

Нанюуглеродные материалы

Технические характеристики

По вопросам продаж и поддержки обращайтесь:

Алматы (7273)495-231
Ангартск (3955)60-70-56
Архангельск (8182)63-90-72
Астрахань (8512)99-46-04
Барнаул (3852)73-04-60
Белгород (4722)40-23-64
Благовещенск (4162)22-76-07
Брянск (4832)59-03-52
Владивосток (423)249-28-31
Владикавказ (8672)28-90-48
Владимир (4922)49-43-18
Волгоград (844)278-03-48
Вологда (8172)26-4159
Воронеж (473)204-51-73
Екатеринбург (343)384-55-89
Иваново (4932)77-34-06
Ижевск (3412)26-03-58
Иркутск (395)279-98-46
Казань (843)206-01-48

Калининград (4012)72-03-81
Калуга (4842)92-23-67
Кемерово (3842)65-04-62
Киров (8332)68-02-04
Коломна (4966)23-41-49
Кострома (4942)77-07-48
Краснодар (861)203-40-90
Красноярск (391)204-63-61
Курск (4712)77-13-04
Курган (3522)50-90-47
Липецк (4742)52-20-81
Магнитогорск (3519)55-03-13
Москва (495)268-04-70
Мурманск (8152)59-64-93
Набережные Челны (8552)20-53-41
Нижний Новгород (831)429-08-12
Новокузнецк (3843)20-46-81
Ноябрьск (3496)41-32-12
Новосибирск (383)227-86-73

Омск (3812)21-46-40
Орел (4862)44-53-42
Оренбург (3532)37-68-04
Пенза (8412)22-31-16
Петрозаводск (8142)55-98-37
Псков (8112)59-10-37
Пермь (342)205-81-47
Ростов-на-Дону (863)308-18-15
Рязань (4912)46-61-64
Самара (846)206-03-16
Саранск (8342)22-96-24
Санкт-Петербург (812)309-46-40
Саратов (845)249-38-78
Севастополь (8692)22-31-93
Симферополь (3652)67-13-56
Смоленск (4812)29-41-54
Сочи (862)225-72-31
Ставрополь (8652)20-65-13
Сургут (3462)77-98-35

Сыктывкар (8212)25-95-17
Тамбов (4752)50-40-97
Тверь (4822)63-31-35
Тольятти (8482)63-91-07
Томск (3822)98-41-53
Тула (4872)33-79-87
Тюмень (3452)66-21-18
Ульяновск (8422)24-23-59
Улан-Удэ (3012)59-97-51
Уфа (347)229-48-12
Хабаровск (4212)92-98-04
Чебоксары (8352)28-53-07
Челябинск (351)202-03-61
Череповец (8202)49-02-64
Чита (3022)38-34-83
Якутск (4112)23-90-97
Ярославль (4852)69-52-93

Россия +7(495)268-04-70

Казахстан +7(7172)727-132

Киргизия +996(312)96-26-47

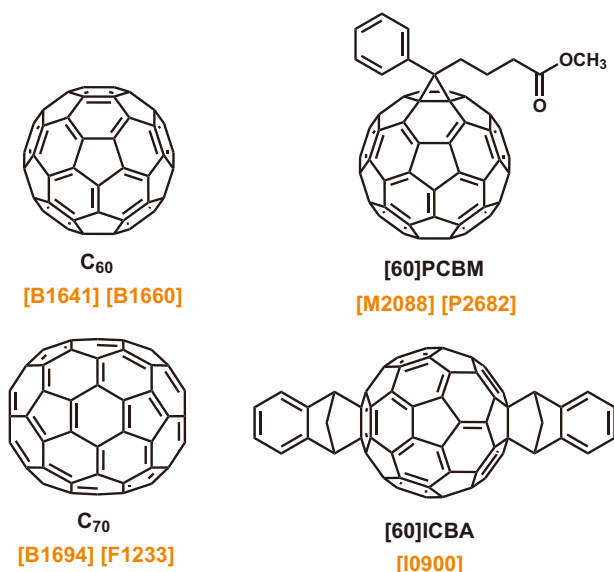
Адрес: <https://tci.nt-rt.ru/> || эл.почта: tic@nt-rt.ru

Nanocarbon Materials

1. Fullerenes

Fullerene is a spherical carbon compound and is an allotrope of carbon such as diamond, graphite and carbon nanotubes. Fullerenes of C_{60} , C_{70} and C_{84} are well known. They are isolable carbon compounds in a sole molecular species. Among them, the C_{60} is a representative species. Kroto, Smalley and Curl *et al.* first observed the C_{60} in which the 60 carbon atoms consist of 12 five-membered rings and 20 six-membered rings.¹⁾ Kroto, Smalley and Curl won their joint Nobel prizes in chemistry in 1996 for their contributions. Osawa predicted existence of fullerene in 1970, earlier than the first observation of fullerene.²⁾

The most specific feature of fullerene is that it is an excellent electron acceptor. Any fullerenes are n-type semiconductors, which are suitable for organic electronic materials with electron carriers. Rubidium- and cesium-doped fullerenes can be superconductors with electron carriers. These superconducting transitions occur at more than 30 K.^{3,4)}



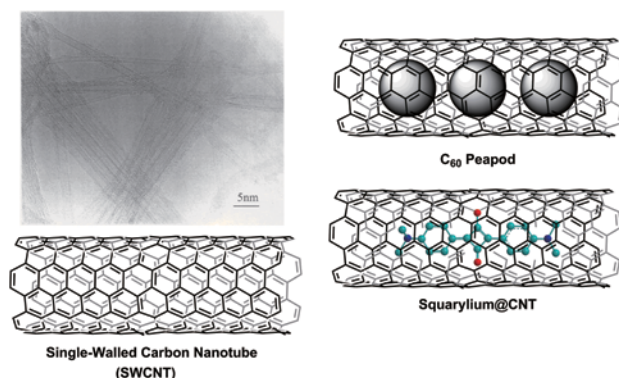
Addition reactions and other chemical modifications of fullerenes easily produce fullerene derivatives. Precise structure analyses of these derivatives are possible because they are molecular species. Non-derivatized fullerenes are poorly soluble in similarity to the other nanocarbon materials. However, we can introduce soluble functional groups to form solution-processible electronic materials. Phenyl- C_{61} -butyric acid methyl ester ([60]PCBM [M2088]) and indene- C_{60} bisadduct ([60]ICBA [I0900]) are useful organic semiconductors for fabricating a solution-processible electronic device.^{5,6)} These fullerene derivatives are n-type organic semiconductors for organic photovoltaics (OPV) by mixing with a p-type conjugated polymer.⁷⁾ An application of a fullerene derivative for organic transistors was also reported.⁸⁾ A complexation of C_{60} with tetrakis(dimethylamino)ethylene (TDAE) gives a

charge transfer complex (TDAE- C_{60}), which is an organic magnet at low temperature.⁹⁾

