MATERIALS

Organic Transistor (OFET) Materials Guide Book

TCI · SEJIN CI

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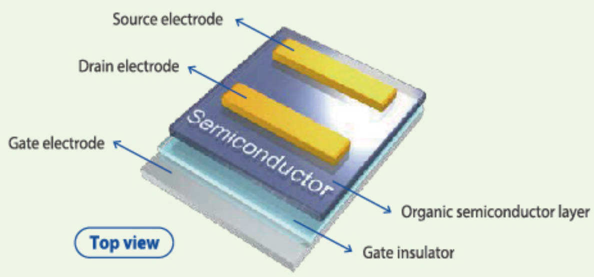
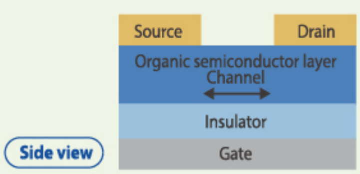
Organic field-effect transistors (OFETs) are promising components for the next-generation electronic devices. In 1984, OFET research began with the first report of mobility in a merocyanine dye-based field-effect device by Kudo *et al.*[1) Since high hole mobility (1.5 cm²/Vs), which comparable to that of amorphous silicon, was achieved using a pentacene-based OFET device in 1997,[2) the possibility of a practical application of OFET's became realistic and the research field became quite popular worldwide. While silicon has performed well in devices, the inorganic nature of them prohibits flexible structures. As a result, OFETs have attracted much attention for their potential to be flexible, thin and light-weight, which could be applicable for foldable electronic circuits and implantable biometric sensors. [3, 4)]

A noted potential application with OFET's involves their "printability". Printed electronics are an innovative technology for mass and low cost device productions, which could allow for the production of high density and large circuits on flexible substrates such as paper and plastic films. A fusion of "Printed electronics" and "Organic transistors" could offer especially promising technology by allowing for low cost and large scale manufacture of various functional devices. [5-7)]

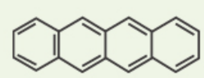
One of the functional parameters evaluated in organic semiconductor materials is mobility (μ), which indicates how fast the holes (p-type) or electrons (n-type) within the semiconducting layer move. A material that possesses high carrier mobility is required for producing high-speed circuits. OFET devices are a largely simple construction containing an organic semiconductor layer, an insulating layer, and source-drain-gate electrodes. These components allow for the evaluation of fundamental transistor parameters including mobility, operation voltage, and driving stability.



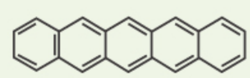


Due to the expanded π-conjugated system within organic semiconductor molecules, these often produce large intermolecular interactions inducing an improvement in the mobility within OFET devices.

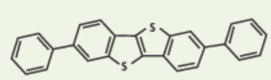
In general, the expansion and extension of π-conjugation is an effective strategy in the molecular design of OFET molecules and polymers. As an example, Pentacene, which consists of 5 fused benzene rings, possesses superior electrical properties compared to that of Tetracene, which consists of 4 fused benzene rings. [8)] However, a linear increase in the number of fused aromatic rings in a simple hydrocarbon system raises the Highest Occupied Molecular Orbital (HOMO), resulting in a critical decrease in the air-stability of the molecule and semiconductor materials. [8)] This trade-off issue between the mobility and the air-stability of the materials has been a key problem to overcome. Given this context, in 2006 DPh-BTBT **[D3526]**, a thienothiophene-fused organic compound, had been reported by Takimiya *et al.*, as an innovative OFET material.[9)] DPh-BTBT features a deep HOMO level (-5.6 eV), which leads to remarkable air-stability during OFET device performance, and the HOMOs are well-distributed over the sulfur atoms of the thienothiophene moieties inducing good hole carrier transport. DPh-BTBT-based FET devise further achieved excellent electrical properties with a high hole mobility of 2.0 cm²/Vs. Followed by the innovation and molecular design of DPh-BTBT, Ph-BTBT-10, an smectic E (SmE) liquid crystalline material, was recently reported by Hanna *et al.*, as a p-type material that bears an asymmetric structure in which the alkyl and the phenyl group are substituted on one side of the benzothienobenzothiophene (BTBT) moiety.[10)] Additionally, Ph-BTBT-10 can be handled in solution processing such the spin-coting method, and possesses both good heat-resistance and film-forming properties. The Ph-BTBT-10 spin-coated devise exhibited not only outstanding OFET performance with ultra-high mobility (μ_{max} = 14.7 cm²/Vs), but also comparable to oxide semiconductors (IGZO) with remarkable air-stability.



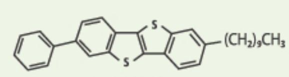
Tetracene
[N0951]



Pentacene
[P2524]



DPh-BTBT
[D3526]



Ph-BTBT-10
[D5491]

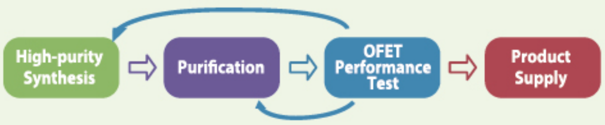
One of the largest benefits of organic compounds for OFET's is their immense structural variety. This variety can be used to control the various properties they possess such as the electrical performance, stability, and processing characteristics through the chemical modification of the molecular units. Within the organic transistor research field, the possibilities for practical application has dramatically improved by introducing new concepts and various materials proposals, including the unique OFET materials and the parent molecules used to create them.

High Quality Organic Semiconductor Materials (For Organic Electronics)

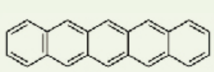
TCI offers "High Quality Organic Semiconductor Materials (For Organic Electronics)" specialized for electrical performance such as OFET mobility*. A material used in the active layer of an OFET device requires exceptionally high-purity to produce good OFET function. However, it is difficult to analytically (HPLC, GC, etc.) determine the purity at the ultra-high levels required for OFET function. To surmount this quality assurance challenge, we have begun in-house fabrication of OFET devices using our OFET materials. Once fabricated, we assess the functionality of the OFET as a quality assurance measure to confirm the electronic properties and device performance of the "High Quality Organic Semiconductor Materials (For Organic Electronics)". We constantly seek to improve our technology and skill in order to provide high-purity and quality materials our customers.

(*The mobility refers to device evaluation measurements obtained within our facility under environment condition.)

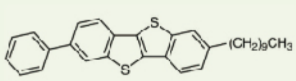
Results of the device test are fed back to the synthesis and purification process



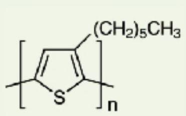
List of High Quality Organic Semiconductor Materials (For Organic Electronics)



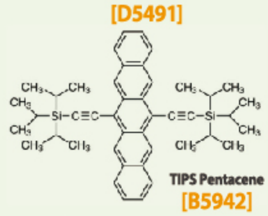
Pentacene
[P2524]



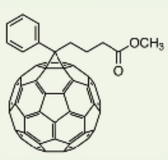
Ph-BTBT-10
[D5491]



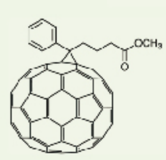
P3HT Mn: 36,000 ~ 45,000
[P2513] RR: > 99.0%



TIPS Pentacene
[B5942]



[60]PCBM
[P2682]



[70]PCBM
[P2683]

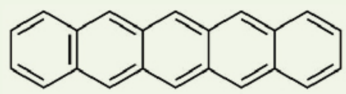
C_{70}
[F1233]

