

Bibliography

1. Iijima, S. (1991). Helical microtubules of graphitic carbon, *Nature*, **354**, pp. 56–58.
2. Osawa, E. (1970). Superaromaticity, *Kagaku*, **25**, pp. 854–863. (in Japanese).
3. Kroto, H. W. Heath, J. R., O'Brien, S. C., Curl, R. F., and Smalley, R. E. (1985). C₆₀: Buckminsterfullerene, *Nature*, **318**, pp. 162–163.
4. Zhao, J., and Zhu, J. (2011). Electron microscopy and *in situ* testing of mechanical deformation of carbon nanotubes, *Micron*, **42**, pp. 663–679.
5. Radushkevich, L. V., and Lukyanovich, V. M. (1952). O strukture ugleroda, obrazujucegosja pri termiceskom razlozenii okisi ugleroda na zeleznom kontakte, *Zurn. Fisic. Chim.*, **26**, pp. 88–95. [Translated into *Russ. J. Phys. Chem.*, **26**, pp. 88–95 (1952)].
6. Oberlin, A., Endo, M., and Koyama, T. (1976). Filamentous growth of carbon through benzene decomposition, *J. Cryst. Growth.*, **32**, pp. 335–349.
7. Boehm, H. P. (1997). The first observation of carbon nanotubes, *Carbon*, **35**, pp. 581–584.
8. Monthoux, M., and Kuznetsov, V. L. (2006). Who should be given the credit for the discovery of carbon nanotubes? *Carbon*, **44**, pp. 1621–1623.
9. The talk was presented in 1979, but the relevant paper was published in 1999 as: Abrahamson, J., Wiles, P. G., and Rhoades, B. L. (1999). Structure of Carbon Fibers Found on Carbon Arc Anodes *Carbon*, **37** pp. 1873–1874.
10. US 4663230, Tennent, Howard G., Carbon fibrils, method for producing same and compositions containing same, issued 1987-05-05.
11. Poncharal, P., Wang, Z. L., Ugarte, D., and de Heer, W. A. (1999). Electrostatic deflections and electromechanical resonances of carbon nanotubes, *Science*, **283**, pp. 1513–1516.

12. Gaillard, J., Skove, M. J., Ciocan, R., and Rao, A. M. (2006) Electrical detection of oscillations in microcantilevers and nanocantilevers, *Rev. Sci. Instrum.*, **77**, p. 073907.
13. Keskar, G., Elliott, B., Gaillard, J., Skove, M. J., Rao, A. M. (2008) Using electric actuation and detection of oscillations in microcantilevers for pressure measurements, *Sens. Actuators A*, **147**, pp. 203–209.
14. Salvat, J.-P., Andrew, G., Briggs, D., Bonard, J.-M., Bacsa, R. R., Kulik, A. J., Stöckli, T., Burnham, N. A., and Forró, L. (1999). Elastic and shear moduli of single-walled carbon nanotube ropes. *Phys. Rev. Lett.*, **82**(5), pp. 944–947.
15. Kreyszig, E. (1993). *Advanced Engineering Mathematics* (7th edn.), (Wiley, New York), pp. 643–644.
16. Treacy, M. M. J., Ebbesen, T. W., and Gibson, J. M. (1996). Exceptionally high Young's modulus observed for individual carbon nanotubes, *Nature*, **381**, pp. 678–680.
17. Krishnan, A., Dujardin, E., Ebbesen, T. W., Yianilos, P. N., and Treacy, M. M. J. (1998). Young's modulus of single-walled nanotubes, *Phys. Rev. B*, **58**, pp. 14013–14019.
18. Chopra, N. G., and Zettl A. (1998). Measurement of the elastic modulus of a multi-wall boron nitride nanotube, *Solid State Commun.*, **105**, pp. 297–300.
19. Wang, Z. L., Poncharal, P., and de Heer, W. A. (2000). Measuring physical and mechanical properties of individual carbon nanotubes by *in situ* TEM, *J. Phys. Chem. Solid.*, **61**, pp. 1025–1030.
20. Griffiths, D. J., and Li, Y. (1996). Charge density on a conducting needle, *Am. J. Phys.*, **64**, pp. 706–714.
21. Meirovich, L. (1986). *Elements of Vibration Analysis*, 2nd ed. (McGraw-Hill, New York).
22. Ruoff, R. S., and Lorents, D. C. (1995). Mechanical and thermal properties of carbon nanotubes, *Carbon*, **33**(7), pp. 925–930.
23. Kuzumaki, T., Hayashi, T., Ichinose, H., Miyazawa, K., Ito, K. and Ishida, Y. (1998). *In-situ* observed deformation of carbon nanotubes, *Phil. Mag. A*, **77**(6), pp. 1461–1469.
24. Wong, E. W., Sheehan, P. E., and Lieber, C. M. (1997). Nanobeam mechanics: elasticity, strength, and toughness of nanorods and nanotubes, *Science*, **277**(5334), pp. 1971–1975.
25. Sheehan, P. E., and Lieber, C. M. (1996). Nanomachining, Manipulation and Fabrication by Force Microscopy, *Nanotechnology*, **7**, pp. 236–240.

26. Salvatat J.-P., Kulik, A. J., Bonard J.-M., Briggs, G. A. D., Stöckli, T., Méténier, K., Bonnamy, S., Béguin, F., Burnham, N. A., and Forró L., (1999). Elastic Modulus of Ordered and Disordered Multiwalled Carbon Nanotubes *Adv. Mater.*, **11**, pp. 161–165.
27. Kis, A., Csányi G., Salvatat J.-P., Lee, T.-N., Couteau, E., Kulik. A. J., Benoit, W., Brugger, J., and Forró, L. (2004). Reinforcement of single-walled carbon nanotube bundles by intertube bridging. *Nature Mater.*, **3**, pp. 153–157.
28. Kis, A., Jensen, K., Aloni, S., Mickelson, W., and Zettl, A. (2006). Interlayer forces and ultralow sliding friction in multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **97**, pp. 025501_1–025501_4.
29. Yu, M.-F., Lourie, O., Dyer, M. J., Moloni, K., Kelly, T. F., and Ruoff, R. S. (2000). Strength and Breaking Mechanism of Multiwalled Carbon Nanotubes Under Tensile Load. *Science*, **287**(5453), pp. 637–640.
30. Yu, M.-F., Files, B. S., Arepalli, S., and Ruoff, R. S. (2000). Tensile loading of ropes of single wall carbon nanotubes and their mechanical properties, *Phys. Rev. Lett.*, **84**, pp. 5552–5555.
31. Iijima, S., Brabec, C., Maiti, A., and Bernholc, J. (1996). Structural flexibility of carbon nanotubes, *J. Chem. Phys.*, **104**, pp. 2089–2092.
32. Yakobson, B. I., Brabec, C. J., and Bernholc, J. (1996). Nanomechanics of carbon tubes: instabilities beyond linear response. *Phys. Rev. Lett.*, **76**(14), pp. 2511–2514.
33. Hernández, E., Goze, C., Bernier, P., and Rubio, A. (1998). Elastic properties of C and BxCyNz composite nanotubes, *Phys. Rev. Lett.*, **80**, pp. 4502–4505.
34. Srivastava, D., Menon, M., and Cho, K. (1999). Nanoplasticity of single-wall carbon nanotubes under uniaxial compression, *Phys. Rev. Lett.*, **83**, pp. 2973–2976.
35. Sánchez-Portal, D., Artacho, E., Soler, J. M., Rubio, A., and Ordejón, P. (1998). *Ab initio* structural, elastic, and vibrational properties of carbon nanotubes, *Phys. Rev. B*, **59**, pp. 12678–12688.
36. Hohenberg, P., and Kohn, W. (1964). Inhomogeneous electron gas, *Phys. Rev.*, **136**, pp. B864–B871.
37. Kohn, W., and Sham, L. J. (1965). Self-consistent equations including exchange and correlation effects, *Phys. Rev.*, **140**, pp. A1133–A1138.
38. Car, R., and Parrinello, M. (1985). Unified approach for molecular dynamics and density-functional theory, *Phys. Rev. Lett.*, **55**, pp. 2471–2474.

39. Payne, M. C., Teter, M. P., Allan, D. C., Arias, T. A., and Joannopoulos J. D. (1992). Iterative minimization techniques for *ab initio* total-energy calculations: molecular-dynamics and conjugate gradients, *Rev. Mod. Phys.*, **64**, pp. 1045–1097.
40. Slater, J. C., and Koster, G. F. (1954). Simplified LCAO Method for the Periodic Potential Problem, *Phys. Rev.*, **94**, pp. 1498–1594.
41. Verlet, L. (1967). Computer “experiments” on classical fluids. I. Thermodynamical properties of lennard-jones molecules, *Phys. Rev.*, **159**, pp. 98–103.
42. Cao, G., and Chen, X. (2006a). Mechanisms of nanoindentation on single-walled carbon nanotubes: the effect of nanotube length, *J. Mater. Res.*, **21**, pp. 1048–1070, and Cao, G., Chen, X., and Kysar, J. W. (2006a). Numerical analysis of the radial breathing mode of individual armchair and zigzag single-walled carbon nanotubes under deformation, *J. Appl. Phys.*, **100**, pp. 124305–124314.
43. Kundin, K. N., Scuseria, G. E., and Yakobson, B. I. (2001). C₂F, BN, and C nanoshell elasticity from *ab initio* computations, *Phys. Rev. B*, **64**, pp. 235406_1–235406_10.
44. Porezag, D., Frauenheim, Th., Kohler, Th., Seifert, G., and Kascher, R. (1995). Construction of tight-binding-like potentials on basis of density-functional theory: application to carbon, *Phys. Rev. B*, **51**, pp. 12947–12957.
45. Nardelli, M., and Bernholc, J. (1999). Mechanical deformations and coherent transport in carbon nanotubes, *Phys. Rev. B*, **60**, pp. 16338–16341.
46. Zhang, P., Lammert, P. E., Crespi, V. H. (1998). Plastic deformations of carbon nanotubes, *Phys. Rev. Lett.*, **81**, pp. 5346–5349.
47. Sun, H. (1998). COMPASS: an *ab initio* force field optimized for condensed-phase applications. Overview with details on alkane and benzene compounds, *J. Phys. Chem. B*, **102**, pp. 7338–7364.
48. Cao, G., and Chen, X. (2006). Buckling behaviors of the single-walled carbon nanotubes and a targeted-molecular dynamics simulation, *Phys. Rev. B*, **74**, pp. 165422_1–165422_10.
49. Cao, G., and Chen, X. (2006). The effect of displacement increment on the axial compressive buckling behavior of single-walled carbon nanotubes, *Nanotechnology*, **17**, pp. 3844–3855.
50. Cao, G., and Chen, X. (2007). The effects of chirality and boundary conditions on the mechanical properties of single-walled carbon nanotubes, *Int. J. Solids Struct.*, **44**, pp. 5447–5465.

51. Abell, G. C. (1985). Empirical chemical pseudopotential theory of molecular and metallic bonding, *Phys. Rev. B*, **31**, pp. 6184–6196.
52. Tersoff, J. (1987). New empirical approach for the structure and energy of covalent systems, *Phys. Rev. B*, **37**(12), pp. 6991–7000.
53. Tersoff, J. (1988). Empirical interatomic potential for carbon, with applications to amorphous carbon, *Phys. Rev. Lett.*, **61**, pp. 2879–2882.
54. Tersoff, J. (1988) New empirical approach for the structure and energy of covalent systems, *Phys. Rev. B*, **37**, pp. 6991–7000.
55. Tersoff, J. (1989). Modeling solid-state chemistry: interatomic potentials for multicomponent systems, *Phys. Rev. B*, **39**, pp. 5566–5568.
56. Brenner, D. W. (1990). Empirical potential for hydrocarbons for use in simulating the chemical vapor deposition of diamond films, *Phys. Rev. B*, **42**, pp. 9458–9471.
57. Brenner, D. W., Shenderova, O. A., Harrison, J. A., Stuart, S. J., Ni, B., and Sinnott, S. B. (2002). A second-generation reactive empirical bond order (REBO) potential energy expression for hydrocarbons, *J. Phys. Condens. Mat.*, **14**, pp. 783–802.
58. Srivastava, D., Wei, C., and Cho, K. (2003). Nanomechanics of carbon nanotubes and composites, *Appl. Mech. Rev.*, **56**, pp. 215–230.
59. Robertson, D. H., Brenner, D. W., and Mintmire J. W. (1992). Energetics of nanoscale graphitic tubules, *Phys. Rev. B*, **45**(21), pp. 12592–12595.
60. Tibbetts, G. G. (1983). Why are carbon filaments tubular? *J. Cryst. Growth*, **66**, pp. 632–638.
61. Lu, J. P. (1997). Elastic properties of carbon nanotubes and nanoropes, *Phys. Rev. Lett.*, **79**, pp. 1297–1300.
62. Soler, J. M., Artacho, E., Gale, J. D., García, A., Junquera, J., Ordejón, P., and Sánchez-Portal, D. (2002). The SIESTA method for *ab initio* order-N materials simulation, *J. Phys. Condens. Mat.*, **14**, pp. 2745–2779.
63. Hernández, E., Goze, C., Bernier, P., and Rubio, A. (1999). Elastic properties of single-wall nanotubes, *Appl. Phys. A*, **68**, pp. 287–292.
64. Chandraseker, K., and Mukherjee, S. (2007). Atomistic-continuum and *ab initio* estimation of the elastic moduli of single-walled carbon nanotubes *Comp. Mater. Sci.*, **40**, pp. 147–158.
65. Kelly B. K. (1981). *Physics of Graphite* (Applied Science, London).
66. Dresselhaus, M. S., and Dresselhaus, G. (1998). *Graphite Fibers and Filaments* (Springer, Berlin, Heidelberg).
67. Iijima, S., Brabec, C., Maiti, A., and Bernholc, J. (1995). Structural flexibility of carbon nanotubes, *J. Chem. Phys.*, **104**, pp. 2082–2093.

68. Cornwell, C. F., and Wille, L. T. (1997). Elastic properties of single-walled carbon nanotubes in compression, *Solid State Commun.*, **101**, pp. 555–558.
69. Popov, V. N., Van Doren V. E., and Balkanski, M. (2000). Elastic properties of single-walled carbon nanotubes, *Phys. Rev. B*, **61**, pp. 3078–3084.
70. Chang, T., and Gao, H. (2003). Size-dependent elastic properties of a single-walled carbon nanotube via a molecular mechanics model, *J. Mech. Phys. Solids*, **51**, pp. 1059–1074.
71. Arroyo, M., and Belytschko, T. (2005). Continuum mechanics modeling and simulation of carbon nanotubes, *Mechanica*, **40**, pp. 455–469.
72. Landau, L. D., and Lifshitz, E. M. (1986). *Theory of Elasticity, 3rd ed.* (Pergamon, New York).
73. Timoshenko, S., and Goodier, S. N. (1970). *Theory of Elasticity, 3rd ed.* (McGraw-Hill).
74. Odegard, G. M., Gates, T. S., Nicholson, L. M., Wise, K. E. (2002). Equivalent-continuum modeling of nano-structured materials, *Comp. Sci. Tech.*, **62**, pp. 1869–1880.
75. Jin, Y., and Yuan, F. G. (2003). Simulation of elastic properties of single-walled carbon nanotubes, *Comp. Sci. Tech.*, **63**, pp. 1507–1515.
76. Vodenitcharova, T., and Zhang, L. C. (2003). Effective wall thickness of a single-walled carbon nanotube, *Phys. Rev. B*, **68**, pp. 165401_1–165401_4.
77. Goupalov, S. V., (2005). Continuum model for long-wavelength phonons in two-dimensional graphite and carbon nanotubes, *Phys. Rev. B*, **71**, pp. 085420_1–085420_7.
78. Wang, L., Zheng, Q., Liu, J. Z., and Jiang, Q., (2005). Size Dependence of the thin-shell model for carbon nanotubes, *Phys. Rev. Lett.*, **95**, pp. 105501_1–105501_4.
79. Harik, V. M. (2002). Mechanics of carbon nanotubes: applicability of the continuum-beam models, *Comput. Mater. Sci.*, **24**, pp. 328–342.
80. Arroyo, M., and Belytschko, T. (2002). An atomistic-based finite deformation membrane for single layer crystalline films, *J. Mech. Phys. Solids*, **50**, pp. 1941–1977.
81. Zhang, P., Huang, Y., Geubelle, P. H., Klein, P. A., and Hwang, K. C. (2002). The elastic modulus of single-wall carbon nanotubes: a continuum analysis incorporating interatomic potentials, *Int. J. Solids Struct.*, **39**, pp. 3893–3906.