2. Carbon Nanotubes

A carbon nanotube (CNT) has a cylindrical structure with a nanoscale diameter that is like a rolled graphene sheet. Iijima first observed a CNT in 1991.¹⁰⁾ A CNT consists of only sp^2 carbons similar to fullerenes. There are diverse CNTs on the basis of their length, diameter of the nanotube, state of chirality, and number of the layer. The variety of these structures provides various band structures and metallic and semiconducting properties.^{11,12)} A normal synthetic procedure gives a mixture of semiconducting CNTs in 2/3 and metallic CNTs in 1/3, because rolling a carbon sheet occurs randomly. Since we need to obtain the semiconducting CNT in pure form in order to utilize the semiconductivity, improved synthetic procedure and efficient purification of CNT are further required.¹³⁻¹⁵⁾

CNTs can enclose nanoscale molecules and atoms in the internal space, because of the cylindrical structure. For instance, there is a fullerene-enclosed CNT, the so-called 'peapod'.¹⁶⁾ In addition, CNTs can enclose metal, water, and molecular oxygen. Properties of the enclosed water in the CNT are different from those of bulk water.^{17,18)} An organic dye (eg. squarylium) can be easily enclosed within the internal space of CNTs in solution. In this case, the enclosed squarylium dye absorbs light and then an energy transfer (sensitization) to the outer CNT occurs.¹⁹⁾ Hydrogen storage using CNTs is expected to be used in the development of a fuel cell.²⁰⁾



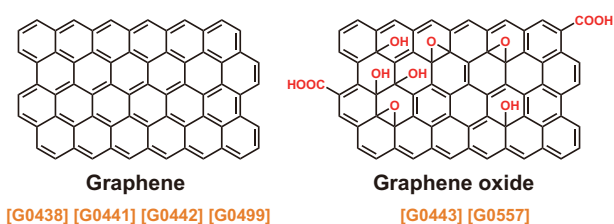
3. Graphene / Graphene Oxides

Graphene, which is one of the nanocarbon materials, consists of all six-membered rings with sp^2 carbons having a two-dimensional sheet structure. Graphene has been known for long time, since graphite is formed by combination of graphenes with van der Waals force. However, details of the properties were unclear until late years, because an isolation procedure of graphene from graphite was not well developed for long time. Geim and Novoselov *et al.* in 2004 successfully isolated a thin-flake graphene by a simple procedure. They used a tape to peel

off a graphene layer from highly oriented pyrolytic graphite (HOPG) and then the peeled graphene layer is stuck on a substrate. After this observation,²¹⁾ studies of graphene have proved the particular characteristics of electronic, mechanical, and chemical properties. Geim and Novoselov won their joint Nobel prizes in physics in 2010 for their contributions.

The most characteristic feature of graphene is its electrical property. The electron mobility in the graphene layer is 100 times greater than that of silicon.²²⁾ Accordingly, we can expect to develop a transistor with high-mobility and low-power consumption. Graphene may be promising for a next generation channel material that is useful for LSI (large-scale integration). In addition, the physical strength of graphene is 100 times greater than that of iron. The current density tolerance is much better than that of copper, thus it is expected to be an electrical wire transporting large currents.²³⁾

Electrons in the graphene behave as massless Dirac fermions as similar to neutrinos,²⁴⁾ and demonstrate a quantum Hall effect at room temperature.²⁵⁾ Graphene is an ideal material for spintronics, since there are small spin orbit interactions and the negligible nuclear magnetic moment of carbon. Hybridization of graphene and a ferromagnetic material is developed for the application of an information processor using the electron spin (spintronics device).²⁶⁾

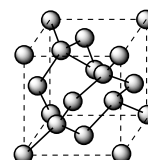


The fabrication procedure for graphene is peeling off the layer from HOPG, a chemical vapor deposition (CVD)²⁷⁾ as well as reduction of a graphene oxide (GO).²⁸⁾ There are various synthetic methods of making GO, and the properties and applications depend on the degree of oxidation. GO disperses in water and several polar solvents, because the structure of GO normally includes hydroxyl, epoxy, and carboxyl groups on the graphene sheet. Accordingly, a GO thin film can be fabricated on a substrate by a solution-process. The reduction of GO provides a reduced graphene oxide (rGO), but it is not a perfect graphene. The rGO contains a few oxygen components and defects on the graphene structure. Although GO is an insulator because there are sp^3 carbon atoms, rGO is conductive. Therefore the rGO is expected to be an electrode material. A water dispersion of GO is used as a lubricant to reduce friction on metal surfaces.²⁹⁾ GO-supported metal catalysts were developed for a cross-coupling reaction and hydrogenation.^{30,31)} We can introduce several functional groups on GO because there are oxygen-based groups. These GO derivatives may be useful for luminescent materials and biosensors.^{32,33)}

4. Nanodiamonds

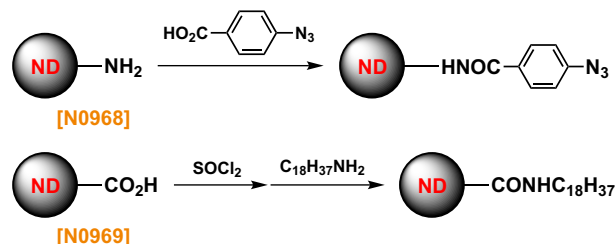
Diamond, an allotrope of carbon, has excellent hardness,

coefficient of friction, thermal conductivity, insulation characteristics, and refractive index. Large and highly pure diamond is good for use as jewelry. Furthermore, the major industrial application of diamond is for cutting and polishing tools, because it is the hardest of natural products. However, diamond is not workable enough because of its hardness so there is a limitation for industrial use of a large diamond. Nanodiamond (ND) is a nanoparticle having the crystal structure of diamond, and it has excellent properties of normal diamond. ND is artificially synthesized and is useful for polishing tools and additives of engine oil.



