus : Phonon-assisted excitonic recombination channels observed in DNA-wrapped carbon nanotubes using Photoluminescence spectroscopy, Phys. Rev. Lett. **94**, 127402-1-4 (2005).

[2] K. Sasaki, Y. Kawazoe, R. Saito : Local energy gap in deformed carbon nanotubes, Prog. Theor. Phys. **113**, 463-480 (2005).

[3] K. Sasaki, S. Murakami, R. Saito , Y. Kawazoe : Controlling edge states of zigzag carbon nanotubes by the Aharonov-Bohm flux, Phys. Rev. B **71**, 195401-1-5 (2005).

[4] J. Jiang, R. Saito , A. Gruneis, S. G. Chou, Ge. G. Samsonidze, A. Jorio, G. Dresselhaus and M. S. Dresselhaus : Intensity of the resonance Raman excitation spectra of single-wall carbon nanotubes, Phys. Rev. B **71**, 205420-1-13 (2005).

[5] Y. Maeda, S. Kimura, M. Kanda, Y. Hirashima, T. Hasegawa, T. Wakahara, Y. Lian, T. Nakahodo, T. Tsuchiya, T. Akasaka, J. Lu, S. Nagase, S. Kazaoui, N. Minami, T. Shimizu, H. Tokumoto, R. Saito : Large-scale separation of metallic and semiconducting single-wall carbon nanotubes, J. Amer. Chem. Soc. **127**, 10287-10290 (2005).

[6] M. S. Dresselhaus, Ge. G. Samsonidze, S. G. Chou, G. Dresselhaus, J. Jiang, R. Saito , A. Jorio : Recent Advances in Carbon Nanotube Photophysics, Physica E **29**, 443-446 (2005).

[7] S. Roche, J. Jiang, F. Triozon, R. Saito : Quantum Decoherence in carbon nanotubes due to electron-phonon coupling, Phys. Rev. Lett **95**, 076803-1-4 (2005).

[8] A. Jorio, A. P. Santos, H. B. Ribeiro, C. Fantini, M. Souza, J. P. M. Vieria, C. A. Furutado, J. Jiang, R. Saito , L. Balzano, D. E. Resasco, M. A. Pimenta : Quantifying carbon nanotube species with resonance Raman scattering, Phys. Rev. B **72**, 075207-1-5 (2005).

[9] C. Fantini, A. Jorio, M. Souza, R. Saito , Ge. G. Samsonidze, M. S. Dresselhaus, and M. A. Pimenta : Step-like dispersion of the intermediate frequency Raman modes in semiconducting and metallic carbon nanotubes, Phys. Rev. B **72**, 085446-1-5 (2005).

[10] S. Roche, J. Jiang, F. Triozon, R. Saito : Conductance and Coherence Lengths in Disordered Carbon Nanotubes : Role of Lattice Defects and Phonon Vibrations, Phys. Rev. B **72**, 113410-1-4 (2005).

[11] U. J. Kim, X. M. Liu, C. A. Furtado, G. Chen, R. Saito , J. Jiang, M. S. Dresselhaus, P. C. Eklund : Infrared-active Vibrational Modes of Single-Walled Carbon Nanotubes, Phys. Rev. Lett. **95**, 157402-1-4 (2005).

[12] R. Saito , K. Sato, Y. Oyama, J. Jiang, Ge. G. Samsonidze, G. Dresslhaus, M. S. Dresselhaus : Cutting lines near the Fermi energy of single wall carbon nanotubes, Phys. Rev. B **72**, 153413-1-4 (2005).

[13] S. G. Chou, M. F. DeCamp, J. Jiang, Ge. G. Samsonidze, E. B. Barros, F. Plentz Filho, A. Jorio, M. Zheng, G. B. Onoa, E. D. Semke, A. Tokmakoff, R. Saito , G. Dresselhaus, M. S. Dresselhaus : A study of phonon-assisted exciton relaxation dynamics for a (6,5) enriched DNA-wrapped single walled carbon nanotube sample, Phys. Rev. B **72**, 195415 (2005).

[14] A. G. Souza Filho, N. Kobayashi, J. Jiang, A. Gruneis, R. Saito , S. B. Cronin, J. Mendes Filho, Ge. G. Samsonidze, G. Dresselhans, M. S. Dresselhaus : Strain-induced quantum interference effects on the resonant Raman cross section of carbon nanotubes, Phys. Rev. Lett. **95**, 217403-1-4 (2005).

[15] Q. H. Yang, P. X. Hou, M. Unno, S. Yamauchi, R. Saito , T. Kyotani : Dual Raman features of double coaxial carbon nanotubes with N-doped and B-doped multiwalls, Nano Letters **5**, 2465-2469 (2005).

[16] J. Jiang, R. Saito , Ge. G. Samsonidze, S. G. Chou, A. Jorio, G. Dresselhaus and M. S. Dresselhaus : Electron-phonon matrix elements in single-wall carbon nanotubes, Phys. Rev. B **72**, 235408-1-11 (2005).

[17] Y. Oyama, R. Saito , K. Sato, J. Jiang, Ge. G. Samsonidze, A. Grüneis, Y. Miyauchi, S. Maruyama, A. Jorio, G. Dresselhaus, M. S. Dresselhaus : Photoluminescomce intensity of single-wall carbon nanotubes, Carbon **44**, 873-879 (2006).

[18] A. Jorio, C. Fantini, M. A. Pimenta, D. A. Heller, M. S. Strano, M. S. Dresselhaus, Y. Oyama, J. Jiang, R. Saito : Carbon nanotube population analysis from Raman and photoluminescence intensities, Appl. Phys. Lett. **88**, 023109-1-3 (2006).

[19] K. Sasaki, M. Murakami, R. Saito : Stabilization mechanism of edge states in graphene, Appl. Phys. Lett. **88**, 113110-1-3 (2006).

[20] T. Okazaki, T. Saito, K. Matsuura, S. Ohshima, M. Yumura, Y. Oyama R. Saito , S. Iijima : Photoluminescence and population analysis of single walled carbon nanotubes produced by CVD and pulsed-laser vaporization methods, Chem. Phys. Lett. **420**, 286-290 (2006).

[21] S. Latil, S. Roche, F. Triozon, J. Jiang, R. Saito : Mesoscopic transport in carbon nanotubes: nobel features, Phys. Stat. Sol. (a) **203**, 1100-1104 (2006).

[22] R. Saito: Nanotube, Encycropedia of Physics, Section 21.2.2, pp.789-795, Asakura Pub. Co. Ltd., (2005)

[23] W. Izumida. M. Grifoni : Phonon-assisted tunneling in interacting suspended single wall carbon nanotubes, New J. Phys. **7**, 244-1-13 (2005).

Master Theses (2005.3)

M1) Double resonance Raman spectroscopy of carbon nanotubes, by K. Sato
M2) Scattering processes and photoluminescence intensity of carbon nanotube by Y. Oyama.