82. Li, C., and Chou, T.-W. (2003). A structural mechanics approach for the analysis of carbon nanotubes, *Int. J. Solids Struct.*, **40**, pp. 2487–2499.
83. Lier, G. V., Alsenoy, C. V., Doren, V. V., and Geerlings, P. (2000). *Ab initio* study of the elastic properties of single-walled carbon nanotubes and graphene, *Chem. Phys. Lett.*, **326**, pp. 181–185.
84. Ruoff, R. S., and Lorents, D. C. (1995). Mechanical and thermal properties of carbon nanotubes, *Carbon*, **33**, pp. 925–930.
85. Lu, J. P. (1997). Elastic properties of single and multilayered nanotubes, *J. Phys. Chem. Solid.*, **58**, pp. 1649–1652.
86. Timoshenko, S., and Woinowsky-Krieger, W. (1959). *Theory of Plates and Shells*, 2nd ed. (McGraw-Hill).
87. Tserpes, K. J., and Papanikos, P. (2005). Finite element modeling of single-walled carbon nanotubes, *Composites B*, **36**, pp. 468–477.
88. See the official Web site: <http://www.ansys.com/>.
89. Kalamkarov, A. L., Georgiades, A. V., Rokkam, S. K., Veedu, V. P., Ghasemi-Nejhad, M. N. (2006). Analytical and numerical techniques to predict carbon nanotubes properties, *Int. J. Solids Struct.*, **43**, pp. 6832–6854.
90. Wan, H., and Delale, F. (2010). A structural mechanics approach for predicting the mechanical properties of carbon nanotubes, *Meccanica*, **45**, pp. 43–51.
91. Ru, C. Q. (2000) Column buckling of multiwalled carbon nanotubes with interlayer radial displacements, *Phys. Rev. B*, **62**, pp. 16962–16967.
92. Lucas, A. A., Lambin, P. H., and Smalley, R. E. (1993). On the energetics of tubular fullerenes, *J. Phys. Chem. Solid.*, **54**, pp. 587–593.
93. Tu, Z. C., and Yang, Z. C. O. (2002). Single-walled and multiwalled carbon nanotubes viewed as elastic tubes with the effective Young's moduli dependent on layer number, *Phys. Rev. B*, **65**, pp. 233407_1–233407_4.
94. Huang, Y., Wu, J., and Hwang, K. (2006). Thickness of graphene and single-wall carbon nanotubes, *Phys. Rev. B*, **74**, pp. 245413_1–245413_9.
95. Chen, X., and Cao, G. (2006). A structural mechanics approach of single-walled carbon nanotubes generalized from atomistic simulation, *Nanotechnology*, **17**, pp. 1004–1015.
96. Pantano, A., Boyce, M. C., and Parks, D. M. (2003). Nonlinear structural mechanics based modeling of carbon nanotube deformation, *Phys. Rev. Lett.*, **91**, pp. 145501–145504.

97. Zhou, X., Zhou, J. J., and Ou-Yang, Z. C. (2000). Strain energy and Young's modulus of single-wall carbon nanotubes calculated from electronic energy-band theory, *Phys. Rev. B*, **62**, pp. 13692–13696.
98. Lu, Q., Arroyo, M., and Huang, R. (2009). Elastic bending modulus of monolayer graphene, *J. Phys. D: Appl. Phys.*, **42**, 102002.
99. Jiang, H., Zhang, P., Liu, B., Huang, Y., Geubelle, P. H., Gao, H., and Hwang, K. C. (2003). The effect of nanotube radius on the constitutive model for carbon nanotubes, *Comput. Mater. Sci.*, **28**, pp. 429–442.
100. Jiang, H., Feng, X. Q., Huang, Y., Hwang, K. C., and Wu, P. (2004a). Defect nucleation in carbon nanotubes under tension and torsion: Stone-Wales transformation, *Comput. Methods Appl. Mech. Eng.*, **193**, pp. 3419–3429.
101. Zhang, P., Huang, Y., Gao, H., and Hwang, K. C. (2002a). Fracture nucleation in single-wall carbon nanotubes under tension: a continuum analysis incorporating interatomic potentials, *J. Appl. Mech. Rev.*, **69**, pp. 454–458.
102. Zhang, P., Huang, Y., Geubelle, P. H., and Hwang, K. C. (2002b). On the continuum modeling of carbon nanotubes, *Acta Mech. Sin.*, **18**, pp. 528–536.
103. Jiang, H., Huang, Y., Zhang, P., and Hwang, K. C. (2006). *Fracture Nucleation in Single-Wall Carbon Nanotubes: The Effect of Nanotube Charality* (Springer, Dordrecht).
104. Zhang, P., Huang, Y., Geubelle, P. H., Klein, P. A., and Hwang, K. C. (2002c). The elastic modulus of single-wall carbon nanotubes: a continuum analysis incorporating interatomic potentials, *Int. J. Solids Struct.*, **39**, pp. 3893–3906.
105. Zhang, P., Jiang, H., Huang, Y., Geubelle, P. H., and Hwang, K. C. (2004). An atomistic-based continuum theory for carbon nanotubes: analysis of fracture nucleation, *J. Mech. Phys. Solids*, **52**, pp. 977–998.
106. Shi, D. L., Feng, X. Q., Jiang, H., Huang, Y., and Hwang, K. C. (2005). Multiscale analysis of fracture of carbon nanotubes embedded in composites, *Int. J. Fract.*, **134**, pp. 369–386.
107. Song, J., Huang, Y., Jiang, H., Hwang, K. C., and Yu, M. F. (2006a). Deformation and bifurcation analysis of boron-nitride nanotubes, *Int. J. Mech. Sci.*, **48**, pp. 1197–1207.
108. Song, J., Jiang, H., Shi, D. L., Feng, X. Q., Huang, Y., Yu, M. F., and Hwang, K. C. (2006b). Stone-Wales transformation: precursor of fracture in carbon nanotubes, *Int. J. Mech. Sci.*, **48**, pp. 1464–1470.

109. Jiang, H., Liu, B., Huang, Y., and Hwang, K. C. (2004b). Thermal expansion of single-wall carbon nanotubes, *J. Eng. Mater. Technol.*, **126**, pp. 265–270.
110. Jiang, H., Huang, Y., and Hwang, K. C. (2005). A finite-temperature continuum theory based on the interatomic potential, *J. Eng. Mater. Technol.*, **127**, pp. 408–416.
111. Johnson, H. T., Liu, B., and Huang, Y. (2004). Electron transport in deformed carbon nanotubes, *J. Eng. Mater. Technol.*, **126**, pp. 222–229.
112. Liu, B., Huang, Y., Jiang, H., Qu, S., and Hwang, K. C. (2004a). The atomic-scale finite-element method, *Comput. Methods Appl. Mech. Eng.*, **193**, pp. 1849–1864.
113. Chandraseker, K., Mukherjee, S., and Mukherjee, Y. X. (2006). Modifications to the Cauchy–Born rule: applications in the deformation of single-walled carbon nanotubes, *Int. J. Solids Struct.*, **43**, pp. 7128–7144.
114. Liu, B., Jiang, H., Johnson, H. T., and Huang, Y. (2004b). The influence of mechanical deformation on the electrical properties of single-wall carbon nanotubes, *J. Mech. Phys. Solids*, **52**, pp. 1–26.
115. Arroyo, M., and Belytschko, T. (2004). Finite crystal elasticity of carbon nanotubes based on the exponential Cauchy–Born rule, *Phys. Rev. B*, **69**, pp. 115415_1–115415_11.
116. Srolovitz, D. J., Safran, S. A., and Tenne, R. (1994). Elastic equilibrium of curved thin films, *Phys. Rev. E*, **49**, pp. 5260–5270.
117. Cao, G., and Chen, X. (2006c). Buckling of single-walled carbon nanotubes under bending: molecular dynamics and finite element simulations, *Phys. Rev. B*, **73**, pp. 155435_1–155435_10.
118. Pantano, A., Parks, D. M., and Boyce, M. C. (2004). Mechanics of deformation of single- and multiwall carbon nanotubes, *J. Mech. Phys. Solids*, **52**, pp. 789–821.
119. Popov, V. N., Van Doren, V. E., and Balkanski, M. (2000). Elastic properties of crystals of single-walled carbon nanotubes, *Solid State Commun.*, **114**, pp. 395–399.
120. Saether, E., Frankland, S. J. V., and Pipes, R. B. (2003). Transverse mechanical properties of single-walled carbon nanotube crystals. Part I: determination of elastic moduli, *Compos. Sci. Technol.*, **63**, pp. 1543–1550.
121. Wang, C. M., Zhang, Y. Y., Xiang, Y., and Reddy, J. N. (2010). Recent studies on buckling of carbon nanotubes, *Appl. Mech. Rev.*, **63**, 030804_1–030804_18.

122. Shima, H. (2012). Buckling of carbon nanotubes: A state of the art review, *Materials*, **5**, pp. 47–84.
123. Brush, D. O., and Almroth, B. O. (1975). *Buckling of bars, plates, and shells* (McGraw-Hill)
124. Ru, C. Q. (2000). Effect of Van der Waals forces on axial buckling of a doublewalled carbon nanotube, *J. Appl. Phys.*, **87**, pp. 7227–7231.
125. Ru, C. Q. (2001). Axially compressed buckling of a doublewalled carbon nanotube embedded in an elastic medium, *J. Mech. Phys. Solids*, **49**, pp. 1265–1279.
126. Ru, C. Q. (2001). Degraded axial buckling strain of multiwalled carbon Nanotubes due to interlayer slips, *J. Appl. Phys.*, **89**, pp. 3426–3433.
127. Ni, B., Sinnott, S. B., Mikulski, P. T., and Harrison, J. A. (2002). Compression of carbon nanotubes filled with C₆₀, CH₄, or Ne: predictions from molecular dynamics simulations, *Phys. Rev. Lett.*, **88**(20), pp. 205505.1–205505.4.
128. Buehler, M. J., Kong, J., and Gao, H. J. (2004). Deformation mechanism of very long single-wall carbon nanotubes subject to compressive loading, *ASME J. Eng. Mater. Technol.*, **126**, pp. 245–249.
129. Waters, J. F., Riester, L., Jouzi, M., Guduru, P. R., and Xu, J. M. (2004). Buckling instabilities in multiwalled carbon nanotubes under uniaxial compression, *Appl. Phys. Lett.*, **85**, pp. 1787–1789.
130. Pantano, A., Boyce, M. C., and Parks, D. M. (2004). Mechanics of axial compression of single- and multi-wall carbon nanotubes, *ASME J. Eng. Mater. Technol.*, **126**, pp. 279–284.
131. Waters, J. F., Guduru, P. R., Jouzi, M., Xu, J. M., Hanlon, T., and Suresh, S. (2005). Shell buckling of individual multi-walled carbon nanotubes using nanoindentation, *Appl. Phys. Lett.*, **87**(10), pp. 103109.1–103109.3.
132. Sears, A., and Batra, R. C. (2006). Buckling of multiwalled carbon nanotubes under axial compression, *Phys. Rev. B*, **73**, pp. 085410.1–085410.11.
133. Zhang, Y. Y., Wang, M., and Tan, V. B. C. (2008). Examining the effects of wall numbers on buckling behavior and mechanical properties of multiwalled carbon nanotubes via molecular dynamics simulations, *J. Appl. Phys.*, **103**, pp. 053505.1–053505.9.
134. Falvo, M. R., Clary G. J., Taylor II, R. M., Chi V., Brooks Jr, F. P., Washburn S., and Superfine, R. (1997). Bending and buckling of carbon nanotubes under large strain, *Nature*, **389**, pp. 582–584.

135. Duan, X. J., Tang, C., Zhang, J., Guo, W. L., and Liu, Z. F. (2007). Two distinct buckling modes in carbon nanotube bending, *Nano Lett.*, **7**, pp. 143–148.
136. Shibusaki, Y., and Ogata, S. (2004). Mechanical integrity of carbon nanotubes for bending and torsion, *Modell. Simul. Mater. Sci. Eng.*, **12**, pp. 599–610.
137. Kutana, A., and Giapis, K. P. (2006). Transient deformation regime in bending of single-walled carbon nanotubes, *Phys. Rev. Lett.*, **97**, pp. 245501_1–245501_4.
138. Yang, H. K., and Wang, X. (2006). Bending stability of multi-wall carbon nanotubes embedded in an elastic medium, *Modell. Simul. Mater. Sci. Eng.*, **14**, pp. 99–116.
139. Wang, X., and Yang, H. K. (2006). Bending stability of multiwalled carbon nanotubes, *Phys. Rev. B*, **73**(8), pp. 085409_1–085409_8.
140. Wang, Q., Liew, K. M., He, X. Q., and Xiang, Y. (2007). Local buckling of carbon nanotubes under bending, *Appl. Phys. Lett.*, **73**(91), pp. 093128_1–093128_3.
141. Jeong, B. W., Lim, J. K., and Sinnott, S. B. (2007). Turning stiffness of carbon nanotube systems, *Appl. Phys. Lett.*, **91**, pp. 093102_1–093102_3.
142. Yang, H. K., and Wang, X. (2007). Torsional buckling of multi-wall carbon nanotubes embedded in an elastic medium, *Compos. Struct.*, **77**, pp. 182–192.
143. Zhang, Y. Y., and Wang, C. M. (2008). Torsional responses of double-walled carbon nanotubes via molecular dynamics simulations, *J. Phys.: Condens. Matter*, **20**(45), pp. 455214_1–455214_7.
144. Wang, Q. (2008). Torsional buckling of double-walled carbon nanotubes, *Carbon*, **46**, pp. 1172–1174.
145. Wang, Q. (2009). Transportation of hydrogen molecules using carbon nanotube in torsion, *Carbon*, **47**, pp. 1870–1873.
146. Wang, X., Sun, B., and Yang, H. K. (2006). Stability of multi-walled carbon nanotubes under combined bending and axial compression loading, *Nanotechnology*, **17**, pp. 815–823.
147. Lu, Y. J., and Wang, X. (2006). Combined torsional buckling of multi-walled carbon nanotubes, *J. Phys. D*, **39**, pp. 3380–3387.
148. Wang, X., Lu, G. X., and Lu, Y. J. (2007). Buckling of embedded multi-walled carbon nanotubes under combined torsion and axial loading, *Int. J. Solids Struct.*, **44**, pp. 336–351.