Nanodiamond (ND)

We can modify the surface of ND by introducing carboxyl and amino groups. These groups are further converted by a chemical modification to functionalize the ND particle.³⁴⁻³⁶⁾ Non-modified ND can be dispersed in water, but coheres in organic solvents. On the other hand, a functionalized ND particle with alkyl groups can be dispersed in organic solvents. We can modify a glass surface with ND that is functionalized with a silane coupling reagent.³⁷⁾



An application of ND is extended for biology and medical use^{38,39)} because it is a harmless nanoparticle in-vivo. Since a diamond with a complex defect (NV) containing nitrogen (N) and vacancy (V) shows fluorescence,⁴⁰⁾ we can monitor movements and structural changes of a biological molecule on a microscope using the NV diamond as a fluorescent labeling reagent.⁴¹⁻⁴³⁾ We can easily detect fluorescent behavior in a complex atmosphere in-vivo, because ND is chemically stable. A publication described that functionalization of ND also showed fluorescent behavior without NV defects.⁴⁴⁾ Protein- and biotin-supported ND were reported in order to enhance affinity toward a biological molecule.^{45,46)} These modified NDs are expected to be used for a drug delivery system.

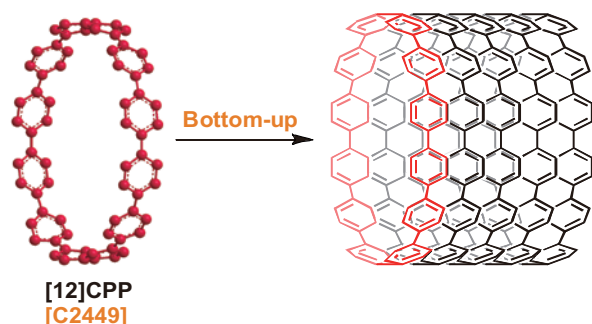
5. Nanocarbon Unit Structures

Cycloparaphenylenes (CPP)

Carbon nanotubes (CNT) have advanced chemistry, material science, life science and other research fields. CNTs can be

prepared by physical methods such as arc discharge, laser furnace, and chemical vapor deposition techniques. One disadvantage of these physical methods is forming several kinds of CNTs with various diameters, thus uniform CNTs do not form.

Cycloparaphenylenes (CPP), the so-called carbon nanoring, have a cyclic structure formed by linkages of p-substituted benzenes. The CPP attracted researchers in fundamental chemistry and material science, because it is a unit structure of CNT. In fact, Itami *et al.* successfully synthesized uniform CNTs by a bottom-up procedure starting from CPP as a template compound.⁴⁷⁾

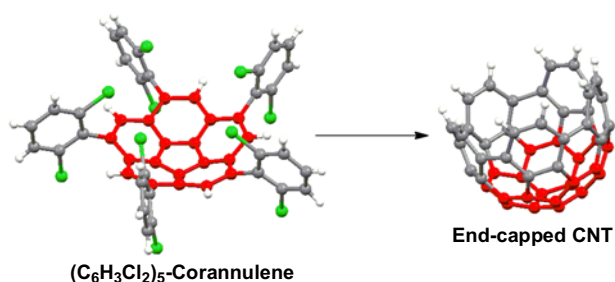


Recently, this research was extended to synthesize a CPP of smaller diameters having a large distortion. Yamago⁴⁸⁾ and Jasti⁴⁹⁾ groups independently reported synthesis of the [5]CPP, which has been the smallest CPP so far. We can expect to synthesize the smallest diameter CNTs from [5]CPP. In addition, the electronic and physical properties of [5]CPP may be interesting, because [5]CPP is a unit structure of C_{60} fullerene, too. CPPs of a specified diameter make an inclusion complex with a fullerene.⁵⁰⁾

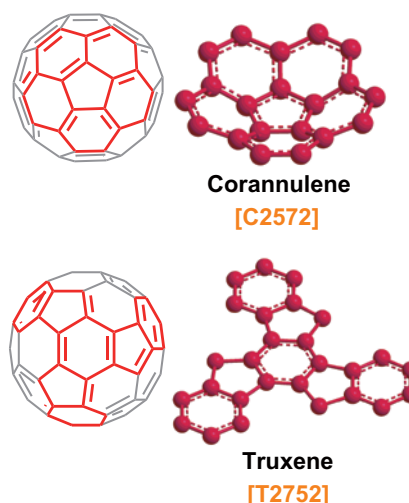
Corannulene and Truxene

Corannulene, the so-called [5]circulene, is one of the polycyclic aromatic compounds. It has a condensed structure of five benzene rings. The corannulene was first synthesized in 1960s,⁵¹⁾ and after that the bowl-type structure was observed.⁵²⁾ The corannulene is attractive as a nanocarbon material, because it is a unit structure of C_{60} fullerene.

Scott *et al.* synthesized a polyarene compound by a flash vacuum pyrolysis (FVP) starting from corannulene. This polyarene compound corresponds to an end-capped CNT. An extension of the end-capped CNT may chemically produce a normal CNT.⁵³⁾ Itami and Scott *et al.* synthesized a grossly warped nanographene compound from corannulene.⁵⁴⁾

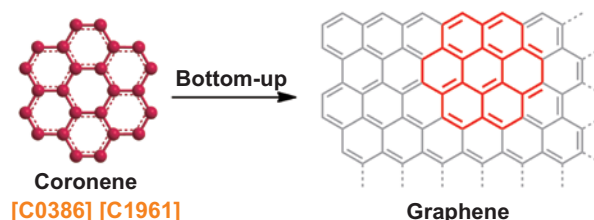


Truxene has star-shaped and rigid planar structures. Truxene is also a unit structure of C_{60} fullerene. Truxene derivatives are useful for OLED materials because they easily form an amorphous structure.⁵⁵⁾ A chemical synthesis for C_{60} fullerene was carried out starting from truxene. Otero *et al.* synthesized a polyarene compound formulated as $C_{60}H_{30}$ by three step reactions, and a thermal treatment of the polyarene on platinum surface gave C_{60} fullerene all.⁵⁶⁾