Compound	Product No.	Specification: Purity (%)	Mobility (cm²/Vs)	Si/SiO₂ Substrate Surface Condition
Pentacene	P2524	> 99.999	> 0.35	Bare
Ph-BTBT-10	D5491	> 99.5	> 10.0	ODTS
P3HT	P2513	Pd: < 100ppm	> 0.10	OTS
TIPS Pentacene	B5942	>99.0	> 0.10	HMDS
C_{70}	F1233	>99.0	> 0.30	HMDS
[60]PCBM	P2682	>99.5	> 0.020	HMDS
[70]PCBM	P2683	>99.0	> 0.015	HMDS

1. An Example of OFET Evaluation 1: Typical p-type Material "Pentacene"

Pentacene [P2524]

(99.999%, trace metals basis) (purified by sublimation)



Pentacene
[P2524]

Pentacene, a simple polyaromatichydrocarbon, has been studied for its fundamental properties and applications in organic electronic research.[11, 12] In particular, many research studies have been conducted to evaluate its potential as a carrier transporter within OFET devices.[2,13] TCI provides two subliminally purified pentacene reagents: P2524 and P0030. P2524 (99.999% trace metal basis) is our high-quality grade reagent, which has additional specifications for its OFET mobility: [> 0.35 cm²/Vs (bare Si/SiO_2)]. We inspect P2524 through the OFET evaluation process in every product lot. Only lots that pass this functional test are packed and shipped as "High Quality Organic Semiconductor Materials (For Organic Electronics)".

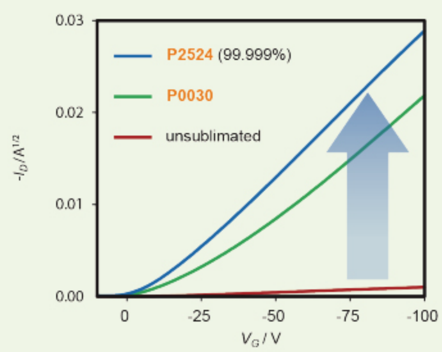


Figure 1. Transfer curves of various grades of pentacene.

Table 1. OFET characteristics of the pentacenes.

Product No.	Sample grade	Substrate	Mobility (cm²/Vs)	V_{th} (V)
-	Pentacene (non-sublimation)	Si/SiO_2 (bare)	5.3×10^{-4}	-13
P0030	Pentacene (purified by sublimation)	Si/SiO_2 (bare)	0.29	-22
P2524	Pentacene (99.999%, trace metals basis) (purified by sublimation)	Si/SiO_2 (bare)	0.39	-10

The performances of the pentacene-based OFET devices are summarized in Table 1 and Figure 1. These devices were fabricated via vacuum deposition method on bare Si/SiO_2 substrate without Self-Assembled Monolayer (SAM) treatment, the characteristics of which were measured under nitrogen conditions. Our sublimed pentacene **[P2524]** showed a large increase OFET performance compared to that of the non-sublimed pentacene. As a result, **P2524** (99.999% trace metal basis) showed an excellent OFET performance with the highest hole mobility of 0.39 cm²/Vs. In comparison to other companies' sublimed pentacene samples, **P2524** (99.999% trace metal basis) possesses the highest drain current and the best OFET potential (Figure 2 and Table 2).

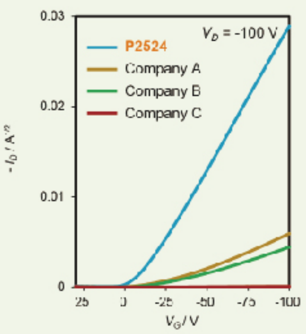


Figure 2. Transfer curves of OFET devices using several companies' pentacene.

Table 2. OFET characteristics of the pentacenes.

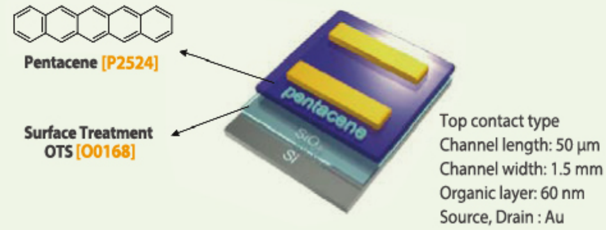
	Substrate	Mobility (cm²/Vs)	V_{th} (V)
P2524	Si/SiO_2 (bare)	0.39	-10
Company A (sublimed)	Si/SiO_2 (bare)	0.002	-25
Company B (sublimed)	Si/SiO_2 (bare)	0.001	-25
Company C (sublimed)	Si/SiO_2 (bare)	5.0 × 10^{-6}	-23

1-a. Optimization of pentacene-based OFET devices

We have examined and optimized the functional preformance of pentacene-based OFET devices via substrate surface modification. The field-effect mobility of pentacene was measured using top-contact thin-film field-effect transistors geometry (Figure 3). The thin film of pentacene **[P2524]** as the active layer (60 nm) was vacuum-deposited onto Si/SiO_2 substrate (bare) or *n*-Octyltrichlorosilane (OTS) **[O0168]** -treated Si/SiO_2 substrate at room temperature (T_{sub} = RT). The drain and source electrodes (40 nm) were then prepared by gold evaporation through a shadow mask on top of the pentacene film; the drain-source channel length (*L*) and width (*w*) were 50 μm and 1.5 mm, respectively. The characteristics of the OFET devices were measured under nitrogen conditions.

The performances of the OFET devices are summarized in Table 3 and figure 4. All pentacene -based devices exhibited pure typical p-channel field-effect transistor (FET) characteristics. The FET performance were significantly improved by the SAM treatment; the OTS-treated device demonstrated the highest performance with a hole carrier mobility of 1.52 cm²/Vs and an on/off ratio of 1.5 × 10^7 (Figure 4).

Figure 3. Illustration for the device structure of pentacene-based OFET device.



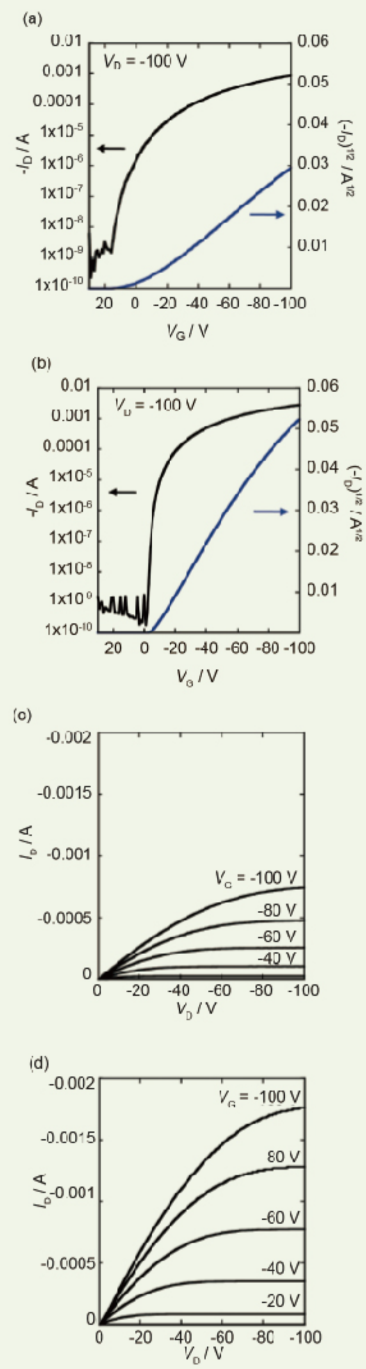


Figure 4. Typical OFET characteristics of top-contact devices fabricated using pentacene **[P2524]**.
(a, c) bare. (b, d) OTS-treated substrate.
(a, b) Transfer curves in the saturated region.
(c, d) Output curves at different gate voltages.

Table 3. OFET characteristics of P2524-based devices.