149. Zhang, C. L., and Shen, H. S. (2007). Buckling and postbuckling of single-walled carbon nanotubes under combined axial compression and torsion in thermal environments, *Phys. Rev. B*, **75**, pp. 045408_1–045408_7.
150. Jeong, B. W., Lim, J. K., and Sinnott, S. B. (2008). Tuning the torsional properties of carbon nanotube systems with axial prestress, *Appl. Phys. Lett.*, **92**, pp. 253114_1–253114_3.
151. Bower, C., Rosen, R., Jin, L., Han, J., and Zhou, O. (1999). Deformation of carbon nanotubes in nanotube–polymer composites, *Appl. Phys. Lett.*, **74**, pp. 3317–3319.
152. Arroyo, M., and Belytschko, T. (2003). Nonlinear mechanical response and rippling of thick multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **91**, pp. 215505_1–215505_4.
153. Chang, T., and Hou, J. (2006). Molecular dynamics simulations on buckling of multiwalled carbon nanotubes under bending, *J. Appl. Phys.*, **100**, pp. 114327_1–114327_5.
154. Li, X. Y., Yang, W., and Liu, B. (2007). Bending induced rippling and twisting of multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **98**, pp. 205502_1–205502_4.
155. Arias, I., and Arroyo, M. (2008). Size-dependent nonlinear elastic scaling of multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **100**, pp. 085503_1–085503_4.
156. Arroyo, M., and Arias, I. (2008). Rippling and a phase-transforming mesoscopic model for multiwalled carbon nanotubes, *J. Mech. Phys. Solids*, **56**, pp. 1224–1244.
157. Huang, X., Zou, J., and Zhang, S. L. (2008). Bilinear responses and rippling morphologies of multi-walled carbon nanotubes under torsion, *Appl. Phys. Lett.*, **93**, pp. 031915_1–031915_3.
158. Zou, J., Huang, X., Arroyo, M., and Zhang, S. L. (2009). Effective coarse-grained simulations of super-thick multi-walled carbon nanotubes under torsion, *J. Appl. Phys.*, **105**, pp. 033516_1–033516_8.
159. Huang, X., Yuan, H. Y., Hsia, K. J., and Zhang, S. L. (2010). Coordinated buckling of thick multi-walled carbon nanotubes under uniaxial compression, *Nano Res.*, **3**(1), pp. 32–42.
160. Knechtel, W. H., Dusberg, G. S., Blau, W. J., Hernandez, E., and Rubio, A. (1998). Reversible bending of carbon nanotubes using a transmission electron microscope, *Appl. Phys. Lett.*, **73**, pp. 1961–1963.
161. Lourie, O., Cox, D. M., and Wagner, H. D. (1998). Buckling and collapse of embedded carbon nanotubes, *Phys. Rev. Lett.*, **81**, pp. 1638–1641.

162. Thomas, W., Tombler, Zhou, C., Alexseyev, L., Kong, J., Dai, H., Liu, L., Jayanthi, C. S., Tang, M., and Wu, S. (2000). Reversible electromechanical characteristics of carbon nanotubes under local-probe manipulation, *Nature*, **405**, pp. 769–772.
163. Lee, C., Wei, X. D., Kysar, J. W., and Hone, J. (2008). Measurement of the elastic properties and intrinsic strength of monolayer graphene, *Science*, **321**, pp. 385–388.
164. Li, X., Maute, K., Dunn, M. L., and Yang, R. (2010). Strain effects on the thermal conductivity of nanostructures, *Phys. Rev. B*, **81**, pp. 245318_1–245318_11.
165. Yang, W., Wang, R. Z., and Yan, H. (2008). Strain-induced Raman-mode shift in single-wall carbon nanotubes: calculation of force constants from molecular-dynamics simulations, *Phys. Rev. B*, **77**, pp. 195440_1–195440_5.
166. Tang, C., Guo, W., and Chen, C. (2010). Bending manipulation induced sp^2-sp^3 bond transition in carbon nanotubes, *J. Appl. Phys.*, **108**, pp. 026108_1–026108_3.
167. Rochefort, A., Avouris, P., Lesage, F., and Salahub D. R. (1999). Electrical and mechanical properties of distorted carbon nanotubes, *Phys. Rev. B*, **60**, pp. 13824–13830.
168. Bozovic, D., Bockrath, M., Hafner, J. H., Lieber, C. M., Park, H., and Tinkham, M. (2001). Electronic properties of mechanically induced kinks in single-walled carbon nanotubes, *Appl. Phys. Lett.*, **78**(23), pp. 3693–3695.
169. Farajian, A. A., Yakobson, B. I., Mizuseki, H., and Kawazoe, Y. (2003). Electronic transport through bent carbon nanotubes: nanoelectromechanical sensors and switches, *Phys. Rev. B*, **67**, pp. 205423_1–205423_5.
170. Peters, M. J., McNeil, L. E., Lu, J. P., and Kahan, D. (2000). Structural phase transition in carbon nanotube bundles under pressure, *Phys. Rev. B*, **61**, pp. 5939–5944.
171. Liu, J. Z., Zheng, Q., and Jiang, Q. (2001). Effect of a rippling mode on resonances of carbon nanotubes, *Phys. Rev. Lett.*, **86**(21), pp. 4843–4846.
172. Chang, T. (2007). Torsional behavior of chiral single-walled carbon nanotubes is loading direction dependent, *Appl. Phys. Lett.*, **90**, pp. 201910_1–201910_3.
173. Geng, J., and Chang, T. (2006). Nonlinear stick-spiral model for predicting mechanical behavior of single-walled carbon nanotubes, *Phys. Rev. B*, **74**, pp. 245428_1–245428_13.

174. Liang, H., and Upmanu, M. (2006). Axial-strain-induced torsion in single-walled carbon nanotubes, *Phys. Rev. Lett.*, **96**, pp. 165501_1–165501_4.
175. Cohen-Karni, T., Segev, L., Srur-Lavi, O., Cohen, S. R., and Joselevich, E. (2006). Torsional electromechanical quantum oscillations in carbon nanotubes, *Nat. Nanotechnol.*, **1**, pp. 36–41.
176. Hall, A. R., Falvo, M. R., Superfine, R., and Washburn, S. (2007). Electromechanical response of single-walled carbon nanotubes to torsional strain in a self-contained device, *Nat. Nanotech.*, **2**, pp. 413–416.
177. Nagapriya, K. S., Berber, S., Cohen-Karni, T., Segev L., Srur-Lavi, O., Tománek, D., and Joselevich, E., (2008). Origin of torsion-induced conductance oscillations in carbon nanotubes, *Phys. Rev. B*, **78**, pp. 165417_1–165417_5.
178. Hall, A. R., Falvo, M. R., Superfine, R., and Washburn, S. (2008). A self-sensing nanomechanical resonator built on a single-walled carbon nanotube, *Nano Lett.*, **8**, pp. 3746–3749.
179. Palaci, I., Fedrigo, S., Brune, H., Klinke, C., Chen, M., and Riedo, E., (2005). Radial elasticity of multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **94**, pp. 175502_1–175502_4.
180. J. Tang, J. C. Qin, T. Sasaki, M. Yudasaka, A. Matsushita, and S. Iijima, (2000). Compressibility and polygonization of single-walled carbon nanotubes under hydrostatic pressure, *Phys. Rev. Lett.*, **85**, pp. 1887–1889.
181. Peters, M. J., McNeil, L. E., Lu J. P., and Kahn, D. (2000). Structural phase transition in carbon nanotube bundles under pressure, *Phys. Rev. B*, **61**(9), pp. 5939–5944.
182. Sharma, S. M., Karmakar, S., Sikka, S. K., Teredesai, P. V., Sood, A. K., Govindaraj, A., and Rao, C. N. R. (2001). Pressure-induced phase transformation and structural resilience of single-wall carbon nanotube bundles, *Phys. Rev. B*, **63**, pp. 205417_1–205417_5.
183. Rols, S., Gontcharenko, I. N., Almairac, R., Sauvajol, J. L., and Mirebeau, I. (2001). Polygonization of single-wall carbon nanotube bundles under high pressure, *Phys. Rev. B*, **64**, pp. 153401_1–153401_4.
184. Reich, S., Thomsen, C., and Ordejón P. (2003). Elastic properties of carbon nanotubes under hydrostatic pressure, *Phys. Rev. B*, **65**, 153407_1–153407_4.
185. Pantano, A., Parks, D. M., and Boyce, M. C. (2004). Mechanics of deformation of single- and multi-wall carbon nanotubes, *J. Mech. Phys. Solid.*, **52**(4), pp. 789–821.

186. Elliott, J. A., Sandler, L. K. W., Windle, A. H., Young, R. J., and Shaffer, M. S. P. (2004). Collapse of single-wall carbon nanotubes is diameter dependent, *Phys. Rev. Lett.*, **92**, pp. 095501_1–095501_4.
187. Tangney, P., Capaz, R. B., Spataru, C. D., Cohen, M. L., and Louie, S. G. (2005). Structural transformations of carbon nanotubes under hydrostatic pressure, *Nano Lett.*, **5**(11), pp. 2268–2273.
188. Gadagkar, V., Maiti, P. K., Lansac, Y., Jagota, A., and Sood, A. K. (2006). Collapse of double-walled carbon nanotube bundles under hydrostatic pressure, *Phys. Rev. B*, **73**, pp. 085402_1–085402_6.
189. Wang, X., and Yang, H. K. (2006). Bending stability of multiwalled carbon nanotubes, *Phys. Rev. B*, **73**(8), pp. 085409_1–085409_8.
190. Zhang, S., Khare, R., Belytschko, T., Hsia, K. J., Mielke, S. L., and Schatz, G. C. (2006). Transition states and minimum energy pathways for the collapse of carbon nanotubes, *Phys. Rev. B*, **73**(7), pp. 075423_1–075423_7.
191. Hasegawa, M., and Nishidate, K. (2006). Radial deformation and stability of single-wall carbon nanotubes under hydrostatic pressure, *Phys. Rev. B*, **74**, pp. 115401_1–115401_11.
192. Yang, X., Wu, G., and Dong, J. (2006). Structural transformations of double-walled carbon nanotube bundle under hydrostatic pressure, *Appl. Phys. Lett.*, **89**(11), pp. 113101_1–113101_3.
193. Christofilos, D., Arvanitidis, J., Kourouklis, G. A., Ves, S., Takenobu, T., Iwasa, Y., and Kataura, H. (2007). Identification of inner and outer shells of double-wall carbon nanotubes using high-pressure Raman spectroscopy, *Phys. Rev. B*, **76**(11), pp. 113402_1–113402_4.
194. Peng, J., Wu, J., Hwang, K. C., Song, J., and Huang, Y. (2008). Can a single-wall carbon nanotube be modeled as a thin shell?, *J. Mech. Phys. Solid.*, **56**(6), pp. 2213–2224.
195. Giusca, C. E., Tison, Y., and Silva, S. R. P. (2008). Evidence for metal-semiconductor transitions in twisted and collapsed double-walled carbon nanotubes by scanning tunneling microscopy, *Nano Lett.*, **8**(10), pp. 3350–3356.
196. Wu, Y., Huang, M., Wang, F., Huang, X. M. H., Rosenblatt, S., Huang, L., Yan, H., O'Brien, S. P., Hone, J., and Heinz, T. F. (2008). Determination of the Young's modulus of structurally defined carbon nanotubes, *Nano Lett.*, **8**(12), pp. 4158–4161.
197. Jeong, B. W., Lim, J. K., and Sinnott, S. B. (2008). Tuning the torsional properties of carbon nanotube systems with axial prestress, *Appl. Phys. Lett.*, **92**(25), pp. 253114_1–3.

198. Kuang, Y. D., He, X. Q., Chen, C. Y., and Li, G. Q. (2009). Buckling of functionalized single-walled nanotubes under axial compression, *Carbon*, **47**(1), pp. 279–285.
199. Lu, W. B., Liu, B., Wu, J., Xiao, J., Hwang, K. C., Fu, S. Y., and Huang, Y. (2009). Continuum modeling of van der Waals interactions between carbon nanotube walls, *Appl. Phys. Lett.*, **94**(10), pp. 101917_1–101917_3.
200. Venkateswaran, U. D., Rao, A. M., Richter, E., Menon, M., Rinzler, A., Smalley, R. E., and Eklund, P. C. (1999). Probing the single-wall carbon nanotube bundle: Raman scattering under high pressure, *Phys. Rev. B*, **59**(16), pp. 10928–10934.
201. Shima, H., and Sato, M. (2008). Multiple radial corrugations in multiwall carbon nanotubes under pressure, *Nanotechnology*, **19**, pp. 495705_1–495705_8.
202. Zhang, D. B., and Dumitrică, T. (2010). Effective shear-strain driven electromechanical response in helical rippled carbon nanotubes, *Phys. Rev. B*, **82**, pp. 193401_1–193401_4.
203. Charlier, J.-C., Ebbesen, T. W., Lambin, Ph. (1996). Structural and electronic properties of pentagon-heptagon pair defects in carbon nanotubes, *Phys. Rev. B*, **53**, pp. 11108–11113 (1996).
204. Charlier, J.-C. (2002). Defects in carbon nanotubes, *Acc. Chem. Res.*, **35**, pp. 1063–1069.
205. Stone, A. J., and Wales, D. J. (1986). Theoretical studies of icosahedral C₆₀ and some related species, *Chem. Phys. Lett.*, **128**(5–6), pp. 501–503.
206. Nardelli, M. B., Yakobson, B. I., and Bernholc, J. (1998). Mechanism of strain release in carbon nanotubes, *Phys. Rev. B*, **57**, pp. R4277–R4280.
207. Jensen, P., Gale, J., and Blase, X. (2002). Catalysis of nanotube plasticity under tensile strain, *Phys. Rev. B*, **66**, pp. 193403_1–193403_4.
208. Zhao, Q., Nardelli M. B., and Bernholc J. (2002). Ultimate strength of carbon nanotubes: a theoretical study, *Phys. Rev. B*, **65**, pp. 144105_1–144105_6.
209. Ewels, C. P., Heggie, M. I., and Briddon, P. R. (2002). Adatoms and nanoengineering of carbon, *Chem. Phys. Lett.*, **351**, pp. 178–182.
210. Yakobson, B. I. (1998). Mechanical relaxation and “intramolecular plasticity” in carbon nanotubes, *Appl. Phys. Lett.*, **72**, pp. 918–920.
211. Nardelli, M. B., Yakobson B. I., and Bernholc J. (1998). Brittle and ductile behavior in carbon nanotubes, *Phys. Rev. Lett.*, **81**, pp. 4656–4659.

212. Nakayama, Y., Nagataki, A., Suekane, O., Cai, X., and Akita, S. (2005). Current-induced plastic deformation of double-walled carbon nanotubes, *Jpn. J. Appl. Phys.*, **44**, pp. L720–L722.
213. Mori, H., Ogata, S., Li, J., Akita, S., and Nakayama, Y. (2006). Energetics of plastic bending of carbon nanotubes, *Phys. Rev. B*, **74**, pp. 165418_1–165418_5.
214. Zhou, L. G., and Shi, S. Q. (2003). Formation energy of Stone–Wales defects in carbon nanotubes, *Appl. Phys. Lett.*, **83**(7), pp. 1222–1224.
215. Li, Z., Dharap, P., Sharma, P., Nagarajaiah, S., and Yakobson, B. I. (2005). Continuum field model of defect formation in carbon nanotubes, *J. Appl. Phys.*, **97**, pp. 074303_1–074303_8.
216. Walters, D. A., Ericson, L. M., Casavant, M. J., Liu, J., Colbert, D. T., Smith, K. A., and Smalley, R. E. (1999). Elastic strain of freely suspended single-wall carbon nanotube ropes, *Appl. Phys. Lett.*, **74**, pp. 3803–3805.
217. Samsonidze, G. G. (2002). Kinetic theory of symmetry-dependent strength in carbon nanotubes, *Phys. Rev. Lett.*, **88**, pp. 065501_1–065501_4.
218. Ouyang, M., Huang, J.-L., Cheung, C. L., and Lieber, C. M. (2001). Atomically resolved single-walled carbon nanotube intramolecular junctions, *Science*, **291**, pp. 97–100.
219. Hashimoto, A., Suenaga, K., Gloter, A., Urita, K., and Iijima, S. (2004). Direct evidence for atomic defects in graphene layers. *Nature*, **430**, pp. 870–873.
220. Ishigami, M., Choi, H. J., Aloni, S., Louie, S. G., Cohen, M. L., and Zettl, A. (2004). Identifying defects in nanoscale materials, *Phys. Rev. Lett.*, **93**, pp. 196803_1–196803_4.
221. Yoon, M., Han, S., Kim, G., Lee, S. B., Berber, S., Osawa, E., Ihm, J., Terrones, M., Banhart, F., Charlier, J.-C., Grobert, N., Terrones, H., Ajayan, P. M., and Tománek, D. (2004). Zipper mechanism of nanotube fusion: theory and experiment, *Phys. Rev. Lett.*, **92**(7), pp. 075504_1–075504_4.
222. Suenaga, K., Wakabayashi H., Koshino, M., Sato Y., Urita K., and Iijima S. (2007). Imaging active topological defects in carbon nanotubes, *Nat. Nanotechnol.*, **2**, pp. 358–360.
223. Yudasaka, M., Kataura, H., Ichihashi, T., Qin, L.-C., Kar, S., and Iijima, S. (2001). Diameter enlargement of HiPco single-wall carbon nanotubes by heat treatment, *Nano. Lett.*, **1**, pp. 487–489.