Coronene

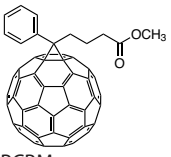
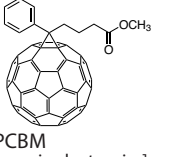
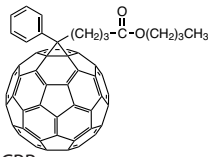
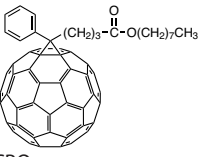
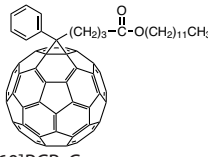
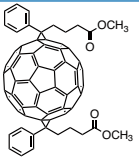
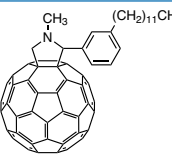
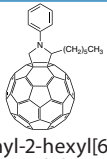
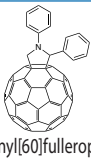
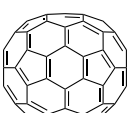
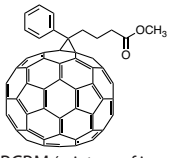
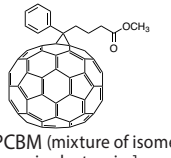
Coronene, the so-called [6]circulene, is another polycyclic aromatic compound. It has a condensed structure of six benzene rings. The coronene is a molecular compound in nanoscale, known as a representative nanographene compound that is smaller than graphene. The coronene can be an organic transistor material⁵⁷⁾ because it is a nanographene compound with a band gap, which is different from graphene. Furthermore, a bottom-up procedure of coronene fabricated a graphene nanostructure.⁵⁸⁾ After Kubozono *et al.* observed superconductivity from an alkali-doped picene,⁵⁹⁾ studies on organic superconductors of polycyclic aromatic compounds recently received much attention.^{60,61)} An alkali-doped coronene also showed superconductivity.⁶²⁾