Compound	SAM	T_{sub} (°C)	Mobility (cm²/Vs)	V_{th} (V)	on/off
Pentacene [P2524]	bare	RT	0.35 ~ 0.37	-5.3	3.9×10^5
	OTS [O0168]	RT	1.50 ~ 1.52	-5.7	1.5×10^7

1-b. AFM images and XRD analysis

To clarify the pentacene thin film morphology and conformation, atomic force microscope (AFM) and X-ray diffraction (XRD) measurement were carried out (Figure 5). Regardless of either bare or OTS-treated substrate, highly regular terrace structures were observed (Figure 5a). In addition, XRD measurements of the pentacene films showed a series of peaks assignable to (00h) reflections; and the diffraction peak at $2\theta = 5.72°$ corresponds to a *d*-spacing of 15.5 Å (Figure 5b). These results demonstrated that the pentacene molecules stood nearly perpendicular to the substrate (thin-film-phase) in the film form.[12, 13]

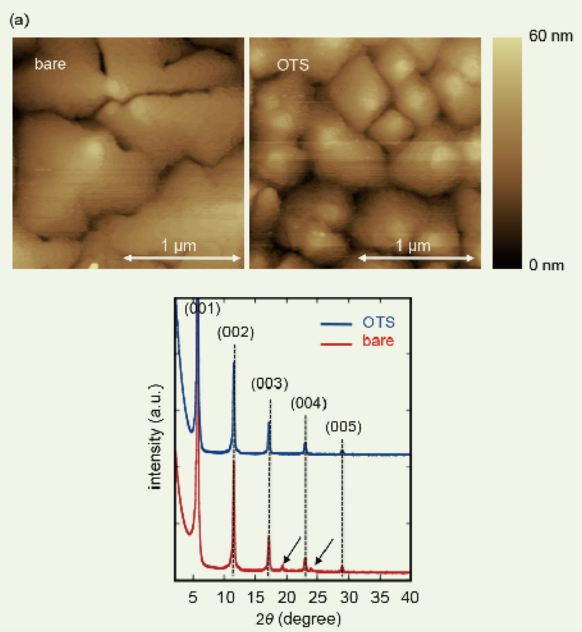


Figure 5. AFM images(a). and XRD analysis(b) of pentacene filims.

In the bare device (without SAM), two weak peaks assignable to face-on orientation were observed (Figure 5b, black arrow), which would create the disadvantage of carrier passes parallel to the substrate (Figure 6a). In contrast, such peaks were not observed in the pentacene film on the OTS-treated substrate (Figure 6b). It is one reason why the mobility was higher in the OTS-treated OFET device.

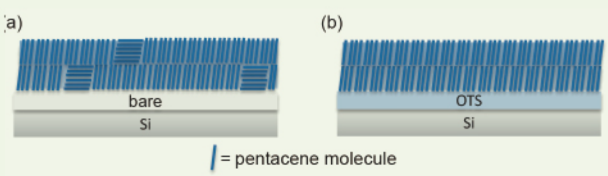
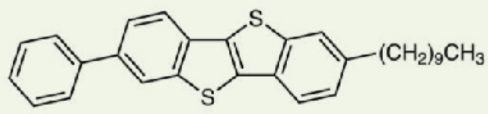


Figure 6. Orientation images of pentacene thin film form.

2. An Ultra-high Performance p-type Semiconductor Material "Ph-BTBT-10"

Ph-BTBT-10 (= 2-Decyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene) [D5491]



Ph-BTBT-10
[D5491]

Ph-BTBT-10, an SmE liquid crystalline material, has been recently reported by Hanna *et al.*, as a p-type material which possesses excellent transport properties.[10] Ph-BTBT-10 exhibits ultra-high mobility (μ_{max} = 14.7 cm²/Vs) comparable to oxide semiconductors (IGZO), and remarkable air stability. TCI has recently commercialized Ph-BTBT-10 as an ultra-high mobility and air stability p-type OFET material, and has begun evaluation via the fabrication and performance measurement of Ph-BTBT-10-based OFET devices using vacuum deposition methods in our laboratories. The devise showed a hole carrier mobility up to 14.0 cm²/Vs. Please see below for details.

2-a. Fabrication and evaluation of Ph-BTBT-10-based OFET device

The field-effect mobility of Ph-BTBT-10 was measured using top-contact thin-film field-effect transistors geometry (Figure 7). The thin film of Ph-BTBT-10 as the active layer (40 nm) was vacuum-deposited onto Si/SiO_2 substrate (bare) or Octadecyltrichlorosilane (ODTS) [O0079]-treated Si/SiO_2 substrate while heating the substrate. The drain and source electrodes (40 nm) were then prepared by gold evaporation through a shadow mask on top of the Ph-BTBT-10 film; the drain-source channel length (*L*) and width (*w*) are 50 µm and 1.5 mm, respectively. After deposition, these devices were thermal annealed at T_{sub} = 120 °C for 5 min under ambient conditions, and the characteristics of the OFET devices were measured.

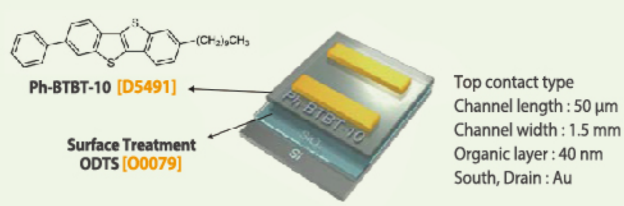


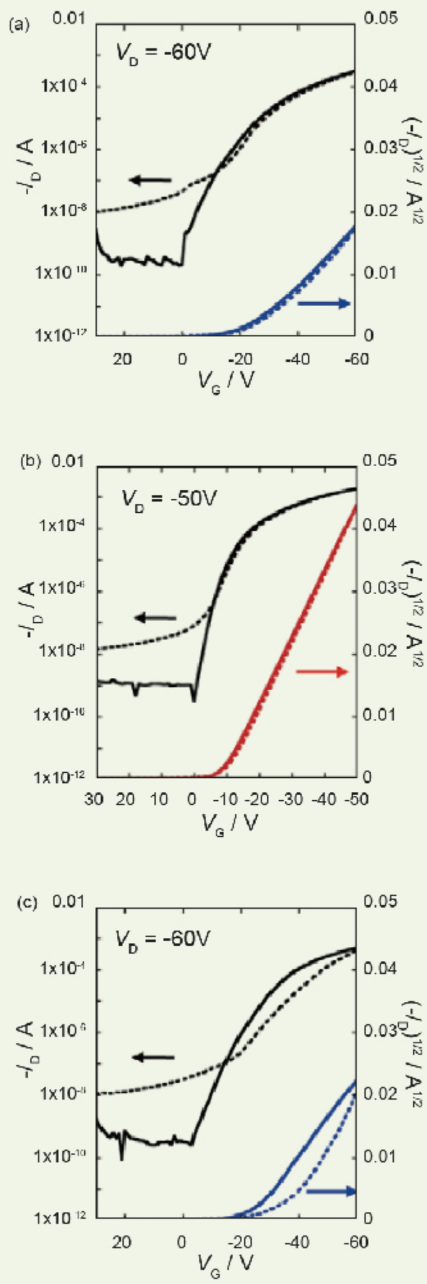
Figure 7. Illustration for the device structure of Ph-BTBT-10-based OFET.

The performances of the OFET devices are summarized in Table 4 and Figure 8. All Ph-BTBT-10-based devices exhibited pure typical p-channel field-effect transistor (FET) characteristics. The FET mobilities were quite dependent on the thermal annealing treatment regardless of the self-assemble-monolayer (SAM)

(Figure 8). This would be attributed to the phase transition from a monolayer to a bilayer crystal structure in the thin-film form. [10] The device fabricated on bare substrate demonstrated good performance with a hole carrier mobility of 4.86 cm^2/Vs and threshold voltage (V_{th}) of -8 V. Moreover, although V_{th} increased, the ODTS-treated devise showed the highest transport performance with a hole carrier mobility of 14.0 cm^2/Vs.