224. Meyer, J. C., Kisielowski, C., Erni, R., Rossell, M. D., Crommie, M. F., and Zettl, A. (2008). Direct imaging of lattice atoms and topological defects in graphene membranes, *Nano. Lett.*, **8**, pp. 3582–3586.
225. Danlap, B. I. (1992). Connecting carbon tubules, *Phys. Rev. B*, **46**, pp. 1933–1936.
226. Baldus, M., Tomaslli, M., Meier B. H., and Ernst, R. R. (1994). Broadband polarization-transfer experiments for rotating solids, *Chem. Phys. Lett.*, **223**, pp. 329–336.
227. Motojima, S., Kawaguchi, M., Nozaki, K., and Iwanaga, H. (1990). Growth of regularly coiled filaments by Ni catalyzed pyrolysis of acetylene, and their morphology and extension characteristics, *Appl. Phys. Lett.*, **56**, pp. 321–323.
228. Bervaerts, D., Bzhang, X., Zhang, X. F., Amelinckx, S., Tendeloo, G. V., Landuyt, J. V., Ivanov, V., and Nagy, J. B. (1995). Electron microscopy study of coiled carbon tubules, *Phil. Mag. A*, **71**, pp. 605–630.
229. Hernadi, K., Thiên-Nga, L., and L. Forró. (2001). Growth and microstructure of catalytically produced coiled carbon nanotubes, *J. Phys. Chem. B*, **105**, pp. 12464–12468.
230. Saito, Y., and Yoshikawa, T. (1993). Bamboo-shaped carbon tube filled partially with nickel, *J. Cryst. Growth*, **134**, pp. 154–156.
231. Kovalevski, V. V., and Safronov, A. N. (1998). Pyrolysis of hollow carbons on melted catalyst, *Carbon*, **36**, pp. 963–968.
232. Kiselev, N. A., Sloan, J., Zakharov, D. N., Kukovitskii, E. F., Hutchison, J. L., Hammers, J., and Kotosonov, A. S. (1998). Carbon nanotubes from polyethylene precursors: structure and structural changed caused by thermal and chemical treatment revealed by hrem, *Carbon*, **36**, pp. 1149–1157.
233. Cortijo, A., and Vozmediano, M. A. H. (2007). Effects of topological defects and local curvature on the electronic properties of planar graphene, *Nucl. Phys. B*, **763**, pp. 293–308.
234. Diudea, M. V. (2005). Corannulene and corazulene tiling of nanostructures, *Phys. Chem. Chem. Phys.*, **7**, pp. 3626–3633.
235. Rode, A. V., Gamaly, E. G., and B. Luther-Davies, (2000). Formation of cluster-assembled carbon nano-foam by high-repetition-rate laser ablation, *Appl. Phys. A*, **70**, pp. 135–144.
236. Okada, S., Nakada, K. Kuwabara, K., Daigoku, K., and Kawai, T. (2006). Ferromagnetic spin ordering on carbon nanotubes with topological line defects, *Phys. Rev. B*, **74**, pp. 121412_1–121412_4.

237. Ding, W., Calabri, L., Kohlhaas, K. M., Chen, X., Dikin, D. A., and Ruoff, R. S. (2007). Modulus, fracture strength, and brittle vs. plastic response of the outer shell of arc-grown multi-walled carbon nanotubes, *Exp. Mech.*, **47**, pp. 25–36.
238. Barber, A. H., Kaplan-Ashiri, I., Cohen, S. R., Tenne, R., and Wagner, H. D. (2005). Stochastic strength of nanotubes: an appraisal of available data, *Compos. Sci. Technol.*, **65**, pp. 2380–2384.
239. Barber, A. H., Andrews, R., Schadler, L. S., and Wagner, H. D. (2005). On the tensile strength distribution of multiwalled carbon nanotubes, *Appl. Phys. Lett.*, **87**, pp. 203106_1–203106_3.
240. Ogata, S., and Shibutani, Y. (2003). Ideal tensile strength and band gap of single-walled carbon nanotubes, *Phys. Rev. B*, **68**, pp. 165409_1–165409_4.
241. Ozaki, T., Iwasa, Y., and Mitani, T. (2000). Stiffness of single-walled carbon nanotubes under large strain, *Phys. Rev. Lett.*, **84**, pp. 1712–1715.
242. Dumitrica, T., Belytschko, T., and Yakobson, B. I. (2003). Bond-breaking bifurcation states in carbon nanotube fracture, *J. Chem. Phys.*, **118**(21), pp. 9485–9488.
243. Dumitrica, T., Ming Hua, M., and Yakobson, B. I. (2006). Symmetry-, time-, and temperature-dependent strength of carbon nanotubes, *PNAS*, **103**, pp. 6105–6109.
244. Mielke, S. L., Troya, D., Zhang, S., Li, J.-L., Xiao, S., Car, R., Ruoff, R. S., Schatz, G. C., and Belytschko, T. (2004). The role of vacancy defects and holes in the fracture of carbon nanotubes, *Chem. Phys. Lett.*, **390**, pp. 413–420.
245. Troya, D., Mielke, S. L., and Schatz, G. C. (2003). Carbon nanotube fracture — differences between quantum mechanical mechanisms and those of empirical potentials, *Chem. Phys. Lett.*, **382**, pp. 133–141.
246. Peng, B., Locascio, M., Zapol, P., Li, S., Mielke, S. L., Schatz, G. C., and Espinosa, H. D. (2008). Measurements of near-ultimate strength for multiwalled carbon nanotubes and irradiation-induced crosslinking improvements, *Nat. Nanotech.*, **3**, pp. 626–631.
247. Wen, B., Sader, J. E., and Boland, J. J. (2008). Mechanical Properties of ZnO Nanowires, *Phys. Rev. Lett.*, **101**, pp. 175502_1–175502_4.
248. Hoffmann, S., Utke, I., Moser, B., Michler, J., Christiansen, S. H., Schmidt, V., Senz, S., Werner, P., Gosele, U., and Ballif, C. (2006). Measurement of the bending strength of vapor-liquid-Solid grown silicon nanowires, *Nano Lett.*, **6**, pp. 622–625.

249. Wu, B., Heidelberg, A., Boland, J. J., Sader, J. E., Sun, X. M., and Li, Y. D. (2006). Microstructure-hardened silver nanowires, *Nano Lett.*, **6**, pp. 468–472.
250. Wu, B., Heidelberg, A., and Boland, J. J. (2005). Mechanical properties of ultrahigh-strength gold nanowires, *Nat. Mater.*, **4**, pp. 525–529.
251. Zhang, S., Mielke, S. L., Khare, R., Troya, D., Ruoff, R. S., Schatz, G. C., and Belytschko, T. (2005). Mechanics of defects in carbon nanotubes: atomistic and multiscale simulations, *Phys. Rev. B*, **71**, pp. 115403_1–115403_12.
252. Ajayan, P. M., Ravikumar, V., Charlier, J.-C. (1998). Surface reconstructions and dimensional changes in single-walled carbon nanotubes, *Phys. Rev. Lett.*, **81**, pp. 1437–1440.
253. Telling, R. H., Ewels, C. P., El-Barbary, A. A., Heggie M. I. (2003). Wigner defects bridge the graphite gap. *Nat. Mater.*, **2**, pp. 333–337.
254. Huang, J. Y., Chen, S., Jo, S. H., Wang, Z., Han, D. X., Chen, G., Dresselhaus, M. S., and Ren, Z. F. (2005). Atomic-scale imaging of wall-by-wall breakdown and concurrent transport measurements in multiwall carbon nanotubes, *Phys. Rev. Lett.*, **94**, pp. 236802_1–236802_4.
255. Huang, J. Y., Chen, S., Wang, Z. Q., Kempa, K., Wang, Y. M., Jo, S. H., Chen, G., Dresselhaus, M. S., and Ren, Z. F. (2006). Superplastic carbon nanotubes, *Nature*, **439**, pp. 281.
256. Troiani, H. E., Miki-Yoshida, M., Camacho-Bragado, G. A., Marques, M. A. L., Rubio, A., Ascencio, J. A., and Jose-Yacaman, M. (2003). Direct observation of the mechanical properties of single-walled carbon nanotubes and their junctions at the atomic level, *Nano Lett.*, **3**, pp. 751–755.
257. von Helden, G., Kemper, P. R., Gotts, N. G., and Bowers, M. T. (1993). Isomers of small carbon cluster anions: linear chains with up to 20 atoms, *Science*, **259**, pp. 1300–1302.
258. Hunter, J., Fye, J., and Jarrold, M. F. (1993). Annealing C_{60}^+ : synthesis of fullerenes and large carbon rings, *Science*, **260**, pp. 784–786.
259. Rinzler, A. G., Hafner, J. H., Nikolaev, P., Lou, L., Kim, S. G., Tomanek, D., Nordlander, P., Colbert, D. T., and Smalley, R. E. (1995). Unraveling nanotubes: field emission from an atomic wire *Science*, **269**, pp. 1550–1553.
260. Yakobson, B. I., Campbell, M. P., Brabec, C. J., and Bernholc, J. (1997). High strain rate fracture and C-chain unraveling in carbon nanotubes, *Comput. Mater. Sci.*, **8**, pp. 341–348.

261. Xu, C. H. Wang, C. Z., Chan, C. T., and Ho, K. M. (1992). A transferable tight-binding potential for carbon, *J. Phys. Condens. Matter*, **4**, pp. 6047–6054.
262. Van Orden, A., and Saykally, R. J. (1998). Small carbon clusters: spectroscopy, structure, and energetics, *Chem. Rev.*, **98**, pp. 2313–2358.
263. Raghavachari, K., and Binkley, J. S. (1987). Structure, stability, and fragmentation of small carbon clusters, *J. Chem. Phys.*, **87**, pp. 2191–2198.
264. Chen, X., Zhang, S., Dikin, D. A., Ding, W. Ruoff, R. S., Pan, L., and Nakayama, Y. (2003). Mechanics of a carbon nanocoil, *Nano Lett.*, **3**, pp. 1299–1304.
265. Poggi, M. A., Boyles, J. S., Bottomley, L. A., McFarland, A. W., Colton, J. S., Nguyen, C. V., Stevens, R. M., and Lillehei, P. T. (2004). Measuring the compression of a carbon nanospring, *Nano Lett.*, **4**(6), pp. 1009–1016.
266. Gao, P. X., Ding, Y., Mai, W., Hughes, W. L., Lao, C., and Wang, Z. L. (2005). Conversion of zinc oxide nanobelts into superlattice-structured nanohelices, *Science*, **309**, pp. 1700–1704.
267. Singh, J. P., Liu, D.-L., Ye, D.-X., Picu, R. C., Lu, T.-M., and Wang, G.-C. (2004). Metal-coated Si springs: nanoelectromechanical actuators, *Appl. Phys. Lett.*, **84**, pp. 3657–3659.
268. Kong, X. Y., Ding, Y., Yang, R., and Wang, Z. L. (2004). Single-crystal nanorings formed by epitaxial self-coiling of polar nanobelts, *Science*, **303**, pp. 1348–1351.
269. Volodin, A., Buntinx, D., Ahlskog, M., Fonseca, A., Nagy, J. B., and Haesendonck, C. V. (2004). Coiled carbon nanotubes as self-sensing mechanical resonators, *Nano Lett.*, **4**, pp. 1775–1779.
270. Ihara, S., and Itoh, S. (1993). Helically coiled cage forms of graphitic carbon, *Phys. Rev. B*, **48**, pp. 5643–5648.
271. Gayathri, V., Devi, N. R., and Geetha, R. (2010). Hydrogen storage in coiled carbon nanotubes, *Int. J. Hydro. Energy*, **35**, pp. 1313–1320.
272. Zhong-can, O.-Y., Su, Z.-B., and Wang, C.-L. (1997). Coil formation in multishell carbon nanotubes: competition between curvature elasticity and interlayer adhesion, *Phys. Rev. Lett.*, **78**, pp. 4055–4058.
273. Volodin, A., Ahlskog, M., Seynaeve, E., Haesendonck, C. V., Fonseca, A., and Nagy, J. B. (2000). Imaging the elastic properties of coiled carbon nanotubes with atomic force microscopy, *Phys. Rev. Lett.*, **84**, pp. 3342–3345.

274. Ivanov, V., Nagy, J. B., Lambin, Ph., Lucas, A., Zhang, X. B., Zhang, X. F., Bemaerts, D., Tendeloo, G. V., Amelinckx, S., and Van Landuyt, J. (1994). The study of carbon nanotubules produced by catalytic method, *Chem. Phys. Lett.*, **223**, pp. 329–335.
275. Zhang, X. B., Zhang, X. F., Bemaerts, D., Van Tendeloo, G., Amelinckx, S., Van Landuyt, J., Ivanov, V., Nagy, J. B., Lambin, Ph., Lucas, A. A. (1994). The texture of catalytically grown coil-shaped carbon nanotubules, *Europhys. Lett.*, **27**(2), pp. 141–146.
276. Pan, L., Hayashida, T., Zhang, M., and Nakayama, Y. (2001). Field emission properties of carbon tubule nanocoils, *Jpn. J. Appl. Phys.*, **40**, pp. L235–L237.
277. Pradhan, D., and Sharon, M. Carbon nanotubes, nanofilaments and nanobeads by thermal chemical vapor deposition process, *Mater. Sci. Eng. B*, **96**, pp. 24–28.
278. Takenaka, S., Ishida, M., Serizawa, M., Tanabe, E., and Otsuka, K. (2004). Formation of carbon nanofibers and carbon nanotubes through methane decomposition over supported cobalt catalysts, *J. Phys. Chem. B*, **108**, pp. 11464–11472.
279. Xie, J., Mukhopadyay, K., Yadav, J., and Varadan, V. K. (2003). Catalytic chemical vapor deposition synthesis and electron microscopy observation of coiled carbon nanotubes, *Smart Mater. Struct.*, **12**, pp. 744–748.
280. Pan, L., Zhang, M., and Nakayama, Y. (2002). Growth mechanism of carbon nanocoils, *J. Appl. Phys.*, **91**(12), pp. 10058–10061.
281. Koós, A. A., Ehlich, R., Horváth, Z. E., Osváth, Z., Gyulai, J., Nagy, J. B., and Biró, L. P. (2003). STM and AFM investigation of coiled carbon nanotubes produced by laser evaporation of fullerene, *Mater. Sci. Eng. C*, **23**, pp. 275–278.
282. Saveliev, A. V., Merchan-Merchan, W., and Kennedy, L. A. (2003). Metal catalyzed synthesis of carbon nanostructures in an opposed flow methane oxygen flame, *Combust. Flame*, **135**, pp. 27–33.
283. Hokushin, S., Pan, L., and Nakayama, Y. (2007). Diameter control of carbon nanocoils by the catalyst of organic metals, *Jpn. J. Appl. Phys.*, **46**, pp. 5383–5385.
284. Hayashida, T., Pan, L., and Nakayama, Y. (2002). Mechanical and electrical properties of carbon tubule nanocoils, *Physica B*, **323**, pp. 352–353.
285. Biró, L. P., Lazarescu, S. D., Thiry, P. A., Fonseca, A., Nagy, J. B., Lucas, A. A., Lambin, P. (2000). Scanning tunneling microscopy observation

- of tightly wound, single-wall coiled carbon nanotubes, *Europhys. Lett.*, **50**, pp. 494–500.
286. Lau, K. T. (2006). Coiled carbon nanotubes: synthesis and their potential applications in advanced composite structures, *Composites B*, **37**, pp. 437–448.
287. Liu, L. Z., Gao, H. L., Zhao, J. J., and Lu, J. P. (2010). Superelasticity of carbon nanocoils from atomistic quantum simulations, *Nanoscale Res. Lett.*, **5** pp. 478–483.
288. Ihara, S., Itoh, S., and Kitakami, J. (1993). Toroidal forms of graphitic carbon, *Phys. Rev. B*, **47**, pp. 12908–12911.
289. Szabó, A., Fonseca, A., Nagy, J. B., Lambin, Ph., Biró, L. P. (2005). Structural origin of coiling in coiled carbon nanotubes, *Carbon*, **43**, pp. 1628–1633.
290. Lu, M., Liu, W. M., Guo, X. Y., and Li, H. L. (2004). Coiled carbon nanotubes growth via reduced-pressure catalytic chemical vapor deposition, *Carbon*, **42**, pp. 805–811.
291. Daraio, C., Nesterenko, V. F., Jin, S., Wang, W., and Rao, A. M. (2004). Impact response by a foamlke forest of coiled carbon nanotubes, *J. Appl. Phys.*, **100**, pp. 064309_1–064309_4.
292. Coluci, V. R., Fonseca, A. F., Galvão and Daraio, C. (2008). Entanglement and the nonlinear elastic behavior of forests of coiled carbon nanotubes, *Phys. Rev. Lett.*, **100**, pp. 086807_1–086807_4.
293. Osváth, Z., Vértesy, G., Tapasztó, L., Wéber, F., Horváth, Z. E., Gyulai, J., and Biró L. P. (2005). Atomically resolved STM images of carbon nanotube defects produced by Ar⁺ irradiation. *Phys. Rev. B*, **72**, pp. 045429_1–045429_6.
294. Urita, K., Suenaga, K., Sugai, T., Shinohara, H., and Iijima, S. (2005). *In situ* observation of thermal relaxation of interstitial-vacancy pair defects in a graphite gap. *Phys. Rev. Lett.*, **94**, pp. 155502_1–155502_4.
295. Raghuveer, M. S., Kumar, A., Frederick, M. J., Louie, G. P., Ganesan, P. G., and Ramanath, G. (2006). Site-selective functionalization of carbon nanotubes. *Adv. Mater.*, **18**, pp. 547–552.
296. Jung, Y. J., Homma, Y., Vajtai, R., Kobayashi, Y., Ogino, T., and Ajayan, P. M. (2004). Straightening suspended single walled carbon nanotubes by ion irradiation, *Nano Lett.*, **4**, pp. 1109–1113.
297. Kim, D.-H., Jang, H.-S., Kim, C.-D., Cho, D.-S., Kang, H.-D., and Lee, H.-R. (2003). Enhancement of the field emission of carbon nanotubes straightened by application of argon ion irradiation, *Chem. Phys. Lett.*, **378**, pp. 232–237.