References

- 1) H. W. Kroto, J. R. Heath, S. C. O'Brien, R. F. Curl, R. E. Smalley, *Nature* **1985**, 318, 162.
- 2) E. Osawa, *Kagaku* **1970**, 25, 854.
- 3) K. Tanigaki, T. W. Ebbesen, S. Saito, J. Mizuki, J. S. Tsai, Y. Kubo, S. Kuroshima, *Nature* **1991**, 352, 222.
- 4) A. Y. Ganin, Y. Takabayashi, Y. Z. Khimyak, S. Margadonna, A. Tamai, M. J. Rosseinsky, K. Prassides, *Nat. Mater.* **2008**, 7, 367.
- 5) J. C. Hummelen, B. W. Knight, F. LePeq, F. Wudl, J. Yao, C. L. Wilkins, *J. Org. Chem.* **1995**, 60, 532.
- 6) Y. He, H.-Y. Chen, J. Hou, Y. Li, *J. Am. Chem. Soc.* **2010**, 132, 1377.
- 7) Review: S. Günes, H. Neugebauer, N. S. Sariciftci, *Chem. Rev.* **2007**, 107, 1324.
- 8) T.-W. Lee, Y. Byun, B.-W. Koo, I.-N. Kang, Y.-Y. Lyu, C. H. Lee, L. Pu, S. Y. Lee, *Adv. Mater.* **2005**, 17, 2180.
- 9) B. Narymbetov, A. Omerzu, V. V. Kabanov, M. Tokumoto, H. Kobayashi, D. Mihailovic, *Nature* **2000**, 407, 883.
- 10) S. Iijima, *Nature* **1991**, 354, 56.
- 11) J. Kim, A. J. Page, S. Irle, K. Morokuma, *J. Am. Chem. Soc.* **2012**, 134, 9311.
- 12) Review: Y. Miyato, *J. MMIJ* **2011**, 127, 61.
- 13) Review: K. Balasubramanian, E. J. H. Lee, R. T. Weitz, M. Burghard, K. Kern, *Phys. Status Solidi A* **2008**, 205, 633.
- 14) J. Park, Y. Kim, G.-T. Kim, J. S. Ha, *Adv. Funct. Mater.* **2011**, 21, 4159.
- 15) N. J. Kybert, M. B. Lerner, J. S. Yodh, G. Preti, A. T. C. Johnson, *ACS Nano* **2013**, 7, 2800.
- 16) J. H. Warner, A. A. R. Watt, L. Ge, K. Porfyrakis, T. Akachi, H. Okimoto, Y. Ito, A. Ardavan, B. Montanari, J. H. Jefferson, N. M. Harrison, H. Shinohara, G. A. D. Briggs, *Nano Lett.* **2008**, 8, 1005.
- 17) H. Kyakuno, K. Matsuda, H. Yahiyo, Y. Inami, T. Fukuoka, Y. Miyata, K. Yanagi, Y. Maniwa, H. Kataura, T. Saito, M. Yumura, S. Iijima, *J. Chem. Phys.* **2011**, 134, 244501.
- 18) J. M. H. Kroes, F. Pietrucci, A. Curioni, R. Jaafar, O. Gröning, W. Andreoni, *J. Phys. Chem. C* **2013**, 117, 1948.
- 19) K. Yanagi, K. Iakoubovskii, H. Matsui, H. Matsuzaki, H. Okamoto, Y. Miyata, Y. Maniwa, S. Kazaoui, N. Minami, H. Kataura, *J. Am. Chem. Soc.* **2007**, 129, 4992.
- 20) E. Tylianakis, G. K. Dimitrakakis, F. J. Martin-Martinez, S. Melchor, J. A. Dobado, E. Klontzas, G. E. Froudakis, *Int. J. Hydrogen Energy* **2014**, 39, 9825.
- 21) K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, I. V. Grigorieva, A. A. Firsov, *Science* **2004**, 306, 666.
- 22) K. I. Bolotin, K. J. Sikes, Z. Jiang, M. Klima, G. Fudenberg, J. Hone, P. Kim, H. L. Stormer, *Solid State Commun.* **2008**, 146, 351.
- 23) A. K. Geim, *Science* **2009**, 324, 1530.
- 24) K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, M. I. Katsnelson, I. V. Grigorieva, S. V. Dubonos, A. A. Firsov, *Nature* **2005**, 438, 197.
- 25) Y. Zhang, Y.-W. Tan, H. L. Stormer, P. Kim, *Nature* **2005**, 438, 201.
- 26) D. Pesin, A. H. MacDonald, *Nat. Mater.* **2012**, 11, 409.
- 27) X. Zhang, L. Wang, J. Xin, B. I. Yakobson, F. Ding, *J. Am. Chem. Soc.* **2014**, 136, 3040.
- 28) C. K. Chua, M. Pumera, *Chem. Soc. Rev.* **2014**, 43, 291.
- 29) H. Kinoshita, Y. Nishina, A. A. Alias, M. Fujii, *Carbon* **2014**, 66, 720.
- 30) S. Yamamoto, H. Kinoshita, H. Hashimoto, Y. Nishina, *Nanoscale* **2014**, 6, 6501.
- 31) N. Morimoto, S. Yamamoto, Y. Takeuchi, Y. Nishina, *RSC Adv.* **2013**, 3, 15608.
- 32) K. Furukawa, Y. Ueno, E. Tamechika, H. Hibino, *J. Mater. Chem. B* **2013**, 1, 1119.
- 33) G. Gou, R. Ren, S. Li, S. Guo, Z. Dong, M. Xie, J. Ma, *New J. Chem.* **2013**, 37, 3861.
- 34) B. T. Branson, P. S. Beauchamp, J. C. Beam, C. M. Lukehart, J. L. Davidson, *ACS Nano* **2013**, 7, 3183.
- 35) V. N. Mochalin, Y. Gogotsi, *J. Am. Chem. Soc.* **2009**, 131, 4594.
- 36) A. Barras, S. Szunerits, L. Marcon, N. Monfiliotte-Dupont, R. Boukherroub, *Langmuir* **2010**, 26, 13168.
- 37) Y. Liu, V. N. Khabashesku, N. J. Halas, *J. Am. Chem. Soc.* **2005**, 127, 3712.
- 38) Review: V. K. A. Sreenivasan, A. V. Zvyagin, E. M. Goldys, *J. Phys.: Condens. Matter* **2013**, 25, 194101.
- 39) Review: A. Krueger, *Chem. Eur. J.* **2008**, 14, 1382.
- 40) Review: A. Krueger, *J. Mater. Chem.* **2011**, 21, 12571.
- 41) S.-J. Yu, M.-W. Kang, H.-C. Chang, K.-M. Chen, Y.-C. Yu, *J. Am. Chem. Soc.* **2005**, 127, 17604.
- 42) T.-J. Wu, Y.-K. Tzeng, W.-W. Chang, C.-A. Cheng, Y. Kuo, C.-H. Chien, H.-C. Chang, J. Yu, *Nat. Nanotechnol.* **2013**, 8, 682.
- 43) L. P. McGuinness, Y. Yan, A. Stacey, D. A. Simpson, L. T. Hall, D. Maclaurin, S. Prawer, P. Mulvaney, J. Wrachtrup, F. Caruso, R. E. Scholten, L. C. L. Hollenberg, *Nat. Nanotechnol.* **2011**, 6, 358.
- 44) V. N. Mochalin, O. Shenderova, D. Ho, Y. Gogotsi, *Nat. Nanotechnol.* **2012**, 7, 11.
- 45) L.-C. L. Huang, H.-C. Chang, *Langmuir* **2004**, 20, 5879.
- 46) A. Krueger, J. Stegk, Y. Liang, L. Lu, G. Jarre, *Langmuir* **2008**, 24, 4200.
- 47) H. Omachi, T. Nakayama, E. Takahashi, Y. Segawa, K. Itami, *Nat. Chem.* **2013**, 5, 572.
- 48) E. Kayahara, V. K. Patel, S. Yamago, *J. Am. Chem. Soc.* **2014**, 136, 2284.
- 49) P. J. Evans, E. R. Darzi, R. Jasti, *Nat. Chem.* **2014**, 6, 404.
- 50) T. Iwamoto, Y. Watanabe, T. Sadahiro, T. Haino, S. Yamago, *Angew. Chem. Int. Ed.* **2011**, 50, 8342.
- 51) W. E. Barth, R. G. Lawton, *J. Am. Chem. Soc.* **1966**, 88, 380.
- 52) J. C. Hanson, C. E. Nordman, *Acta Cryst.* **1976**, B32, 1147.
- 53) L. T. Scott, E. A. Jackson, Q. Zhang, B. D. Steinberg, M. Bancu, B. Li, *J. Am. Chem. Soc.* **2012**, 134, 107.
- 54) K. Kawasumi, Q. Zhang, Y. Segawa, L. T. Scott, K. Itami, *Nat. Chem.* **2013**, 5, 739.
- 55) Z. Yang, B. Xu, J. He, L. Xue, Q. Guo, H. Xia, W. Tian, *Org. Electron.* **2009**, 10, 954.
- 56) G. Otero, G. Biddau, C. Sánchez-Sánchez, R. Caillard, M. F. López, C. Rogero, F. J. Palomares, N. Cabello, M. A. Basanta, J. Ortega, J. Méndez, A. M. Echavarren, R. Pérez, B. Gómez-Lor, J. A. Martín-Gago, *Nature* **2008**, 454, 865.
- 57) I. Diez-Perez, Z. Li, J. Hihath, J. Li, C. Zhang, X. Yang, L. Zang, Y. Dai, X. Feng, K. Muellen, N. Tao, *Nat. Commun.* **2010**, 1, 1.
- 58) X. Wan, K. Chen, D. Liu, J. Chen, Q. Miao, J. Xu, *Chem. Mater.* **2012**, 24, 3906.
- 59) R. Mitsuhashi, Y. Suzuki, Y. Yamanari, H. Mitamura, T. Kambe, N. Ikeda, H. Okamoto, A. Fujiwara, M. Yamaji, N. Kawasaki, Y. Maniwa, Y. Kubozono, *Nature* **2010**, 464, 76.
- 60) X. F. Wang, R. H. Liu, Z. Gui, Y. L. Xie, Y. J. Yan, J. J. Ying, X. G. Luo, X. H. Chen, *Nat. Commun.* **2011**, 2, 1513/1.
- 61) M. Xue, T. Cao, D. Wang, Y. Wu, H. Yang, X. Dong, J. He, F. Li, G. F. Chen, *Sci. Rep.* **2012**, 2, srep00389.
- 62) Y. Kubozono, H. Mitamura, X. Lee, X. He, Y. Yamanari, H. Takahashi, Y. Suzuki, Y. Kaji, R. Eguchi, K. Akaike, T. Kambe, H. Okamoto, A. Fujiwara, T. Kato, T. Kosugi, H. Aoki, *Phys. Chem. Chem. Phys.* **2011**, 13, 16476.