Table 4. OFET characteristics of the Ph-BTBT-10-based devices

Compound	SAM	Annealing Temp. (°C)	Mobility (cm^2/Vs)	V_{th} (V)
Ph-BTBT-10 [D5491]	bare	w/o	0.87 ~ 0.91	-24
		120	4.24 ~ 4.86	-8
	ODTS [O0079]	w/o	1.40 ~ 1.42	-23
		120	10.3 ~ 14.0	-22



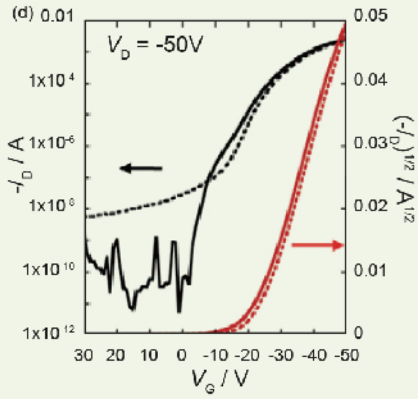


Figure 8. Transfer curves of the Ph-BTBT-10-based OFET devices.
(a) w/o annealing (bare) (b) annealing 120°C, 5min (bare)
(c) w/o annealing (ODTS) (d) annealing 120°C, 5min (ODTS)

2-b. 2D-GIXD Analysis

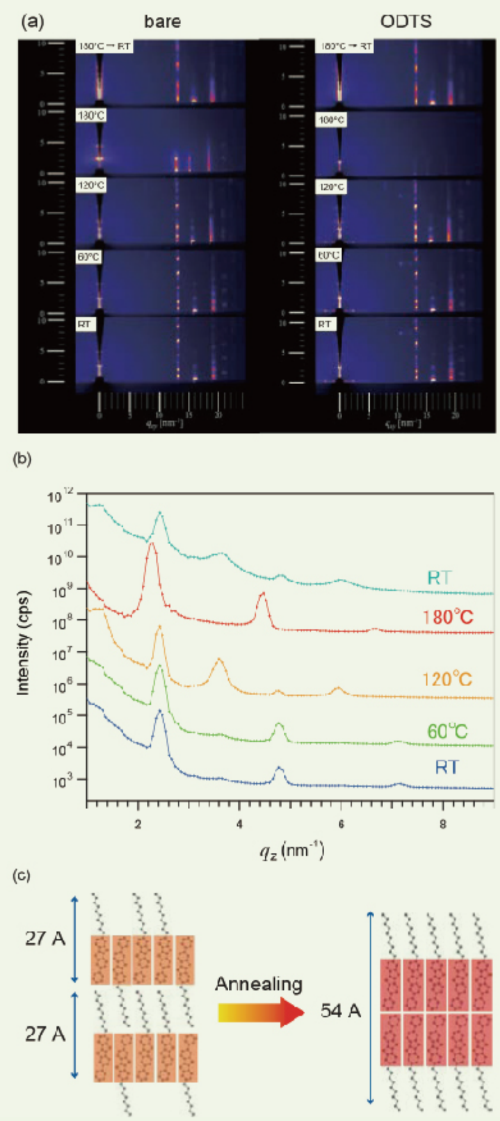


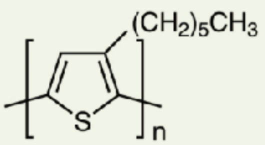
Figure 9. (a) 2D-GIXD analysis (Thermal in situ mesurement),
(b) 2D-GIXD analysis (Out-of-plane, bare substrate),
(c) Phase transition images of Ph-BTBT-10

The crystal structures of Ph-BTBT-10 thin films were analyzed by 2D-GIXD using synchrotron radiation. Figure 9 (a) and (b) display the thermal *in situ* 2D-GIXD data at different temperatures. The Ph-BTBT-10 films at RT and 60°C showed a similar series of peaks assignable to a monolayer structure with a *d*-spacing of 27 Å. When the substrate temperature was increased to 120°C, the diffraction peaks clearly changed, which suggested a transformation from a monolayer structure (*d* = 27 Å) into a bilayer structure with a d-spacing of 54 Å as shown in Figure 9 (c). Since the phase transition temperature to the SmE mesophase is 144°C, 10) a series of peaks assignable to SmE were observed when heated to 180°C. In addition, a mixed layer of monolayer and bilayer structures appeared when the Ph-BTBT-10 thin film was rapidly cooled from 180°C to RT. These results indicate that under these conditions the cooling speed might be a significant factor in forming a well-uniformed crystalline thin film structure. Based on these results, Ph-BTBT-10 can be handled through vacuum deposition method, and the phase transition from the monolayer to the bilayer structure can occur in the same way in which it occurs for solution processed Ph-BTBT-10 thin films.[10)] Finally, we demonstrated top-ranked FET performances via vacuum deposition process using our in-house equipment.

3. Performance Evaluation of Highly Regioregular "P3HT"

P3HT(= Poly(3-hexylthiophene-2,5-diyl) (regioregular) [P2513]

P3HT
[P2513]



TCI's P3HT (Poly(3-hexylthiophene-2,5-diyl)) **[P2513]** features a very high regioregularity (RR > 99%), a narrow molecular weight distribution (Mn = 36k ~ 45k), and a low metal content ratio (Pd < 100 ppm) in order to provide high quality solution-processed organic materials for organic electronics. The synthesis was conducted via the direct aryration polymerization (DArP) method in collaboration with Prof. Fumiyuki Ozawa at Institute for Chemical Research, Kyoto University.[14, 15)]

We fabricated organic thin-film transistor (OFET) devices to validate and demonstrate hole transport properties of P3HTs. By comparing OFET characteristics of six P3HT samples including **P2513**, we revealed a correlation between OFET performances and (1) molecular weights and (2) regioregularities of P3HTs. As the result, the **P2513** devise showed the highest hole mobility, among the other P3HT devices. This suggested that the carrier transport property of P3HT was improved by both the regioregularity and the molecular weight of polymer parameters. In particular, the regioregularity could be considered the most significant factor for enhancing the electrical properties of P3HT in an OFET device.

3-a. Fabrication and Evaluation of P3HT-based OFET devices

The hole mobility of **P2513** was measured using top-contact OFET geometry (Figure 10). The P3HT **[P2513]** was dissolved in chloroform:trichlorobenzene at a concentration of 10 mg/ml. The solution of **P2513** was spin-coated (1500 RPM) onto *n*-Octyltrichlorosilane (OTS) **[O0168]**-treated Si/SiO_2 substrate in a nitrogen glove box, then thermally annealed for 30 min. A gold layer with 40 nm thickness was deposited in vacuum chamber to serve as drain and source electrodes through a shadow mask on top of the **P2513** film; the drain-source channel length (*L*) and width (*W*) are 50 μm and 1.5 mm, respectively. The characteristics of the OFET devices were measured under nitrogen conditions. The other five P3HTs were also evaluated under the same protocol.

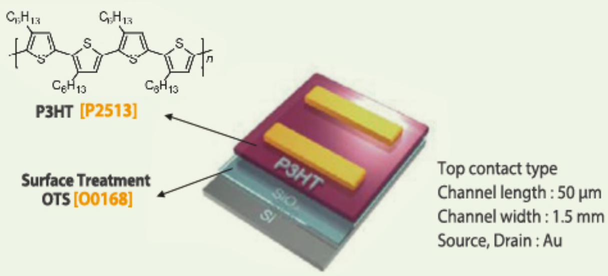


Figure 10. Illustration for the device structure of P3HT-based OFET.