298. Ni, B., Andrews, R., Jacques, D., Qiau, D., Wijesundara, M. B. J., Choi, Y., Hanley, L., and Sinnott, S. B. (2001). A combined computational and experimental study of ion-beam modification of carbon nanotube bundles, *J. Phys. Chem. B*, **105**, pp. 12719–12725.
299. Yang, D. Q., Rochette, J., and Sacher, E. (2005). Controlled chemical functionalization of multiwalled carbon nanotubes, by kiloelectronvolt argon ion treatment and air exposure. *Langmuir*, **21**, pp. 8539–8545.
300. Zhu, Y., Yi, T., Zheng, B., and Cao, L. (1999). The interaction of C₆₀ fullerene and carbon nanotube with Ar ion beam, *Appl. Surf. Sci.*, **137**, pp. 83–90.
301. Geim, A. K., and Novoselov, K. S. (2007). The rise of grapheme, *Nature Mater.*, **6**, pp. 183–191.
302. Krasheninnikov, A. V., Nordlund, K., and Keinonen, J. (2002). Production of defects in supported carbon nanotubes under ion irradiation, *Phys. Rev. B*, **65**, pp. 165423_1–165423_8.
303. Lu, A. J., and Pan, B. C. (2004). Nature of single vacancy in achiral carbon nanotubes, *Phys. Rev. Lett.*, **92**, pp. 105504_1–105504_4.
304. Rossato, J., Baierle, R. J., Fazzio, A., and Mota, R. (2005). Vacancy formation process in carbon nanotubes: first-principles approach, *Nano Lett.*, **5**, pp. 197–200.
305. Krasheninnikov, A. V., Lehtinen, P. O., Foster, A. S., and Nieminen, R. M. (2006). Bending the rules: contrasting vacancy energetics and migration in graphite and carbon nanotubes, *Chem. Phys. Lett.*, **418**, pp. 132–136.
306. Ugarte, D. (1992). Curling and closure of graphitic networks under electron-beam irradiation, *Nature*, **359**, pp. 707–709.
307. Banhart, F., and Ajayan, P. M. (1996). Carbon onions as nanoscopic pressure cells for diamond formation, *Nature*, **382**, pp. 433–435.
308. Smith, B. W., Monthoux, M., and Luzzi, D. E. (1998). Encapsulated C₆₀ in carbon nanotubes, *Nature*, **396**, pp. 323–324.
309. Gómez-Navarro, C., de Pablo, P., Gómez-Herrero, J., Biel, B., García-Vidal, F., Rubio, A., and Flores, F. (2005). Tuning the conductance of single-walled carbon nanotubes, by ion irradiation in the Anderson localization regime, *Nature Mater.*, **4**, pp. 534–539.
310. Terrones, M., Terrones, H., Banhart, F., Charlier, J.-C., and Ajayan, P. M. (2000). Coalescence of single-walled carbon nanotubes, *Science*, **288**, pp. 1226–1229.

311. Mickelson, W., Aloni, S., Han, W. Q., Cumings, J., and Zettl, A. (2003). Packing C_{60} in boron nitride nanotubes, *Science*, **300**, pp. 467–469.
312. Terrones, M., Banhart, F., Grobert, N., Charlier, J.-C., Terrones, H., and Ajayan, P. M. (2002). Molecular junctions by joining single-walled carbon nanotubes, *Phys. Rev. Lett.*, **89**, pp. 075505_1–075505_4.
313. Skákálová, V., Dettlaff-Weglikowska, U., and Roth, S. (2004). Gamma-irradiated and functionalized single wall nanotubes, *Diamond Relat. Mater.*, **13**, pp. 296–298.
314. Hulman, M., Skákálová, V., Roth, S., and Kuzmany, H. (2005). Raman spectroscopy of single-wall carbon nanotubes and graphite irradiated by γ rays, *J. Appl. Phys.*, **98**, pp. 024311_1–024311_5.
315. Beuneu, F., l'Huillier, C., Salvetat, J. P., Bonard, J. M., and Forró, L. (1999). Modification of multiwall carbon nanotubes by electron irradiation: an ESR study, *Phys. Rev. B*, **59**, pp. 5945–5949.
316. Basiuk, V. A., Kobayashi, K., Kaneko, T., Negishi, Y., Basiuk, E., and Saniger-Blesa, J.-M. (2002). Irradiation of single-walled carbon nanotubes with high-energy protons, *Nano Lett.*, **2**, pp. 789–791.
317. Khare, B., Meyyappan, M., Moore, M. H., Wilhite, P., Imanaka, H., and Chen, B. (2003). Proton irradiation of carbon nanotubes, *Nano Lett.*, **3**, pp. 643–646.
318. Banhart, F. (1999). Irradiation effects in carbon nanostructures, *Rep. Prog. Phys.*, **62**, pp. 1181–1221.
319. Yuzvinsky, T. D., Mickelson, W., Aloni, S., Begtrup, G. E., Kis, A., and Zettl, A. (2006). Shrinking a Carbon Nanotube, *Nano Lett.*, **6**, pp. 2718–2722.
320. Adhikari, A. R., Huang, M. B., Bakhru, H., Talapatra, S., Ajayan, P. M., and Ryu, C. Y. (2006). Effects of proton irradiation on thermal stability of single-walled carbon nanotubes mat, *Nucl. Instrum. Methods Phys. Res. B*, **245**, pp. 431–434.
321. Talapatra, S., Ganeshan, P. G., Kim, T., Vajtai, R., Huang, M., Shima, M., Ramanath, G., Srivastava, D., Deevi, S. C., and Ajayan, P. M. (2005). Irradiation-induced magnetism in carbon nanostructures, *Phys. Rev. Lett.*, **95**, pp. 097201_1–097201_4.
322. Tolvanen, A., Kotakoski, J., Krasheninnikov, A. V., and Nordlund, K. (2007). Relative abundance of single and double vacancies in irradiated single-walled carbon nanotubes, *Appl. Phys. Lett.*, **91**, pp. 173109_1–173109_3.
323. O'Rourke Muisener, P. A., Clayton, L., Angelo, J. D., Harmon, J. P., Sukder, A. K., Kumar, A., Cassell, A. M. and Meyyappan, M. (2002). Effects of

- gamma radiation on poly(methyl methacrylate)/single-wall nanotube composites, *J. Mater. Res.*, **17**, pp. 2507–2513.
324. Banhart, F. (2006). Irradiation of carbon nanotubes with a focused electron beam in the electron microscope, *J. Mater. Sci.*, **41**, pp. 4505–4511.
325. Baughman, R. H. (2006). Dangerously Seeking Linear Carbon, *Science*, **312**, pp. 1009–1110.
326. Itzhaki, L., Altus, E., Basch, H., and Hoz, S. (2005). Harder than diamond: determining the cross-sectional area and Young's modulus of molecular rods, *Angew. Chem.*, **117**, pp. 7598–7601.
327. Lehtinen, P. O., Foster, A. S., Ma, Y., Krasheninnikov, A. V., and Nieminen, R. M. (2004). Irradiation-induced magnetism in graphite: a density functional study, *Phys. Rev. Lett.*, **93**, pp. 187202_1–187202_4.
328. El-Barbary, A. A., Telling, R. H., Ewels, C. P., Heggie, M. I., and Briddon, P. R. (2003). Structure and energetics of the vacancy in graphite, *Phys. Rev. B*, **68**, pp. 144107_1–144107_7.
329. Warner, J. H., Schäffel, F. G., Zhong, M. H., Rümmeli, B., Büchner, J., Robertson, and G. Briggs, (2009). Investigating the diameter-dependent stability of single-walled carbon nanotubes, *ACS Nano*, **3**, pp. 1557–1563.
330. Niyogi, S., Hamon, M. A., Hu, H., Zhao, B., Bhowmik, P., Sen, R., Itkis, M. E., and Haddon, R. C. (2002). Chemistry of single-walled carbon nanotubes, *Acc. Chem. Res.*, **35**, pp. 1105–1113.
331. Krasheninnikov, A. V., Banhart, F., Li J. X., Foster, A. S., and Nieminen, R. M. (2005). Stability of carbon nanotubes under electron irradiation: role of tube diameter and chirality. *Phys. Rev. B*, **72**, pp. 125428_1–125428_6.
332. Banhart, F., Li, J. X., and Krasheninnikov, A. V. (2005). Carbon nanotubes under electron irradiation: stability of the tubes and their action as pipes for atom transport, *Phys. Rev. B*, **71**, pp. 241408(R)_1–241408(R)_4.
333. Gan, Y., Kotakoski, J., Krasheninnikov, A. V., Nordlun, K., and Banhart, F. (2008). The diffusion of carbon atoms inside carbon nanotubes, *New J. Phys.*, **10**, pp. 023022_1–023022_9.
334. Sun, L., Banhart, F., Krasheninnikov, A. V., Rodríguez-Manzo, J. A., Terrons, M., and Ajayan, P. M. (2006). Carbon nanotubes as high-pressure cylinders and nanoextruders, *Science*, **312**, pp. 1199–1202.
335. Shima, H., Sato, M., Iiboshi, K., Ghosh, S., and Arroyo, M. (2010). Diverse corrugation pattern in radially shrinking carbon nanotubes, *Phys. Rev. B*, **82**, pp. 085401_1–085401_7.

336. Endo, M., Hayashi, T., Muramatsu, H., Kim, Y. A., Terrones, H., Terrones, M., and Dresselhaus, M. S. (2004). Coalescence of double-walled carbon nanotubes: formation of novel carbon bicables, *Nano Lett.*, **4**, pp. 1451–1454.
337. Kawai, T., Yoshiyuki Miyamoto, Y., Sugino, O., and Koga, Y. (2002). General sum rule for chiral index of coalescing ultrathin nanotubes, *Phys. Rev. Lett.*, **89**, pp. 085901_1–085901_4.
338. Li, J. X., and Banhart, F. (2004). The engineering of hot carbon nanotubes with an electron beam, *Nano Lett.*, **4**, pp. 1143–1146.
339. Banhart, F., Li, J. X., and Terrones, M. (2005). Cutting single-walled carbon nanotubes with an electron beam: evidence for atom migration inside nanotubes, *Small*, **1**, pp. 953–956.
340. Jin, C. H., Suenaga, K., Iijima, S. (2008). Plumbing carbon nanotubes, *Nat. Nano.*, **3**, pp. 17–21.
341. Krasheninnikov, A. V., Nordlund, K., Keinonen, J., and Banhart, F. (2003). Making junctions between carbon nanotubes using an ion beam, *Nucl. Instrum. Meth. Phys. Res. B*, **202**, pp. 224–229.
342. Wei, D., and Liu, Y. (2008). The intramolecular junctions of carbon nanotubes, *Adv. Mater.*, **20**, pp. 2815–2841.
343. Jang, I., Sinnott, S. B., Danailov, D., and Kebblinski, P. (2004). Molecular dynamics simulation study of carbon nanotube welding under electron beam irradiation, *Nano Lett.*, **4**(1), pp. 109–114.
344. Tsai, P. C., Jeng, Y. R., and Fang, T.-H. (2006). Coalescence, melting, and mechanical characteristics of carbon nanotube junctions, *Phys. Rev. B*, **74**, pp. 045406_1–045406_10.
345. Menon, M., Andriotis, A. N., Srivastava, D., Ponomareva, I., and Chernozatonskii, L. A. (2003). Carbon nanotube “T junctions”: formation pathways and conductivity, *Phys. Rev. Lett.*, **91**(14), pp. 145501_1–145501_14.
346. Ponomareva, I., Chernozatonskii, L. A., Andriotis, A. N., and Menon, M. (2003). Formation pathways for single-wall carbon nanotube multiterminal junctions *New J. Phys.*, **5**, pp. 119_1–119_12.
347. Meng, F. Y., Shi, S. Q., Xu, D. S., and Yang, R. (2004). Multiterminal junctions formed by heating ultrathin single-walled carbon nanotubes, *Phys. Rev. B*, **70**, pp. 125418_1–125418_6.
348. Srivastava, D., Menon, M., and Ajayan, P. M. (2003). Branched carbon nanotube junctions predicted by computational nanotechnology, and fabricated through nanowelding, *J. Nanoparticle Res.*, **5**, pp. 395–400.

349. Meng, F. Y., Shi, S. Q., Xu, D. S., and Yang, R. (2003). Size effect of X-shaped carbon nanotube junctions, *Carbon*, **44**, pp. 1263–1266.
350. Zhao, Y., Smalley, R. E., and Yakobson, B. I. (2002). Coalescence of fullerene cages: topology, energetics, and molecular dynamics simulation, *Phys. Rev. B*, **66**, pp. 195409_1–195409_9.
351. Cumings, J., and Zettl, A. (2000). Low-friction nanoscale linear bearing realized from multiwall carbon nanotubes, *Science*, **289**, pp. 602–604.
352. Yu, M.-F., Yakobson, B. I., and Ruoff, R. S. (2000). Controlled sliding and pullout of nested shells in individual multiwalled carbon nanotubes, *J. Phys. Chem. B*, **104**, pp. 8764–8767.
353. Bourlon, B., Glattli, D. C., Miko, C., Forro, L., and Bachtold, A. (2004). Carbon nanotube based bearing for rotational motions, *Nano Lett.*, **4**, pp. 709–712.
354. Deshpande, V. V., Chiu, H.-Y., Postma, H. W. Ch., Mikó, C., Forró, L., and Bockrath, M. (2006). Carbon nanotube linear bearing nanoswitches, *Nano Lett.*, **6**, pp. 1092–1095.
355. Subramanian, A., Dong, L. X., Nelson, B. J., and Ferreira, A. (2010). Supermolecular switches based on multiwalled carbon nanotubes, *Appl. Phys. Lett.*, **96**, pp. 073116_1–073116_3.
356. Fennimore, A. M., Yuzvinsky, T. D., Han, W.-Q., Fuhrer, M. S., Cumings, J., and Zettl, A. (2003). Rotational actuators based on carbon nanotubes, *Nature*, **424**, pp. 408–410.
357. Bourlon, B., Glattli, D. C., Plaçais, B., Berroir, J. M., Forró, L., and Bachtold, A. (2004). Geometrical dependence of high-bias current in multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **92**, pp. 026804_1–026804_4.
358. Dong, L., Nelson, B. J., Fukuda, T., and Arai, F. (2006). Towards nanotube linear servomotors, *IEEE Trans.*, **3**(3), pp. 228–235.
359. Barreiro, A., Rurali, R., Hernández, E. R., Moser, J., Pichler, T., Forró, L., and Bachtold, A. (2008). Subnanometer motion of cargoes driven by thermal gradients along carbon nanotubes, *Science*, **320**, pp. 775–778.
360. Servantie, J., and Gaspard, P. (2006). Rotational dynamics and friction in double-walled carbon nanotubes, *Phys. Rev. Lett.*, **97**, pp. 186106_1–186106_4.
361. Maslov, L. (2006). Concept of nonvolatile memory based on multiwall carbon nanotubes, *Nanotechnology*, **17**, pp. 2475–2482.