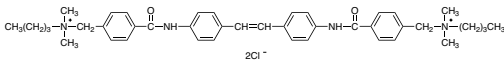
Fullerenes

		B1660 100mg 1g	B1641 100mg 500mg 1g	F1232 100mg
				
		Fullerene C ₆₀ CAS RN: 99685-96-8	Fullerene C ₆₀ (pure) CAS RN: 99685-96-8	Fullerene C ₆₀ (purified by sublimation) [for organic electronics] CAS RN: 99685-96-8
M2088 100mg	P2682 100mg	P2013 100mg	P2014 100mg	P2015 100mg
				
[60]PCBM CAS RN: 160848-22-6	[60]PCBM [for organic electronics] CAS RN: 160848-22-6	PCBB CAS RN: 571177-66-7	PCBO CAS RN: 571177-68-9	[60]PCB-C ₁₂ CAS RN: 571177-69-0
B4576 50mg	C2415 100mg	P2744 100mg	D5757 100mg	I0900 50mg
				
Bis-PCBM (mixture of isomers) CAS RN: 1048679-01-1	C ₆₀ MC ₁₂ CAS RN: 403483-19-2	N-Phenyl-2-hexyl[60]- fulleropyrrolidine CAS RN: 1426332-00-4	N,2-Diphenyl[60]fulleropyrrolidine (contains 5% Hexane at maximum) CAS RN: 1373934-14-5	ICBA CAS RN: 1207461-57-1
B1694 100mg	F1233 100mg	M2550 50mg	P2683 100mg	
				
Fullerene C ₇₀ CAS RN: 115383-22-7	Fullerene C ₇₀ [for organic electronics] CAS RN: 115383-22-7	[70]PCBM (mixture of isomers) CAS RN: 609771-63-3	[70]PCBM (mixture of isomers) [for organic electronics] CAS RN: 609771-63-3	

Carbon Nanotubes (CNTs)

C2154 1g 5g	C2157 1g	C2156 1g 5g	C2150 1g 5g	C2155 1g
Carbon Nanotube Multi-walled 20-40nm(diam.), 5-15µm(length)	Carbon Nanotube Multi-walled 40-60nm(diam.), 1-2µm(length)	Carbon Nanotube Multi-walled 40-60nm(diam.), 5-15µm(length)	Carbon Nanotube Multi-walled 10-20nm(diam.), 5-15µm(length)	Carbon Nanotube Multi-walled 20-40nm(diam.), 1-2µm(length)
CAS RN: 308068-56-6	CAS RN: 308068-56-6	CAS RN: 308068-56-6	CAS RN: 308068-56-6	CAS RN: 308068-56-6
C2158 1g 5g	G0620 100mg 500mg			
Carbon Nanotube Multi-walled 60-100nm(diam.), 5-15µm(length)	Graphene/CNT Nanocomposite			
CAS RN: 308068-56-6				

CNT Dispersant

E1127 1g

4,4'-[1,2-Ethenediylbis(4,1-phenyleneiminocarbonyl)]- bis(N-butyl-N,N-dimethylbenzenemethanaminium) Dichloride CAS RN: 1296211-78-3

Carbon Nanofibers (CNFs)

C3766 25g	C3767 25g
Carbon Nanofibers [for reinforcement]	Carbon Nanofibers [for conductivity]

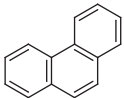
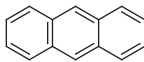
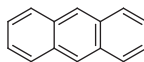
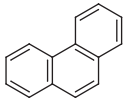
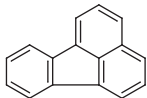
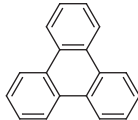
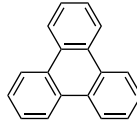
Graphene / Graphene Oxides (GOs)

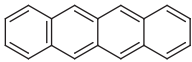
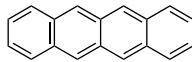
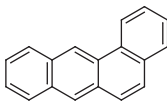
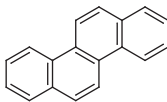
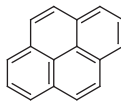
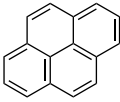
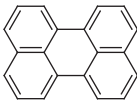
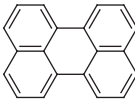
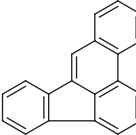
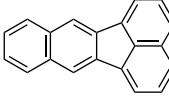
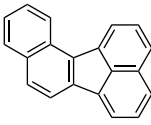
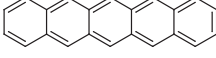
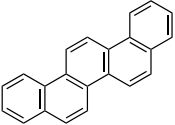
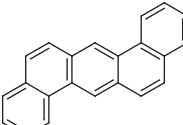
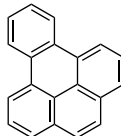
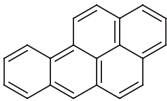
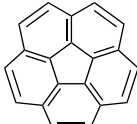
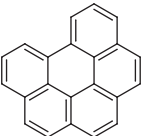
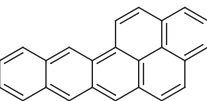
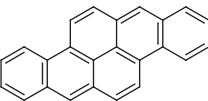
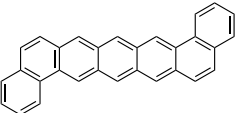
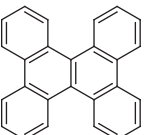
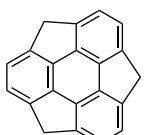
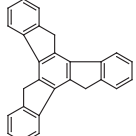
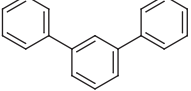
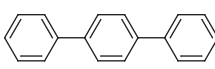
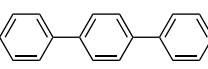
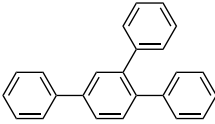
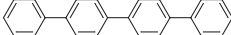
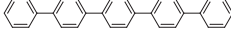
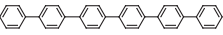
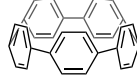
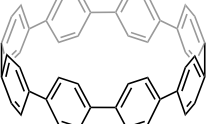
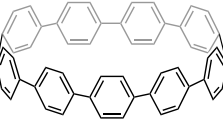
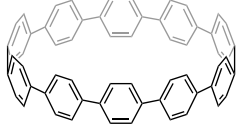
G0438 5g 25g Graphene Nanoplatelets 6-8nm(thick), 25µm(wide) CAS RN: 1034343-98-0	G0499 1g 5g Graphene Nanoplatelets 2-10nm(thick), 5µm(wide) CAS RN: 1034343-98-0	G0441 5g 25g Graphene Nanoplatelets 6-8nm(thick), 5µm(wide) CAS RN: 1034343-98-0	G0442 5g 25g Graphene Nanoplatelets 6-8nm(thick), 15µm(wide) CAS RN: 1034343-98-0
N1234 100mg 500mg Nitrogen/Sulfur Co-doped Graphene	G0500 5g 25g Graphene Nanoplatelets Aggregates (sub-micron particles, surface area 300m ² /g) CAS RN: 1034343-98-0	G0501 5g 25g Graphene Nanoplatelets Aggregates (sub-micron particles, surface area 500m ² /g) CAS RN: 1034343-98-0	G0502 5g 25g Graphene Nanoplatelets Aggregates (sub-micron particles, surface area 750m ² /g) CAS RN: 1034343-98-0
G0620 100mg 500mg Graphene/CNT Nanocomposite	G0443 100mg Graphene Oxide CAS RN: 2640657-49-2	G0557 5mL 25mL 100mL Graphene Oxide (10mg/mL, Dispersion in Water) CAS RN: 2640657-49-2	R0254 100mg Reduced Graphene Oxide
N1233 100mg 500mg Nitrogen-doped Graphene	G0539 200mg Graphitic Carbon Nitride CAS RN: 143334-20-7		