3-b. A correlation between the hole transport mobility and the molecular weight[18)]

The device performances of **P2513** (high molecular weight Mn: 40K) and the other three P3HT samples having low molecular weights (Mn: 8K~28K), are summarized in Figure 11 and Table 5. Samples 1 and 2 were synthesized via the same DArP method same as with **P2513**.

The OFET performances of P3HT-based devices were improved by increasing the molecular weights of P3HT. In the case of **P2513**, the device achieved the highest transport performance with a hole mobility of 0.1 cm^2/Vs and an on/off ratio of 9×10^4. The high molecular weight could enhance a crystallinity of P3HT in the film form, that could be a reason why **P2513** possesses the excellent performances of OFET. The molecular weight of **P2513** was set 30K ~ 45K as a specification.

Table 5. Properties of P3HTs and mobility of OFET devices.

	RR (%)	M_n	Mobility ($\times 10^{-2}$ cm^2/Vs)
P2513	**99**	**40K**	**10.5±0.4**
Sample 1	99	18K	5.9±0.3
Sample 2	99	8K	3.0±0.4
Sample 3	98	28K	6.5±0.7
Sample 4	91	39K	1.2±0.1
Sample 5	93	-	1.7±0.3

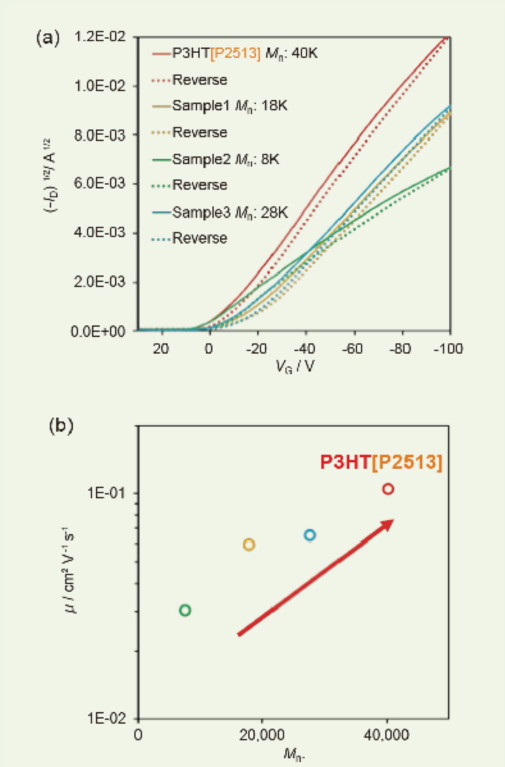
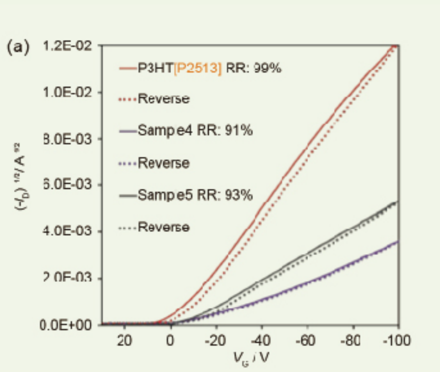


Figure 11. (a) Transfer curves of P3HT-based devices differ from molecular weight of P3HT, (b) A correlation between the hole transport mobility and the molecular weight.

3-c. A correlation between the hole transport mobility and the regioregularity[19)]

The device performances of **P2513** (the high regioregularity >99%) and the other two P3HT samples having low regioregularities (91, 93%) are summarized in Figure 12 and Table 5. Samples 4 and 5 indicate other companies' P3HT. The OFET performances of P3HT-based devices were drastically improved with increasing the regioregularities within P3HTs. While sample 4 (RR: 91%, Mn: 39K) displayed a high molecular weight as **P2513** (Mn: 40K), the hole transport mobility of the sample 4-based device was lower than that of the sample 2 (RR: 99%, Mn: 8K) -based device. From these results, the OFET performances of P3HT could be enhanced by the regioregularity rather than the molecular weight of P3HT.



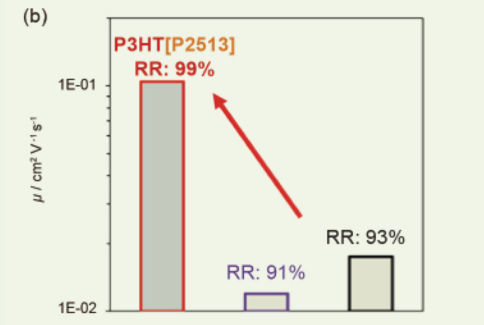


Figure 12. (A) Transfer curves of P3HT-based devices differ from regioregularity of P3HT, (b) A correlation between the hole transport mobility and the regioregularity.

References

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2) Y. Y. Lin, D. J. Gundlach, S. F. Nelson and T. N. Jackson, *IEEE Trans. Electron Devices* **1997**, *44*, 1325.

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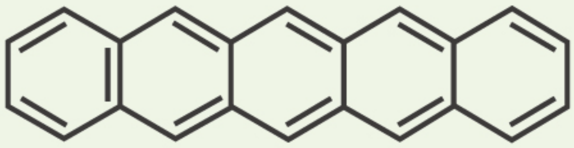
p-Type Organic Semiconductor High-purity and High-performance Pentacene

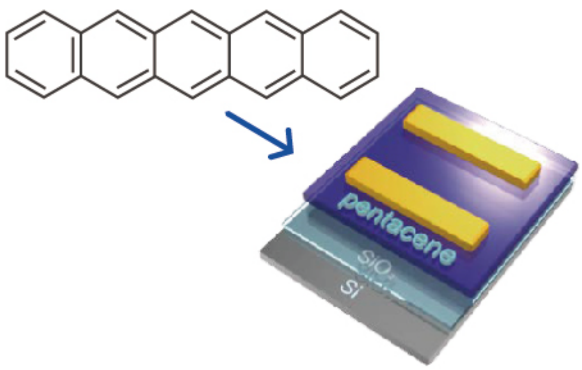


Pentacene (99.999%, trace metals basis)
(purified by sublimation) [for organic electronics]
100mg / 1g

[P2524]

Advantages
- **Electronic material grade [High-purity, low metal (< 10 ppm)]**
- **Extremely purified by sublimation**
- **Ensures semiconductor performance by OFET devices**
  [Specification : hole mobility > 0.35 cm²/Vs (bare Si/SiO_2 substrate)]

Comparison of transistor performance



Top-contact device
[Si^{n+} / SiO_2 / pentacene / Au]

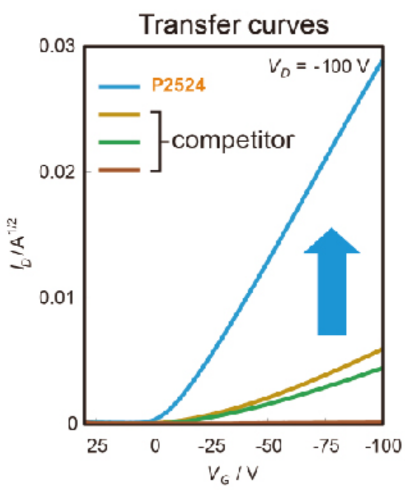


Table 1. OFET characteristics (using in-house equipment)

	Substrate	Hole Mobility (cm² /Vs)	Threshold voltage (V)
P2524	Si/SiO_2 (bare)	0.39	-10
Competitor A (sublimed)		0.002	-25
Competitor B (sublimed)		0.001	-25
Competitor C (sublimed)		5.0×10^{-6}	-23

Applications

The FET performance was significantly improved by surface modification with Self-Assembled Monolayer (SAM)(OTS: *n*-octyltrichlorosilane **[O0168]**); the OTS-treated device with the pentacene **[P2524]** demonstrated very high FET performance (Figure 1 and Table 2).