362. Subramanian, A., Dong, L., and Nelson, B. J. (2009). Stability and analysis of configuration-tunable bi-directional MWNT bearings, *Nanotechnology*, **20**, pp. 495704_1–495704_7.
363. Takagi, Y., Uda, T., and Ohno, T. (2008). Carbon nanotube motors driven by carbon nanotube, *J. Chem. Phys.*, **128**, pp. 194704_1–194704_7.
364. Yan, Q., Zhou, G., Hao, S., Wu, J., and Duan, W. (2006). Mechanism of nanoelectronic switch based on telescoping carbon nanotubes, *Appl. Phys. Lett.*, **88**, pp. 173107_1–173107_3.
365. Bailey, S. W. D., Amanatidis, I., and Lambert, C. J. (2008). Carbon nanotube electron windmills: a novel design for nanomotors, *Phys. Rev. Lett.*, **100**, pp. 256802_1–256802_4.
366. Li, Y., Hu, N., Yamamoto, G., Wang, Z., Hashida, T., Asanuma, H., Dong, C., Okabe, T., Arai, M., and Fukunaga, H. (2010). Molecular mechanics simulation of the sliding behavior between nested walls in a multi-walled carbon nanotube, *Carbon*, **48**, pp. 2934–2940.
367. Neild, A., Ng, T. W., and Zheng, Q. (2009). Controlled driven oscillations of double-walled carbon nanotubes, *Eur. Phys. Lett.*, **87**, pp. 16002_1–16002_5.
368. Po, G., and Ghoniem, N. M. (2010). Coupled oscillations of double-walled carbon nanotubes, *J. Appl. Phys.*, **107**, pp. 094310_1–094310_5.
369. Charlier, J.-C., and Michenaud, J.-P. (1993). Energetics of multilayered carbon tubules, *Phys. Rev. Lett.*, **70**, pp. 1858–1861.
370. Dienwiebel, M., Verhoeven, G. S., Pradeep, N., Frenken, J. W. M., Heimberg, J. A., and Zandbergen, H. W. (2004). Superlubricity of graphite, *Phys. Rev. Lett.*, **92**, pp. 126101_1–126101_4.
371. Kolmogorov, A. N., and Crespi, V. H. (2000). Smoothest bearings: interlayer sliding in multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **85**, pp. 4727–4730.
372. Saito, R., Matsuo, R., Kimura, T., Dresselhaus, G., and Dresselhaus, M. S. (2001). Anomalous potential barrier of double-wall carbon nanotube, *Chem. Phys. Lett.*, **348**, pp. 187–193.
373. Damnjanović, M., Vuković, T., and Milošević, I. (2002). Super-slippery carbon nanotubes, *Eur. Phys. J. B*, **25**, pp. 131–134.
374. Xia, Z., and Curtin, W. A. (2004). Pullout forces and friction in multiwall carbon nanotubes, *Phys. Rev. B*, **69**, pp. 233408_1–233408_4.
375. Zhao, Y., Ma, C.-C., Chen, G. H., and Jiang, Q. (2003). Energy dissipation mechanisms in carbon nanotube oscillators. *Phys. Rev. Lett.*, **91**, pp. 175504_1–175504_4.

376. Tangney, P., Louie, S. G., and Cohen, M. L. (2004). Dynamic sliding friction between concentric carbon nanotubes, *Phys. Rev. Lett.*, **93**(6), pp. 065503_1–065503_4.
377. Servantie, J., and Gaspard, P. (2003). Methods of calculation of a friction coefficient: application to nanotubes, *Phys. Rev. Lett.*, **91**, pp. 185503_1–185503_4.
378. Socoliuc, A., Bennewitz, R., Gnecco, E., and Meyer, E. (2004). Transition from stick-slip to continuous sliding in atomic friction: entering a new regime of ultralow friction, *Phys. Rev. Lett.*, **92**, pp. 134301_1–134301_4
379. Zheng, Q., and Jiang, Q. (2002). Multiwalled carbon nanotubes as gigahertz oscillators, *Phys. Rev. Lett.*, **88**(4), pp. 045503_1–045503_4.
380. Rivera, J. L., McCabe, C., and Cummings, P. T. (2003). Oscillatory behavior of double-walled nanotubes under extension: a simple nanoscale damped spring, *Nano Lett.*, **3**, pp. 1001–1005.
381. Hong, B. H., Small, J. P., Purewal, M. S., Mullokandov, A., Sfeir, M. Y., Wang, F., Lee, J. Y., Heinz, T. F., Brus, L. E., Kim, P., and Kim, K. S. (2005). Extracting subnanometer single shells from ultralong multiwalled carbon nanotubes, *Proc. Natl. Acad. Sci.*, **102**, pp. 14155–14158.
382. Hertel, T., Walkup, R. E., and Avouris, P. (1998). Deformation of carbon nanotubes by surface van der Waals forces, *Phys. Rev. B*, **58**, pp. 13870–13873.
383. Williams, P. A., Papadakis, S. J., Patel, A. M., Falvo, M. R., Washburn, S., and Superfine, R. (2002). Torsional response and stiffening of individual multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **89**(25), pp. 255202_1–255202_4.
384. Williams, P. A., Papadakis, S. J., Patel, A. M., Falvo, M. R., Washburn, S., and Superfine, R. (2003). Fabrication of nanometer-scale mechanical devices incorporating multiwalled carbon nanotubes as torsional springs, *Appl. Phys. Lett.*, **82**, pp. 805–807.
385. Papadakis, S. J., Hall, A. R., Williams, P. A., Vicci, L., Falvo, M. R., Superfine, R., and Washburn, S. (2004). Resonant oscillators with carbon-nanotube torsion springs, *Phys. Rev. Lett.*, **93**(14), pp. 146101_1–146101_4.
386. Collins, P. G., Hersam, M., Arnold, M., Martel, R., and Avouris, P. (2001). Current saturation and electrical breakdown in multiwalled carbon nanotubes, *Phys. Rev. Lett.*, **86**, pp. 3128–3131.
387. Collins, P. G., Arnold, M. S., and Avouris, P. (2001). Engineering carbon nanotubes and nanotube circuits using electrical breakdown, *Science*, **292**, pp. 706–709.

388. Soule, D. E., and Nezbeda, C. W. (1968). Direct basal-plane shear in single-crystal graphite, *J. Appl. Phys.*, **39**, pp. 5122–5139.
389. Zheng, Q., Liu, J. Z., and Jiang, Q. (2002). Excess van der Waals interaction energy of a multiwalled carbon nanotube with an extruded core and the induced core oscillation, *Phys. Rev. B*, **65** pp. 245409_1–245409_6.
390. Henrard, L., Hernandez, E., Bernier, P., and Rubio, A. (1999). van der Waals interaction in nanotube bundles: consequences on vibrational modes, *Phys. Rev. B*, **60**, pp. R8521–R8524.
391. Kang, J. W., and Lee, J. H. (2008). Frequency characteristics of triple-walled carbon nanotube gigahertz devices, *Nanotechnology*, **19**, pp. 285704_1–285704_6.
392. Lebedeva, I. V., Knizhnik, A. A., Popov, A. M., Lozovik, Y. E., and Potapkin, B. V. (2009). Dissipation and fluctuations in nanoelectromechanical systems based on carbon nanotubes, *Nanotechnology*, **20**, pp. 105202_1–105202_13.
393. Ershova, O. V., Lebedeva, I. V., Lozovik, Y. E., Popov, A. M., Knizhnik, A. A., Potapkin, B. V., Bubel, O. N., Kislyakov, E. F., and Poklonskii, N. A. (2010). Nanotube-based nanoelectromechanical systems: control versus thermodynamic fluctuations, *Phys. Rev. B*, **81**, pp. 155453_1–155453_15.
394. Jensen, K., Girit, C., Mickelson, W., and Zettl, A. (2006). Tunable nanoresonators constructed from telescoping nanotubes, *Phys. Rev. Lett.*, **96**, pp. 215503_1–215503_4.
395. Cleland, A. N., and Roukes, M. L. (1996). Fabrication of high frequency nanometer scale mechanical resonators from bulk Si crystals *Appl. Phys. Lett.*, **69**, pp. 2653–2625.
396. Dalton, A. B., Collins, S., Munoz, E., Razal, J. M., Ebron, V. H., Ferraris, J. P., Coleman, J. N., Kim, B. G., and Baughman, R. H. (2003). Super-tough carbon-nanotube fibres, *Nature (London)* **423**, pp. 703.
397. Yang, L., Park, C.-H., Son, Y.-W., Cohen, M. L., and Louie, S. G. (2007). Quasiparticle energies and band gaps in graphene nanoribbons, *Phys. Rev. Lett.*, **99**, pp. 186801_1–186801_4.
398. Chen, Z. H., Lin, Y. M., Rooks, M. J., and Avouris, P. (2007). Graphene nano-ribbon electronics, *Physica E*, **40**, pp. 228–232.
399. Han, M. Y., Ozyilmaz, B., Zhang, Y. B., and Kim, P. (2007). Energy band-gap engineering of graphene nanoribbons, *Phys. Rev. Lett.*, **98**, pp. 206805_1–206805_4.

400. Tapaszto, L., Dobrik, G., Lambin, P., and Biro, L. P. (2008). Tailoring the atomic structure of graphene nanoribbons by scanning tunnelling microscope lithography, *Nat. Nanotechnol.*, **3**, pp. 397–401.
401. Bai, J. W., Duan, X. F., and Huang, Y. (2009). Rational fabrication of graphene nanoribbons using a nanowire etch mask, *Nano Lett.*, **9**, pp. 2083–2087.
402. Wang, X. R., and Dai, H. J. (2010). Etching and narrowing of graphene from the edges, *Nat. Chem.*, **2**, pp. 661–665.
403. Li, X. L., Wang, X. R., Zhang, L., Lee, S. W., and Dai, H. J. (2008). Chemically derived, ultrasmooth graphene nanoribbon semiconductors, *Science*, **319**, pp. 1229–1232.
404. Wu, Z. S., Ren, W. C., Gao, L. B., Liu, B. L., Zhao, J. P., and Cheng, H. M. (2010). Efficient synthesis of graphene nanoribbons sonochemically cut from graphene sheets, *Nano Res.*, **3**, pp. 16–22.
405. Campos-Delgado, J., Romo-Herrera, J. M., Jia, X. T., Cullen, D. A., Muramatsu, H., Kim, Y. A., Hayashi, T., Ren, Z. F., Smith, D. J., Okuno, Y., Ohba, T., Kanoh, H., Kaneko, K., Endo, M., Terrones, H., Dresselhaus, M. S., and Terrones, M. (2008). Bulk production of a new form of sp² carbon: crystalline graphene nanoribbons, *Nano Lett.*, **8**, pp. 2773–2778.
406. Wei, D. C., Liu, Y. Q., Zhang, H. L., Huang, L. P., Wu, B., Chen, J. Y., and Yu, G. (2009). Scalable synthesis of few-layer graphene ribbons with controlled morphologies by a template method and their applications in nanoelectromechanical switches, *J. Am. Chem. Soc.*, **131**, pp. 11147–11154.
407. Datta, S. S., Strachan, D. R., Khamis, S. M., and Johnson, A. T. C. (2008). Crystallographic etching of few-layer graphene, *Nano Lett.*, **8**(7), pp. 1912–1915.
408. Ci, L. J., Xu, Z. P., Wang, L. L., Gao, W., Ding, F., Kelly, K. F., Yakobson, B. I., and Ajayan, P. M. (2008). Controlled nanocutting of graphene, *Nano Res.*, **1**, pp. 116–122.
409. Campos, L. C., Manfrinato, V. R., Sanchez-Yamagishi, J. D., Kong, J., and Jarillo-Herrero, P. (2009). Anisotropic etching and nanoribbon formation in single-layer graphene, *Nano Lett.*, **9**, pp. 2600–2604.
410. Kosynkin, D. V., Higginbotham, A. L., Sinitskii, A., Lomeda, J. R., Dimiev, A., Price, B. K., and Tour, J. M. (2009). Longitudinal unzipping of carbon nanotubes to form graphene nanoribbons, *Nature*, **458**, pp. 872–876.
411. Santos, H., Chico, L., and Brey, L. (2009). Carbon nanoelectronics: unzipping tubes into graphene ribbons, *Phys. Rev. Lett.*, **103**, pp. 086801_1–086801_4.

412. Jiao, L. Zhang, L., Wang, X., Diankov, G., and Dai, H. (2009). Narrow graphene nanoribbons from carbon nanotubes, *Nature* **458**, pp. 877–880.
413. Cano-Márquez, A. G., Rodriguez-Macías, F. J., Campos-Delgado, J., Espinosa-González, C. G., Tristán-López, F., Ramírez-Gonzalez, C. G., Cullen, D. A., Smith, D. J., Terrones, M., and Vega-Cantu, Y. I. (2009). Ex-MWNTs: graphene sheets and ribbons produced by lithium intercalation and exfoliation of carbon nanotubes, *Nano Lett.*, **9**(4), pp. 1527–1533.
414. Elías, A. L., Botello-Méndez, A. R., Meneses-Rodríguez, D., González, V. J., Ramírez-González, D., Ci, L., Muñoz-Sandoval, E., Ajayan, P. M., Terrones, H., and Terrones, M. (2010). Longitudinal cutting of pure and doped carbon nanotubes to form graphitic nanoribbons using metal clusters as nanoscalpels, *Nano Lett.*, **10**, pp. 366–372.
415. Kim, K., Sussman, A., and Zettl, A. (2010). Graphene nanoribbons obtained by electrically unwrapping carbon nanotubes, *ACS Nano* **4**(3), pp. 1362–1366.
416. Jiao, L., Zhang, L., Ding, L., Liu, J., and Dai, H. (2010). Aligned graphene nanoribbons and crossbars from unzipped. Carbon nanotubes, *Nano Res.*, **3**, pp. 387–394.
417. Liang, F., Sadana, A. K., Peera, A., Chattopadhyay, J., Gu, Z., Hauge, R. H., and Billups, W. E. (2004). A convenient route to functionalized carbon nanotubes, *Nano Lett.*, **4**, pp. 1257–1260.
418. Chattopadhyay, J., Sadana, A. K., Liang, F., Beach, J. M., Xiao, Y., Hauge, R. H., and Billups, W. E. (2005). Carbon nanotube salts. Arylation of single-wall carbon nanotubes, *Org. Lett.*, **7**(19), pp. 4067–4069.
419. Ci, L., Xu, Z., Wang, L., Gao, W., Ding, F., Kelly, K. F., Yakobson, B. I., and Ajayan, P. M. (2008). Controlled nanocutting of graphene, *Nano Res.*, **1**, pp. 116–122.
420. Yuzvinsky, T. D., Mickelson, W., Aloni, S., Konsek, S. L., Fennimore, A. M., Begtrup, G. E., Kis, A., Regan, B. C., and Zettl, A. (2005). Imaging the life story of nanotube devices, *Appl. Phys. Lett.*, **87**, pp. 053109_1–053109_3.
421. Kim, W. S., Moon, S. Y., Bang, S. Y., Choi, B. G., Ham, H., Sekino, T., and Shim, K. B. Fabrication of graphene layers from multiwalled carbon nanotubes using high dc pulse. *Appl. Phys. Lett.*, **95**, pp. 083103_1–083103_3.
422. Ajayan, P. M., and Tour, J. M. (2007). Nanotube composites, *Nature*, **447**, pp. 1066–1068.