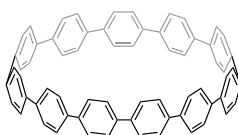
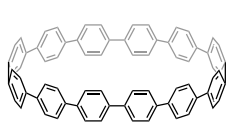
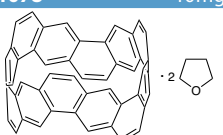
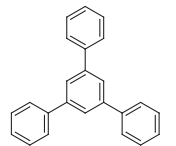
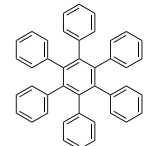
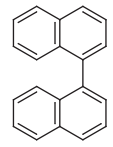
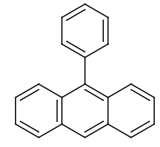
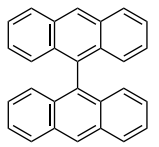
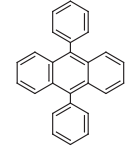
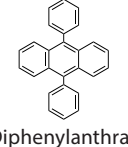
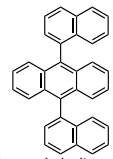
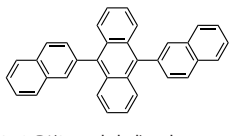
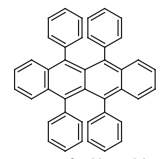
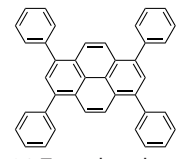
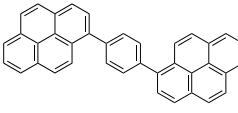
Nanodiamonds (NDs)

N1083 5g 25g Nanodiamond (particle size : <10nm) (Amine-modified) (3%, Dispersion in Ethylene Glycol)	N0962 1g 5g Nanodiamond (particle size : <10nm) CAS RN: 7782-40-3	N1057 1g Nanodiamond (particle size : <10nm) (Hydrogen-terminated)	N0968 1g Nanodiamond (particle size : <10nm) (Amine-modified)
N0969 1g Nanodiamond (particle size : <10nm) (Carboxyl-modified)	N1194 5g Nanodiamond (Carboxyl-modified) (5%, Dispersion in Water)		

Nanocarbon Unit Structures

P0079 25g 500g  Phenanthrene (>97.0%) CAS RN: 85-01-8	A0005 5g 25g  Acenaphthylene CAS RN: 208-96-8	A0495 25g 100g 500g  Anthracene (>97.0%) CAS RN: 120-12-7	A0405 1sample  Anthracene Zone Refined (number of passes:30) CAS RN: 120-12-7
P0331 1sample  Phenanthrene Zone Refined (number of passes:30) CAS RN: 85-01-8	F0016 25g 100g 500g  Fluoranthene CAS RN: 206-44-0	T0513 100mg 1g  Triphenylene CAS RN: 217-59-4	T3267 200mg 1g  Triphenylene (purified by sublimation) CAS RN: 217-59-4