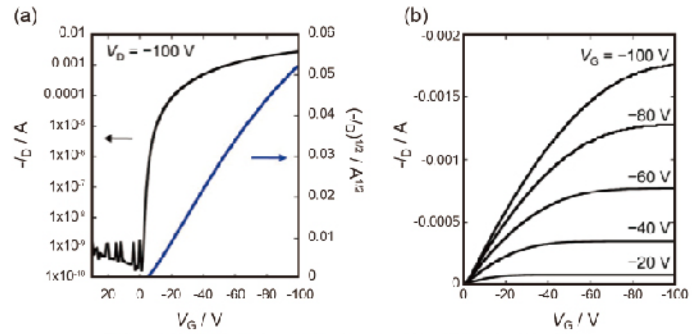


Figure 1. (a) transfer curves (b) output curves

Table 2. OFET characteristics (using in-house equipment)

	SAM	*T*sub (°C)	Hole Mobility (cm² / Vs)	*V*TH (V)	on/off ratio
Pentacene [P2524]	**OTS [O0168]**	RT	1.50 - 1.52	-5.7	1.5×10^7

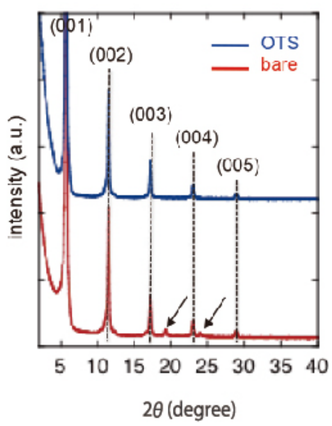
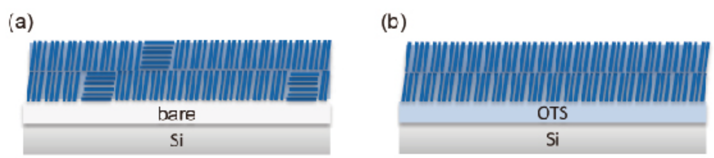


Figure 2. XRD analysis



/ = pentacene molecule

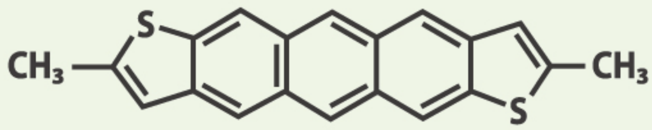
Figure 3. Orientation images of pentacene thin film form

In the bare device (without SAM), two weak peaks assignable to face-on orientation were observed (Figure 2, black arrow). This may cause a strong barrier to reduce carrier mobility (Figure 3a). On the other hand, the pentacene film on the OTS-treated substrate did not show such peaks (Figure 2). These results indicate that the OTS-treated device involves an excellent thin-film drastically enhancing the FET performance (Figure 3b).

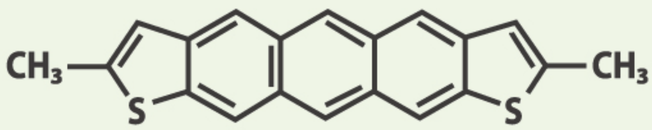
A part of X-ray diffraction (XRD: Smart Lab) was conducted at Advanced Characterization Nanotechnology Platform of the University of Tokyo, supported by "Nanotechnology Platform" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

Related Product ***n*-Octyltrichlorosilane (= OTS)** 25g / 250g **[O0168]**

Stable p-Type Organic Semiconductor Dimethylanthradithiophene (DMADT)



***anti*-DMADT** (purified by sublimation)
100mg
[D4617]



***syn*-DMADT** (purified by sublimation)
100mg
[D4618]

Advantages

- **More stable toward oxidation because of its lower HOMO-level compared with pentacene**
- **Applicable to device-fabrication using the single isomer because high pure *anti*-DMADT and *syn*-DMADT are free from isomer contamination**

FET Characteristics

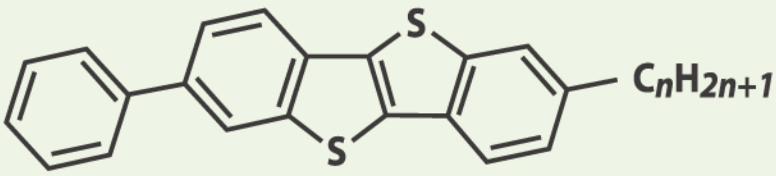
	Mobility μ (cm^2/Vs)	On/Off ratio	Threshold (V)
***anti*-DMADT**	0.41	10^6	-19
***syn*-DMADT**	0.084	10^5	-25

Reference M. Mamada, T. Minamiki, H. Katagiri, S. Tokito, *Org. Lett.* **2012**, *14*, 4062.
DOI: https://doi.org/10.1021/ol301626u

Related Products

Pentacene (purified by sublimation) 100mg / 1g **[P0030]**
Pentacene (99.999%, trace metals basis) (purified by sublimation) 100mg / 1g **[P2524]**

High-Mobility / High-Solubility p-Type Organic Semiconductor Ph-BTBT-*n* Series



(n = 12) Ph-BTBT-12
(n = 10) Ph-BTBT-10
(n = 8) Ph-BTBT-8
(n = 6) Ph-BTBT-6
(n = 4) Ph-BTBT-4

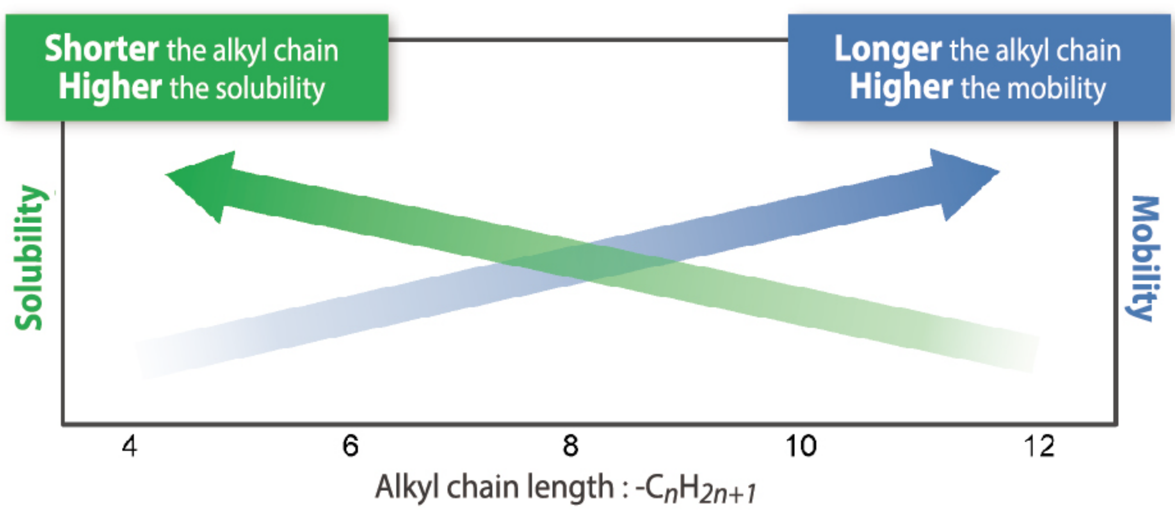
Ph-BTBT-12	100mg / 250mg / 1g	[D5910]
Ph-BTBT-10	100mg / 250mg / 1g	[D5491]
Ph-BTBT-8	100mg / 250mg / 1g	[O0576]
Ph-BTBT-6	100mg / 250mg / 1g	[H1769]
Ph-BTBT-4	100mg / 250mg / 1g	[B6248]