423. Mehta, P., and Monteiro, P. (2005). *Concrete: Microstructure, Properties, and Materials, 3rd ed.* (McGraw-Hill Professional).
424. Bard, K. A. (2008). *An Introduction to the Archaeology of Ancient Egypt* (Oxford: Blackwell Publishing Ltd).
425. Hata, K., Futaba, D. N., Mizuno, K., Namai, T., Yumura, M., and Iijima, S. (2004). Water-assisted highly efficient synthesis of impurity-free singlewalled carbon nanotubes. *Science*, **306**, pp. 1362–1364.
426. Chou, T.-W. (1992). *Microstructural Design of Fiber Composites* (Cambridge University Press).
427. Frankland, S. J. V., Caglar, A., Brenner, D. W., and Griebel, M. (2002). Molecular simulation of the influence of chemical cross-links on the shear strength of carbon nanotube–polymer interfaces, *J. Phys. Chem. B*, **106**, pp. 3046–3048.
428. Liao, K., and Li, S. (2001). Interfacial characteristics of a carbon nanotube-polystyrene composite system, *Appl. Phys. Lett.*, **79**, pp. 4225–4227.
429. Frogley, M. D., Ravich, D., and Wagner, H. D. (2003). Mechanical properties of carbon nanoparticle-reinforced elastomers, *Compos. Sci. Technol.*, **63**, pp. 1647–1654.
430. Dai, H. (2002). Carbon nanotubes: opportunities and challenges, *Surf. Sci.*, **500**, pp. 218–241.
431. Harris, P. J. F. (2004). Carbon nanotube composites. *Int. Mater. Rev.*, **49**, pp. 31–43.
432. Jin, L., Bower, C., and Zhou, O. (1999). Alignment of carbon nanotubes in a polymer matrix by mechanical stretching, *Appl. Phys. Lett.*, **73**(9), pp. 1197–1199.
433. Haggenmueller, R., Gommans, H. H., Rinzler, A. G., Fischer, J. E., and Winey, K. I. (2000). Aligned single-wall carbon nanotubes composites by melt processing methods, *Chem. Phys. Lett.*, **330**(3–4), pp. 219–225.
434. Shaffer, M., and Kinloch, I. A. (2004). Prospects for nanotube and nanofibre composites, *Compos. Sci. Technol.*, **64**, pp. 2281–2282.
435. Tucker, C. L., and Liang, E. (1999). Stiffness predictions for unidirectional shortfiber composites: review and evaluation, *Compos. Sci. Technol.*, **59**, 5, pp. 655–671.
436. Daniel, I. M., and Ishai, O. (1994). *Engineering Mechanics of Composite Materials*, (Oxford University Press).
437. Callister, W. D. (2003). *Materials Science and Engineering, an Introduction*, (Wiley, New York).

438. Cox, H. L. (1952). The elasticity and strength of paper and other fibrous materials, *Br. J. Appl. Phys.*, **3**, pp. 72–79.
439. Kelley, A. (1966). *Strong Solids*, (Oxford University Press).
440. Zhang, X., Cao, A., Wei, B., Li, Y., Wei, J., Xu, C., Wu, D. (2002). Rapid growth of well aligned carbon nanotube arrays, *Chem. Phys. Lett.*, **362**, pp. 285–290.
441. Zhong, G., Iwasaki, T., Robertson, J., and Kawarada, H. (2007). Growth kinetics of 0.5 cm vertically aligned single-walled carbon nanotubes, *J. Phys. Chem. B*, **111**, pp. 1907–1910.
442. Ci, L., Suhr, J., Pushparaj, V., Zhang, X., and Ajayan, P. M. (2008). Continuous carbon nanotube reinforced composites, *Nano Lett.*, **8**(9), pp. 2762–2766.
443. Yap, H. W., Lakes, R. S., and Carpick, R. W. (2007). Mechanical instabilities of individual multiwalled carbon nanotubes under cyclic axial compression, *Nano Lett.*, **7**, pp. 1149–1154.
444. Thostenson, E. T., and Chou, T.-W. (2004). Nanotube buckling in aligned multi-wall carbon nanotube composites, *Carbon*, **42**, pp. 3015–3018.
445. Kuzumaki, T., and Mitsuda, Y. (2006). Nanoscale mechanics of carbon nanotube evaluated by nanoprobe manipulation in transmission electron Microscope, *Jpn. J. Appl. Phys.*, **45**, pp. 364–368.
446. Schadler, L. S., Giannaris, S. C and Ajayan, P. M. (1998). Load transfer in carbon nanotube epoxy composites, *Appl. Phys. Lett.*, **73**(26), pp. 3842–3844.
447. Andrews, R., Jacques, D., Rao, A. M., Rantell, T., Derbyshire, F., Chen, Y., Chen, J., and Haddon, R. C. (1999). Nanotube composite carbon fibers, *Appl. Phys. Lett.*, **75**, pp. 1329–1331.
448. Mamedov, A. A., Kotov, N. A., Prato, M., Guldi, D. M., Wicksted, J. P., and Hirsch, A. (2002). Molecular design of strong single-wall carbon nanotube/polyelectrolyte multilayer composites, *Nature Mater.*, **1**, pp. 190–194.
449. Frogley, M. D., Ravich, D., and Wagner, H. D. (2003). Mechanical properties of carbon nanoparticle-reinforced elastomers, *Compos. Sci. Technol.*, **63**, pp. 1647–1654.
450. Barber, A. H., Cohen, S. R., and Wagner, H. D. (2003). Measurement of carbon nanotube–polymer interfacial strength, *Appl. Phys. Lett.*, **82**, pp. 4140–4142.
451. Wagner, H. D., and Vaia, R. A. (2004). Carbon nanotube-based polymer composites: outstanding issues at the interface for mechanics, *Mater. Today*, **7**, pp. 38–42.

452. Barber, A. H., Cohen, S. R., Kenig, S., and Wagner, H. D. (2004). Interfacial fracture energy measurements for multi-walled carbon nanotubes pulled from a polymer matrix, *Compos. Sci. Technol.*, **64**, pp. 2283–2289.
453. Liu, J. Q., Xiao, T., Liao, K., and Wu, P. (2007). Interfacial design of carbon nanotube polymer composites: a hybrid system of noncovalent and covalent functionalizations, *Nanotechnology*, **18**, pp. 165701_1–165701_6.
454. Kim, B. W., and Nairn, J. A. (2002). Observations of fiber fracture and interfacial debonding phenomena using the fragmentation test in single fiber composites, *J. Comp. Mater.*, **36**, pp. 1825–1858.
455. Zhandarov, S., Pisanova, E., Mader, E., and Nairn, J. A. (2001). Investigation of load transfer between the fiber and the matrix in pull-out tests with fibers having different diameters, *J. Adhesion Sci. Tech.*, **15**, pp. 205–222.
456. Pisanova, E., Zhandarov, S., Mader, E., Ahmad, I., and Young, R. J. (2001). Three techniques of interfacial bond strength estimation from direct observation of crack initiation and propagation in polymer-fibre systems, *Composites A*, **32**, pp. 435–443.
457. Pisanova, E., Zhandarov, S., and Mader, E. (2001). How can adhesion be determined from micromechanical tests? *Composites A*, **32**, pp. 425–434.
458. Nairn, J. A. (2000). Analytical fracture mechanics analysis of the pull-out test including the effects of friction and thermal stresses, *Adv. Comp. Lett.*, **9**, pp. 373–383.
459. Leung, C. K. Y., and Li, V. C. (1991). New strength-based model for the debonding of discontinuous fibres in an elastic matrix, *J. Mater. Sci.*, **26**, pp. 5996–6010.
460. Kerans, R. J., and Parthasarathy, T. A. (1991). Theoretical Analysis of the Fiber Pullout and Pushout Tests, *J. Am. Ceramic Soc.*, **74**, pp. 1585–1596.
461. Jia, Z., Wang, Z., Xu, C., Liang, J., Wei, B., Wu, D., and Zhu, S. (1999). Study on poly(methyl methacrylate)/carbon nanotube composites, *Mater. Sci. Eng. A*, **271**, pp. 395–400.
462. Mylvaganam, K., and Zhang, L. C. (2004). Chemical bonding in polyethylene-nanotube composites: a quantum mechanics prediction, *J. Phys. Chem. B*, **108**, pp. 5217–5220.

463. Eitan, A., Jiang, K., Dukes, D., Andrews, R., and Schadler, L. S. (2003). Surface modification of multiwalled carbon nanotubes: toward the tailoring of the interface in polymer composites, *Chem. Mater.*, **15**, pp. 3198–3201.
464. Goh, H. W., Goh, S. H., Xu, G. Q., Pramoda, K. P., and Zhang, W. D. (2003). Dynamic mechanical behavior of *in situ* functionalized multi-walled carbon nanotube/phenoxy resin composite, *Chem. Phys. Lett.*, **373**, pp. 277–283.
465. Jang, J., Bae, J., and Yoon, S.-H. (2003). A study on the effect of surface treatment of carbon nanotubes for liquid crystalline epoxide-carbon nanotube composites, *J. Mater. Chem.*, **13**, pp. 676–681.
466. Sun, Y.-P., Fu, K., Lin, Y., and Huang, W. (2002). Functionalized carbon nanotubes: properties and applications, *Acc. Chem. Res.*, **35**, pp. 1096–1104.
467. Wong, M., Paramsothy, M., Xu, X. J., Ren, Y., Li, S., and Liao, K. (2003). Physical interactions at carbon nanotube–polymer interface, *Polymer*, **44**, pp. 7757–7764.
468. Bai, J. B., and Allaoui, A. (2003). Effect of the length and the aggregate size of MWNTs on the improvement efficiency of the mechanical and electrical properties, *Composites A*, **34**, pp. 689–694.
469. Bai, J. B. (2003). Evidence of the reinforcement role of CVD multi-walled carbon nanotubes in a polymer matrix, *Carbon*, **41**, pp. 1331–1334.
470. Wagner, H. D., Lourie, O., Feldman, Y., and Tenne, R. (1998). Stress-induced fragmentation of multiwall carbon nanotubes in a polymer matrix, *Appl. Phys. Lett.*, **72**, pp. 188–190.
471. Lordi, V., and Yao, N. (2002). Molecular mechanics of binding in carbon nanotubes-polymer composites, *J. Mater. Res.*, **15**, pp. 2770–2779.
472. Moon, C. K., Lee, J.-O., Cho, H. H., and Kim, K. S. (1992). Effect of diameter and surface treatment of fiber on interfacial shear strength in glass fiber/epoxy and HDPE, *J. Appl. Polym. Sci.*, **45**, pp. 443–450.
473. Koss, D. A., Petrich, R. R., Kallas, M. N., and Hellmann, J. R. (1994). Interfacial shear and matrix plasticity during fiber push-out in a metal-matrix composite, *Compos. Sci. Technol.*, **51**, pp. 27–33.
474. Tripathi, D., Turton, T., Chen, F., and Jones, F. (1997). A new method to normalize the effect of matrix properties on the value of interfacial shear strength obtained from the fragmentation test, *J. Mater. Sci.*, **32**, pp. 4759–4765.

475. Huang, Y., and Young, R. J. (1996). Interfacial micromechanics in thermoplastic and thermosetting matrix carbon fibre composites, *Composites A*, **27**, pp. 973–980.
476. Chua, P. S., and Piggott, M. R. (1985) The glass fibre-polymer interface: I—theoretical consideration for single fibre pull-out tests, *Compos. Sci. Technol.*, **22**, pp. 33–42.
477. Ajayan, P. M., Stephan, O., Colliex, C., and Trauth, D. (1994). Aligned carbon nanotube arrays formed by cutting a polymer resin-nanotube composite, *Science*, **265**(5176), pp. 1212–1214.
478. Cooper, C. A., Cohen, S. R., Barber, A. H., and Wagner, H. D. (2002). Detachment of nanotubes from a polymer matrix, *Appl. Phys. Lett.*, **81**(20), pp. 3873–3875.
479. Coleman, J. N., Khan, U., Blau, W. J., and Gun'ko, Y. K. (2006). Small but strong: a review of the mechanical properties of carbon nanotube-polymer composites, *Carbon*, **44**, pp. 1624–1652.
480. Dufresne, A., Paillet, M., Putaux, J. L., Canet, R., Carmona, F., Delhaes, P., and Cui, S. (2002). Processing and characterization of carbon nanotube/poly(styrene-co-butyl acrylate) nanocomposites, *J. Mater. Sci.*, **37**(18), pp. 3915–3923.
481. Probst, O., Moore, E. M., Resasco, D. E., and Grady, B. P. (2004). Nucleation of polyvinyl alcohol crystallization by single-walled carbon nanotubes, *Polymer*, **45**(13), pp. 4437–4443.
482. Dalmas, F., Chazeau, L., Gauthier, C., Masenelli-Varlot, K., Dendievel, R., Cavaillé, J. Y., and Folló, L. et al. (2005). Multiwalled carbon nanotube/polymer nanocomposites: processing and properties, *J. Polym. Sci. Part B: Polym. Phys.*, **43**, pp. 1186–1197.
483. Shaffer, M. S. P., and Windle, A. H. (1999). Fabrication and characterization of carbon nanotube/poly(vinyl alcohol) composites, *Adv. Mater.*, **11**(11), pp. 937–941.
484. Coleman, J. N., Cadek, M., Blake, R., Nicolosi, V., Ryan, K. P., Belton, C., Fonseca, A., Nagy, J. B., Gun'ko, Y. K., and Blau, W. J. (2004). High performance nanotube-reinforced plastics: understanding the mechanism of strength increase, *Adv. Funct. Mater.*, **14**(8), pp. 791–798.
485. Andrews, R., Jacques, D., Minot, M., and Rantell, T. (2002). Fabrication of carbon multiwall nanotube/polymer composites by shear mixing, *Macromol. Mater. Eng.*, **287**(6), pp. 395–403.
486. Breuer, O., and Sundararaj, U. (2004). Big returns from small fibers: a review of polymer/carbon nanotube composites, *Polym. Compos.*, **25**(6), pp. 630–645.

487. Jin, Z., Pramoda, K., Xu, G., and Goh, S. H. (2001). Dynamic mechanical behavior of melt-processed multi-walled carbon nanotube/poly(methyl methacrylate) composites, *Chem. Phys. Lett.*, **337**(1–3), pp. 43–47.
488. Liu, T. X., Phang, I. Y., Shen, L., Chow, S. Y., and Zhang, W.-D. (2004). Morphology and mechanical properties of multiwalled carbon nanotubes reinforced nylon-6 composites, *Macromolecules*, **37**(19), pp. 7214–7222.
489. De Zhang, W., Shen, L., Phang, I. Y., and Liu, T. X. (2004). Carbon nanotubes reinforced nylon-6 composite prepared by simple melt-compounding, *Macromolecules*, **37**(2), pp. 256–259.
490. Ajayan, P. M., Schadler, L. S., Giannaris, C., and Rubio, A. (2000). Single-walled carbon nanotube–polymer composites: strength and weakness, *Adv. Mater.*, **12**(10), pp. 750–753.
491. Xu, X., Thwe, M. M., Shearwood, C., and Liao, K. (2002). Mechanical properties and interfacial characteristics of carbon-nanotube-reinforced epoxy thin films, *Appl. Phys. Lett.*, **81**(15), pp. 2833–2835.
492. Allaoui, A., Bai, S., Cheng, H. M., and Bai, J. B. (2002). Mechanical and electrical properties of a MWNT/epoxy composite, *Compos. Sci. Technol.*, **62**(15), pp. 1993–1998.
493. Bai, J. (2003). Evidence of the reinforcement role of chemical vapour deposition multi-walled carbon nanotubes in a polymer matrix, *Carbon*, **41**(6), pp. 1325–1328.
494. Viswanathan, G., Chakrapani, N., Yang, H., Wei, B., Chung, H., Cho, K., Ryu, C. Y., and Ajayan, P. M. (2003). Single-step *in situ* synthesis of polymer-grafted single-wall nanotube composites, *J. Am. Chem. Soc.*, **125**(31), pp. 9258–9259.
495. Fu, K., Huang, W., Lin, Y., Riddle, L. A., Carroll, D. L., and Sun, Y. P. (2001). Defunctionalization of functionalized carbon nanotubes, *Nano Lett.*, **1**(8), pp. 439–441.
496. Peigney, A. (2002). Tougher ceramics with nanotubes, *Nat. Mater.*, **2**, pp. 15–16.
497. Cho, J., Boccaccini, A. R., and Shaffer, M. S. P. (2009). Ceramic matrix composites containing carbon nanotubes, *J. Mater. Sci.*, **44**, pp. 1934–1951.
498. Sun, J., Gao, L., and Li, W. (2002). Colloidal processing of carbon nanotube/alumina composites, *Chem. Mater.*, **14**, pp. 5169–5172.
499. Zhan, G. D., Kuntz, J. D., Wan, J. L., and Mukherjee, A. K. (2003). Single-wall carbon nanotubes as attractive toughening agents in alumina-based nanocomposites, *Nat. Mater.*, **2**, pp. 38–42.