N0001 100mg 1g 5g  Naphthalene CAS RN: 92-24-0	N0951 200mg 1g  Naphthalene (purified by sublimation) CAS RN: 92-24-0	B0017 1g 5g 25g  Tetraphene CAS RN: 56-55-3	C0339 100mg 1g  Chrysene (purified by sublimation) CAS RN: 218-01-9	P1104 25g 100g 500g  Pyrene CAS RN: 129-00-0
P2072 1g  Pyrene (purified by sublimation) CAS RN: 129-00-0	P0078 1g 5g 25g  Perylene CAS RN: 198-55-0	P1629 1g  Perylene (purified by sublimation) CAS RN: 198-55-0	B2982 100mg  Benzo[b]fluoranthene CAS RN: 205-99-2	B6317 100mg 500mg  Benzo[k]fluoranthene CAS RN: 207-08-9
B6424 100mg 500mg  Benzo[j]fluoranthene CAS RN: 205-82-3	P0030 100mg 1g  Pentacene (purified by sublimation) CAS RN: 135-48-8	P2207 100mg 500mg  Picene (purified by sublimation) (>99.9%) CAS RN: 213-46-7	D0145 100mg  Dibenz[a,h]anthracene CAS RN: 53-70-3	B0086 50mg 250mg  Benzo[e]pyrene CAS RN: 192-97-2
B0085 100mg 1g  3,4-Benzopyrene (purified by sublimation) CAS RN: 50-32-8	C2572 20mg 100mg  Corannulene CAS RN: 5821-51-2	B2983 100mg  Benzo[ghi]perylene CAS RN: 191-24-2	N0599 100mg  Naphtho[2,3-a]pyrene CAS RN: 196-42-9	D1005 100mg  Dibenzo[a,h]pyrene CAS RN: 189-64-0
D5488 100mg  Dibenzo[a,l]pentacene CAS RN: 227-09-8	D3736 200mg 1g  Dibenzo[g,p]chrysene CAS RN: 191-68-4	C0386 1g 5g  Coronene CAS RN: 191-07-1	C1961 100mg  Coronene (purified by sublimation) CAS RN: 191-07-1	S0888 20mg 100mg  Sumanene CAS RN: 151253-59-7
T2752 100mg 1g  Truxene CAS RN: 548-35-6	T0019 25g 100g 500g  o-Terphenyl CAS RN: 84-15-1	T0018 5g 25g 100g  m-Terphenyl CAS RN: 92-06-8	T0020 25g 100g 500g  p-Terphenyl CAS RN: 92-94-4	T3263 5g 25g  p-Terphenyl (purified by sublimation) CAS RN: 92-94-4
P2693 200mg 1g  1,2,4-Triphenylbenzene CAS RN: 1165-53-3	Q0001 1g 5g 25g  p-Quaterphenyl CAS RN: 135-70-6	Q0018 100mg 1g  p-Quinquephenyl CAS RN: 3073-05-0	S0220 100mg 1g  p-Sexiphenyl CAS RN: 4499-83-6	C2931 20mg 100mg  [5]Cycloparaphenylene CAS RN: 96100-94-6
C3386 20mg  [6]Cycloparaphenylene CAS RN: 156980-13-1	C3571 10mg  [7]Cycloparaphenylene CAS RN: 1222105-42-1	C3544 20mg  [8]Cycloparaphenylene CAS RN: 1217269-85-6	C3465 20mg  [9]Cycloparaphenylene CAS RN: 1092522-74-1	C3493 20mg  [10]Cycloparaphenylene CAS RN: 1222105-46-5

C3536 10mg  [11]Cycloparaphenylene CAS RN: 1222105-48-7	C2449 10mg  [12]Cycloparaphenylene CAS RN: 1092522-75-2	I1078 10mg  (6,6)Carbon Nanobelt Bis(tetrahydrofuran) Adduct CAS RN: 2245104-25-8	T0509 25g  1,3,5-Triphenylbenzene CAS RN: 612-71-5	H1412 1g 5g  Hexaphenylbenzene CAS RN: 992-04-1
B0805 1g 5g  1,1'-Binaphthyl CAS RN: 604-53-5	P0138 1g 5g 25g  9-Phenylanthracene CAS RN: 602-55-1	B4095 1g 5g  9,9'-Bianthryl CAS RN: 1055-23-8	D1689 1g 25g  9,10-Diphenylanthracene CAS RN: 1499-10-1	D4401 1g  9,10-Diphenylanthracene (purified by sublimation) CAS RN: 1499-10-1
D3975 1g 5g  9,10-Di(1-naphthyl)anthracene CAS RN: 26979-27-1	D4127 1g  9,10-Di(2-naphthyl)anthracene CAS RN: 122648-99-1	T0561 100mg 1g  Rubrene CAS RN: 517-51-1	T2233 250mg 1g  Rubrene (purified by sublimation) CAS RN: 517-51-1	T3042 50mg 200mg  1,3,6,8-Tetraphenylpyrene CAS RN: 13638-82-9
D4922 200mg 1g  1,4-Di(1-pyrenyl)benzene CAS RN: 475460-77-6				

По вопросам продаж и поддержки обращайтесь:

Алматы (7273)495-231
Ангарск (3955)60-70-56
Архангельск (8182)63-90-72
Астрахань (8512)99-46-04
Барнаул (3852)73-04-60
Белгород (4722)40-23-64
Благовещенск (4162)22-76-07
Брянск (4832)59-03-52
Владивосток (423)249-28-31
Владикавказ (8672)28-90-48
Владимир (4922)49-43-18
Волгоград (844)278-03-48
Вологда (8172)26-4159
Воронеж (473)204-51-73
Екатеринбург (343)384-55-89
Иваново (4932)77-34-06
Ижевск (3412)26-03-58
Иркутск (395)279-98-46
Казань (843)206-01-48

Калининград (4012)72-03-81
Калуга (4842)92-23-67
Кемерово (3842)65-04-62
Киров (8332)68-02-04
Коломна (4966)23-41-49
Кострома (4942)77-07-48
Краснодар (861)203-40-90
Красноярск (391)204-63-61
Курск (4712)77-13-04
Курган (3522)50-90-47
Липецк (4742)52-20-81
Магнитогорск (3519)55-03-13
Москва (495)268-04-70
Мурманск (8152)59-64-93
Набережные Челны (8552)20-53-41
Нижний Новгород (831)429-08-12
Новокузнецк (3843)20-46-81
Ноябрьск (3496)41-32-12
Новосибирск (383)227-86-73

Омск (3812)21-46-40
Орел (4862)44-53-42
Оренбург (3532)37-68-04
Пенза (8412)22-31-16
Петрозаводск (8142)55-98-37
Псков (8112)59-10-37
Пермь (342)205-81-47
Ростов-на-Дону (863)308-18-15
Рязань (4912)46-61-64
Самара (846)206-03-16
Саранск (8342)22-96-24
Санкт-Петербург (812)309-46-40
Саратов (845)249-38-78
Севастополь (8692)22-31-93
Симферополь (3652)67-13-56
Смоленск (4812)29-41-54
Сочи (862)225-72-31
Ставрополь (8652)20-65-13
Сургут (3462)77-98-35

Сыктывкар (8212)25-95-17
Тамбов (4752)50-40-97
Тверь (4822)63-31-35
Тольятти (8482)63-91-07
Томск (3822)98-41-53
Тула (4872)33-79-87
Тюмень (3452)66-21-18
Ульяновск (8422)24-23-59
Улан-Удэ (3012)59-97-51
Уфа (347)229-48-12
Хабаровск (4212)92-98-04
Чебоксары (8352)28-53-07
Челябинск (351)202-03-61
Череповец (8202)49-02-64
Чита (3022)38-34-83
Якутск (4112)23-90-97
Ярославль (4852)69-52-93

Россия +7(495)268-04-70

Казахстан +7(7172)727-132

Киргизия +996(312)96-26-47

Адрес: <https://tci.nt-rt.ru/> || эл.почта: tic@nt-rt.ru