Advantages

- **"Mobility" and "Solubility" highly depend on the alkyl chain length**
- **Material choice according to user's purpose and operating environment**
- **Applicable to both dry and wet processes**

A correlation between "alkyl chain length" and "mobility / solubility"

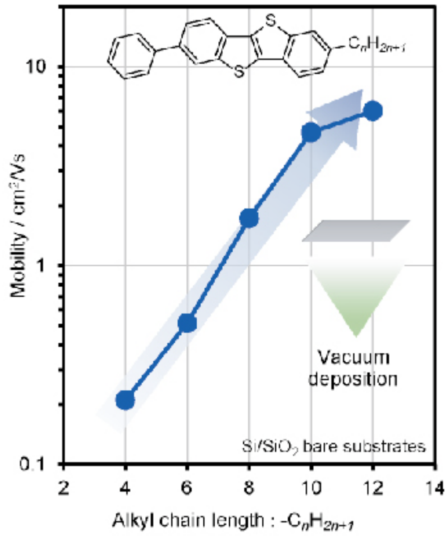
Ph-BTBT-4	Ph-BTBT-6	Ph-BTBT-8	Ph-BTBT-10	Ph-BTBT-12
[B6248]	[H1769]	[O0576]	[D5491]	[D5910]



The products are assessed for its electrical performance (mobility) as a quality assurance through our in-house OFET device evaluation.

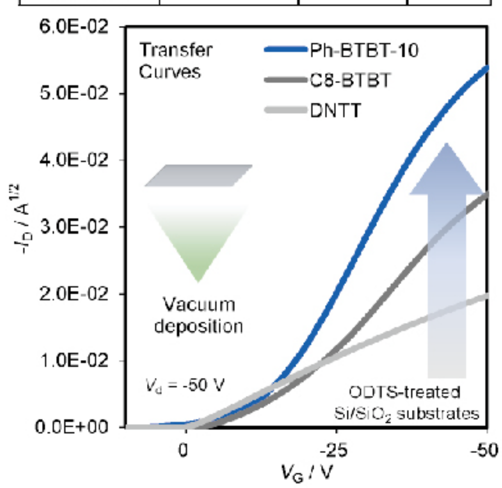
Assessment of vacuum deposited transistor devices (in-house data)

A comparison of mobilities : Ph-BTBT-n series



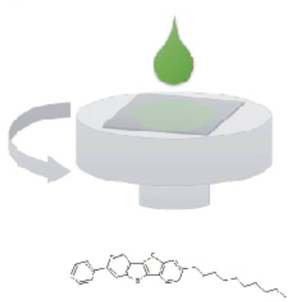
A comparison of OFET performance : Typical transistor materials

Compound	Ph-BTBT-10	C8-BTBT	DNTT
Mobility / cm^2/Vs	11.0	4.2	0.7



Fabrication and evaluation of transistor devices by wet processes (previous works)

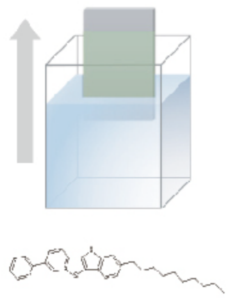
Spin-coating method[1)]



Ph-BTBT-10
[D5491]

- Hot spin-coating deposition
- Polycrystalline thin-film
- Bottom-contact type
- Mobility : 11cm²/Vs

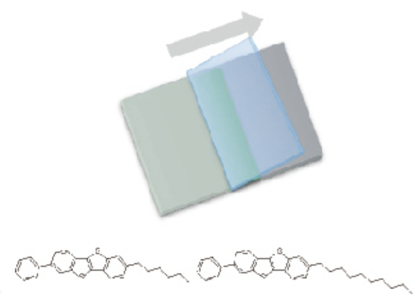
Dip-coating method[2)]



Ph-BTBT-10
[D5491]

- Hot dip-coating and high speed deposition
- Polycrystalline thin-film (large area)
- Bottom-contact type
- Mobility : 4 cm²/Vs

Blade-coating method[3)]



Ph-BTBT-6 + **Ph-BTBT-10**
[H1769] **[D5491]**

- Blade-coating deposition
- Control over the number of deposited layers by mixing two materials
- Single crystalline thin-film (large area)
- Top-contact type
- Mobility : 6 cm²/Vs

References:

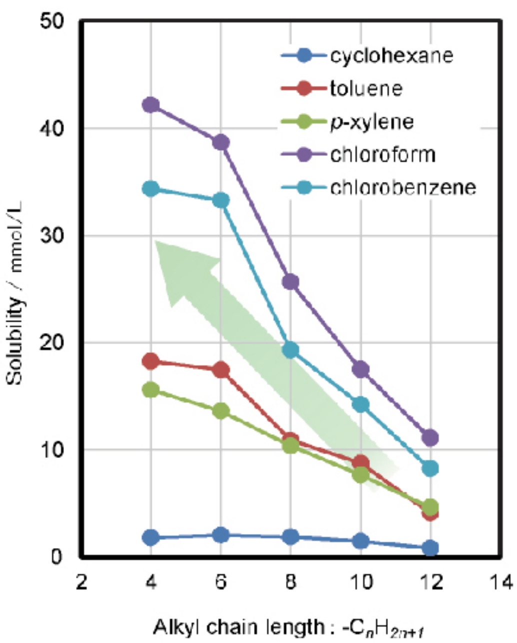
1) H. Iino, T. Usui, J. Hanna, *Nat. Commun.* **2015**, *6*, 6828.
2) H. Wu, H. Iino, J. Hanna, *ACS Appl. Mater. Interfaces* **2020**, *12*, 29497–29504.
3) S. Arai, S. Inoue, T. Hamai, R. Kumai, T. Hasegawa, *Adv. Mater.* **2018**, *30*, 1707256.

Physical property data

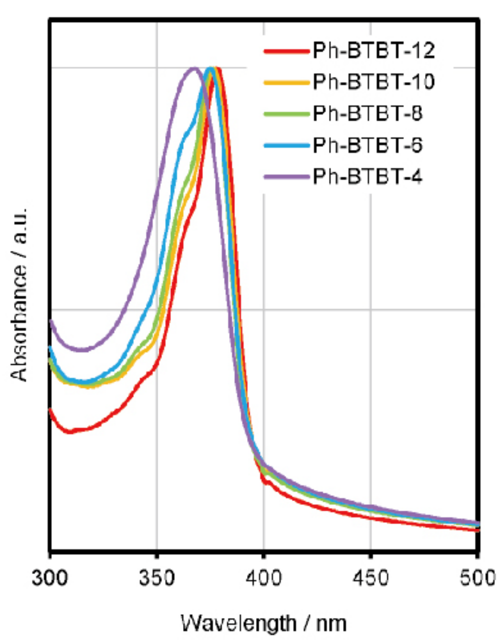
compound	mobility[a] / cm²/Vs	solubility[b] / mmol/L		absorption spectra[c] / nm		phase transition temp.[4] / ºC	mp[4] / ºC
	bare substrate (ODTS substrate)	toluene	chloroform	absorption maximaum	absorption edge		
Ph-BTBT-12	6.0	4.1	11.1	378	396	140	218
Ph-BTBT-10	4.7 (11.0)	8.8	17.5	377	395	147	225
Ph-BTBT-8	1.7	10.9	25.7	376	394	148	231
Ph-BTBT-6	0.5	17.5	38.7	375	394	159	237
Ph-BTBT-4	0.2	18.3	42.2	368	393	-	245

[a]Top-contact transistor devices fabricated by vacuum deposition method (in-house). [b]Data obtained at room temperature. [c]In vacuum deposited thin-films.