500. Wang, X. T., Padture, N. P., and Tanaka, H. (2004). Contact-damage-resistant ceramic/single-wall carbon nanotubes and ceramic/graphite composites, *Nat. Mater.*, **3**, pp. 539–544.
501. Jiang, D. T., Thomson, K., Kuntz, J. D., Ager, J. W., and Mukherjee, A. K. (2007). Effect of sintering temperature on a single-wall carbon nanotube-toughened alumina-based nanocomposite, *Scripta. Mater.*, **56**, pp. 959–962.
502. Ahmad, K., and Pan, W. (2008). Hybrid nanocomposites: a new route towards tougher alumina ceramics, *Compos. Sci. Technol.*, **68**(6), pp. 1321–1327.
503. Balani, K., Zhang, T., Karakoti, A., Li, W. Z., Seal, S., Agarwal, A. (2008). *In situ* carbon nanotube reinforcements in plasma sprayed aluminum oxide nanocomposite coating, *Acta Mater.*, **56**(3), pp. 571–579.
504. Xia, Z. H., Lou, J., and Curtin, W. A. (2008). A multiscale experiment on the tribological behavior of aligned carbon nanotube/ceramic composites, *Scripta. Mater.*, **58**, pp. 223–226.
505. Estili, M., and Kawasaki, A. (2008). An approach to mass-producing individually alumina-decorated multi-walled carbon nanotubes with optimized and controlled compositions, *Scripta. Mater.*, **58**, pp. 906–909.
506. Sridhar, I., and Narayanan, K. R. (2009). Processing and characterization of MWCNT reinforced aluminum matrix composites, *J. Mater. Sci.*, **44**, pp. 1750–1756.
507. Flahaut, E., Peigney, A., Laurent, Ch., Marlière, Ch., Chastel, F., and Rousset, A. (2000). Carbon nanotube-metal-oxide nanocomposites: microstructure, electrical conductivity and mechanical properties, *Acta Mater.*, **48**(14), pp. 3803–3812.
508. Peigney, A., Laurent, Ch., Flahaut, E., and Rousset, A. (2000). Carbon nanotubes in novel ceramic matrix nanocomposites, *Ceram. Int.*, **26**(6), pp. 667–683.
509. Peigney, A., Laurent, Ch., Dumortier, O., and Rousset, A. (1998). Carbon nanotubes-Fe-alumina nanocomposites. Part I: influence of the Fe content on the synthesis of powders. *J. Eur. Ceram. Soc.*, **18**(14), pp. 1995–2004.
510. Peigney, A., Laurent, Ch., Dumortier, O., and Rousset, A. (1998). Carbon nanotubes-Fe-alumina nanocomposites. Part II: microstructure and mechanical properties of the hot-pressed composites, *J. Eur. Ceram. Soc.*, **18**(14), pp. 2005–2013.
511. Peigney, A., Laurent, Ch., and Rousset, A. (1997). Synthesis and characterization of alumina matrix nanocomposites containing carbon nanotubes, *Key Eng. Mater.*, **132–136**, pp. 743–746.

512. Bakshi, S. R., Lahiri, D., and Agarwal, A. (2010). Carbon nanotube reinforced metal matrix composites—a review, *Int. Mater. Rev.*, **55**, pp. 41–64.
513. George, R., Kashyap, K. T., Rahul, R., and Yamdagni, S. (2005). Strengthening in carbon nanotube/aluminium (CNT/Al) composites, *Scr. Mater.*, **53**, pp. 1159–1163.
514. Tokunaga, T., Kaneko, K., and Horita, Z. (2008). Production of aluminum-matrix carbon nanotube composite using high pressure torsion, *Mater. Sci. Eng.*, **A490**, pp. 300–304.
515. Kwon, H., Estili, M., Takagi, K., Miyazaki, T., and Kawasaki, A. (2009). Combination of hot extrusion and spark plasma sintering for producing carbon nanotube reinforced aluminum matrix composites, *Carbon*, **47**(4), pp. 570–577.
516. Dong, S. R., Tu, J. P., and Zhang, X. B. (2001). An investigation of the sliding wear behavior of Cu-matrix composite reinforced by carbon nanotubes, *Mater. Sci. Eng.*, **A313**, pp. 83–87.
517. Kim, K. T., Eckert, J., Menzel, S. B., Gemming, T., and Hong, S. H. (2008). Grain refinement assisted strengthening of carbon nanotube reinforced copper matrix nanocomposites, *Appl. Phys. Lett.*, **92**, pp. 121901_1–121901_3.
518. Li, H., Misra, A., Horita, Z., Koch, C. C., Mara, N. A., Dickerson, P. O., and Zhu, Y. (2009). Strong and ductile nanostructured Cu-carbon nanotube composite, *Appl. Phys. Lett.*, **95**, pp. 071907_1–071907_3.
519. Goyal, A., Wiegand, D. A., Owens, F. J., and Iqbal, Z. (2006). Enhanced yield strength in iron nanocomposite with *in situ* grown single-wall carbon nanotubes, *J. Mater. Res.*, **21**, pp. 522–528.
520. Jeong, Y. J., Cha, S. I., Kim, K. T., Lee, K. H., Mo, C. B., and Hong, S. H. (2007). Synergistic strengthening effect of ultrafine-grained metals reinforced with carbon nanotubes, *Small*, **3**, pp. 840–844.
521. Dong, L., Subramanian, A., and Nelson, B. J. (2007) Carbon nanotubes for nanorobotics, *Nano Today*, **2**, pp. 12–21.
522. Huang, X., and Zhang, S. (2010). Load-driven morphological evolution in covalently bridged multiwalled carbon nanotubes, *Appl. Phys. Lett.*, **96**, pp. 203106_1–203106_3.
523. Zhu, T., Li, J., Ogata, S., and Yip, S. (2009) Mechanics of ultra-strength materials, *MRS Bull.*, **34**, pp. 167–172.

Index

- 5-7 paired defect 108, 109, 116, 117, 138
5-7-7-5 defect 82, 83, 88, 90, 91, 104, 109, 111, 114, 117, 141
- actuator 133, 158, 165, 166
adatom 136, 141
Ag nanowire 102
Al-nanotube composites 208
armchair carbon nanotube 37, 140
as-grown nanotube structures 101
asbestos fiber 187
atomic force microscope (AFM) 13, 100, 126, 180, 201
atomic reconstruction 103, 117, 136, 138–40, 144, 145, 151
Au nanowire 102
- bamboo-shaped carbon nanotube 91
beam deformations 43
beam extension 172
bending 2, 25, 35, 48, 60, 61, 75
bending deformations 43, 45–46
bending modulus 12
bending moment 43, 44, 60
bending rigidity 44–46, 50–52
elastic 52–53
bending strain 37
bending stress 42
- biased carbon nanotubes 118
bond energies 27–29
bond formation 143–44
bond rotations 82, 87, 96, 114–15
bond vector, deformed 54–55
bonds, pentagon 140–41
boron nitride nanotube 11
breaking strength 99
brittle behavior 112, 207
brittle crack 74, 110, 114
brittle failure 114, 116
brittle material 100, 107
brittle mechanism 114
buckling 15, 25, 35, 48, 59, 195
buckling point 65–67
buckling shear strains, critical 72–73
bulk modulus 40
bundle geometries 31
- cantilever 19, 126, 202
cantilever beam 45
carbon filaments 5, 7
carbon foam 95
carbon nanocoil 91, 121–24, 126–29, 131
multi-walled 123, 126
single-walled 123–24
synthesis of 123
carbon nanocoil forest 131
carbon nanocoil array 131, 132
carbon nanotube, discovery of 4–5
carbon nanotube array 194–96

- carbon nanotube bundle 15, 17, 19, 31
carbon nanotube composites 137
carbon nanotube deformation 82
carbon nanotube fiber,
macroscopic 17
carbon nanotube morphology 135
carbon nanotubular structures 57
carbon tetrapod 95
carbyne 140
catalytic hydrogenation 182
Cauchy–Born rule 53–55
ceramics 100, 137, 190, 207–8
chemical vapor deposition (CVD)
123, 129–30, 176
chirality 30, 37, 52, 53, 64, 65, 71,
73, 84, 88, 95, 101, 109, 110,
112, 142, 159
cohesive energy 122
coil geometry statistics 129
coiled carbon nanotube 121
conjugate gradient method 23
continuous nanotubes
threading 194
continuum shell modeling 53
critical buckling angle 77
critical buckling bending
curvature 76
critical buckling pressure 78
critical buckling strain 72
critical buckling torque 71
cumulene 118, 119
current annealing 156
cushioning effect 131, 133
- dangling bond 138, 140, 151
dangling bond saturation 136,
142, 145
defect 3, 25, 54, 62
defect, irradiation-induced 135,
138
defect aggregation 83
defect nucleation 54, 109
- deformation
rippled 70
torsional 36, 72, 74
density functional theory (DFT)
22, 24, 29, 31, 33
diamond buckling pattern 69
diamond-like corrugation 69
diketone 178
dimerization 119
dislocation 81
divacancy 117, 140
doped carbon nanotubes 183
double-walled carbon nanotube
(DWNT) 73, 157–58, 184
ductile elongation 111
ductile mechanism 115, 116
- elastic constant 40
electron beam irradiation 18, 97,
135–38, 145–47, 149, 151,
154, 156
electron microscope 2
epoxy-nanotube composite 204
- failure strain 104
failure strength 99, 104
failure-strain map 115
fiber-reinforced composite 188,
190
first-generation Brenner potential
26, 28
force constant 10, 15, 19, 26, 27,
119
formation energy 84–88, 143–45
fracture strength 99
full width at half maximum
(FWHM) 128
fusion 91, 96, 97, 151, 152
- γ -ray irradiation 137
graphene 41, 49–50, 146, 177

- graphene nanoribbon 175–77,
179, 183–84
- graphene sheet 30, 37, 50–51, 61,
85–86, 88–89, 146, 175,
181–82
- graphite 35–36, 50, 53, 56–57,
144, 159
- helical buckling 74
- helical carbon nanotube 121
- high-strength fiber 190
- high-strength material 102
- hole-shaped vacancy 104
- Hooke's law 41–42, 63
- intercalation-induced
exfoliation 180–81
- interfacial bonding 205
- interfacial coupling 189, 190
- interfacial strength 199–201
- internal sliding 157, 159
- ion beam irradiation 136, 137,
156
- kink 61, 62, 65, 67, 69, 108, 109,
116, 200
- large-hole effect 104–5
- left-handed rotation 71, 72
- linear acetylenic carbon 140
- long-fiber situation 190, 193
- low-friction sliding 159–61
- mechanical entanglement 203
- mixture rule 190–93, 196, 205
- molecular dynamics simulation
21, 23–25, 27, 30, 33, 34, 62,
72, 200
- moment of inertia 17, 41, 44, 173
- Morse-type functions 27–28
- multi-walled carbon nanotube
(MWNT) 4
- multishell nanotube elasticity 56
- nanocutting 176, 182–83
- nanoelectromechanical system
(NEMS) 128, 133
- nanoribbon 175–80, 184–85
multilayer 180
- nanoscale pullout tests 201–2
- nanotube–alumina composite 208
- nanotube atomic network 144
- nanotube axial stiffness 37
- nanotube-based
nanocomposites 57
- nanotube buckling 15, 61–62, 71
- nanotube deformation 112
- nanotube dispersion 204–5
- nanotube elasticity 41
- nanotube–epoxy composite 204
- nanotube–inorganic matrix
composite 208
- nanotube–metal oxide composite
208
- nanotube–polymer composites
197, 203
- nanotube–reinforced composite
199
- nanotube–silicon carbide
composite 208
- one-atom vacancy effect 102–3
- pentagonal defect 92
- plasma etching 176, 179
- plastic deformation 100, 126–27,
208
- polymer reinforcement 203, 205
- proton beam irradiation 137
- pullout, single-fiber 201

- quantum-mechanical simulation 21, 24, 101, 104, 105
 quantum-mechanics 22
 quasi-one-dimensional nanotube template 176
- radial corrugation 77, 79
 radial deformation 25
 radial shrinkage 141, 145, 147, 149
 re-hybridization defect 81
 reinforced composite 54
 reinforced fiber 61, 121, 187
 right-handed rotation 71, 72
 rippling 13, 61, 67–70, 74, 75
 rule of mixtures 190–93, 196, 205
- scanning electron microscope (SEM) 2
 scanning probe microscope (SPM) 201
 scanning tunneling microscope (STM) 124
 Schrödinger equation 22
 second moment of area 17, 44
 second-generation Brenner potential 27, 28
 self-healing 138
 shear modulus 56
 shear strength 157, 199–201
 shell-by-shell extraction 163
 short-fiber situation 192, 195
 Si nanocoil 127
 Si nanowire 102
 single vacancy 102, 140, 142, 144
 single-walled carbon nanotube (SWNT) 11
 SiO nanocoil 127
 sliding friction 161, 172
 sliding friction force 160
 slit defects 105
 circumferential 105
- slit-shaped vacancy 104
 sp^2 bonding 2, 9, 81, 85, 121, 128, 136, 138, 139, 182, 200
 sp^3 bonding 61, 81, 85
 spring constant 10, 19, 126, 127
 Stone–Wales transformation 82–84, 87, 90, 96, 97, 109, 111, 116
 Stone–Wales defect 25, 82
 strain energy 30, 35, 37, 41, 51, 59, 63, 65, 66, 69, 70, 74, 75, 83, 88, 125, 151
 strain-induced defect 86–87, 89
 stress 2
 stress–strain curve 33, 99, 102, 195, 204
 stress-strain curve 18
 sword-in-sheath mechanism 100, 160
- telescopic oscillation 167, 169
 tensile strength 2
 tensile test 19, 99, 101, 126
 tension 25
 Tersoff–Brenner potential 25, 27, 52
 tetravacancy 141
 thermoplastic polymer 203, 204
 thermosetting polymer 204
 tight-binding calculation 21, 23, 24, 31, 33, 34, 39, 118, 119
 topological defect 81, 88, 91, 108, 117, 122
 topological line defect 95
 torsion 25, 35, 48, 60, 61, 71, 72, 75
 torsional buckling 71, 72
 torsional rippling 74
 torsional spring 165
 torsional stress 42
 transient bending regime (TBR) 66

- transmission electron microscope (TEM) 2, 10
- triple-walled carbon nanotube 107
- tunable nanoresonator 171–73
- twist buckling 71, 73
- twisting 2
- ultimate strength 99, 208
- vacancy, 81
- van der Waals distance 65, 67
- van der Waals energy 69, 70, 168, 169
- van der Waals force 56, 158, 161, 189, 203
- van der Waals interaction 67, 157, 160, 162, 165, 168
- van der Waals energy 70
- van der Waals interaction 16, 17
- WS₂ nanotube 102
- X-shaped junction 156
- Y-shaped junction 156
- yield point 99, 100
- yield strength 208
- Yoshimura pattern 61, 69, 75
- Young's modulus 2, 9, 40, 49, 53, 191
- zigzag carbon nanotube 37
- ZnO nanohelices 127
- ZnO nanowire 102