Solubility in organic solvents (in-house data)



UV-vis spectra of vacuum deposited thin-films (in-house data)



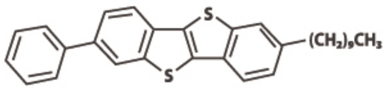
References:

4) S. Inoue, H. Minemawari, J. Tsutsumi, M. Chikamatsu, T. Yamada, S. Horiuchi, M. Tanaka, R. Kumai, M. Yoneya, T. Hasegawa, *Chem. Mater.* **2015**, *27*, 3809–3812.

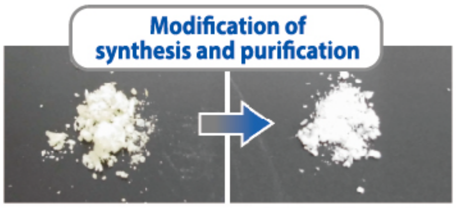
Quality assurance by FET mobility

An effect of low amount of impurities on electrical properties

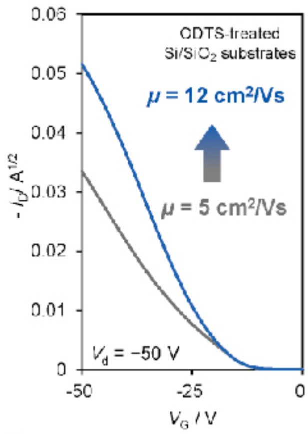
- Both purities are over 99.5%.
- Clear difference of FET performance
- FET mobility is set as a specification. TCI offers real "practical materials".

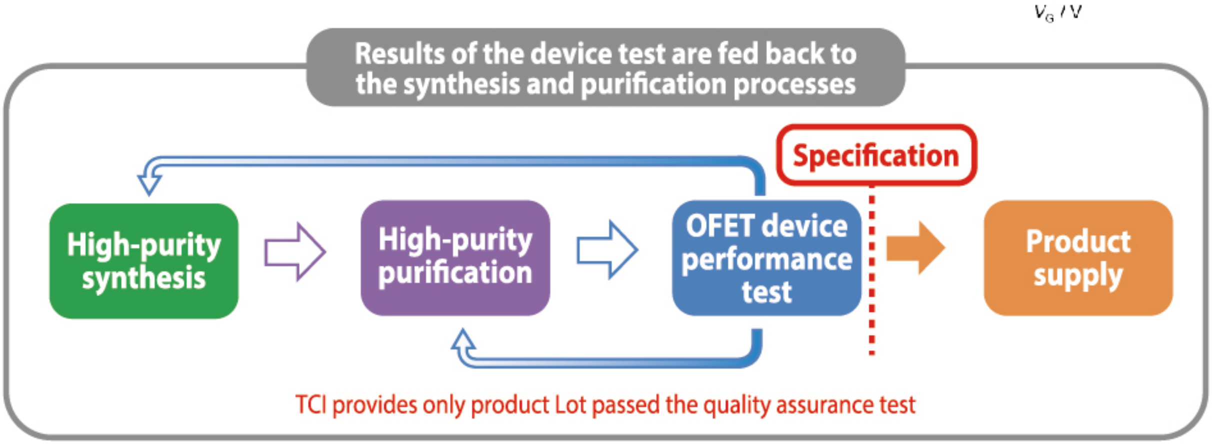


Ph-BTBT-10
[D5491]



Evaluation of vacuum deposited OFET devices: Ph-BTBT-10 sample





Each product has a product specification as below.

Ph-BTBT-12 [D5910] hole mobility of > 5.0 cm²/Vs (vacuum deposition method, Si/SiO_2 bare substrate)
Ph-BTBT-10 [D5491] hole mobility of > 10.0 cm²/Vs (vacuum deposition method, ODTS-treated Si/SiO_2 substrate)
Ph-BTBT-8 [O0576] hole mobility of > 1.2 cm²/Vs (vacuum deposition method, Si/SiO_2 bare substrate)
Ph-BTBT-6 [H1769] hole mobility of > 0.4 cm²/Vs (vacuum deposition method, Si/SiO_2 bare substrate)
Ph-BTBT-4 [B6248] hole mobility of > 0.1 cm²/Vs (vacuum deposition method, Si/SiO_2 bare substrate)

Related Products

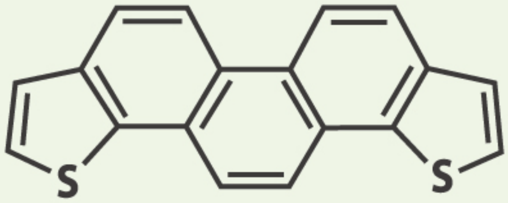
High-performance organic semiconductors

S-DNTT-10 [for organic electronics]	100mg / 250mg	[D5796]
TU-1 [for organic electronics]	100mg / 250mg	[T3922]
TU-3 [for organic electronics]	100mg / 250mg	[T3924]

Surface treatment agent

Octadecyltrichlorosilane (>99.0%) (= ODTS)	1g	[T3815]

p-Type Semiconducting Picene Derivative Phenanthrodithiophene

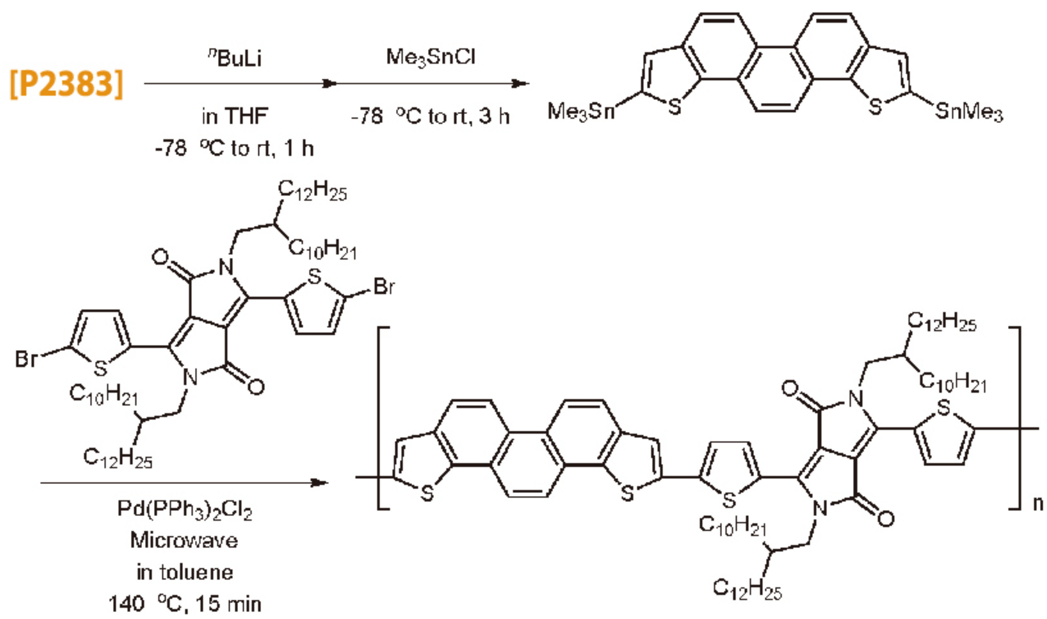


Phenanthro[1,2-*b*:8,7-*b'*]dithiophene
100mg
[P2383]

Advantages

- **The field-effect mobility is as high as 10^{-1} cm^2/Vs when used in the thin films of the field-effect transistor (FET).**
- **Applicable to the synthesis of semiconducting polymers by using stannylated or brominated P2383.**

Application

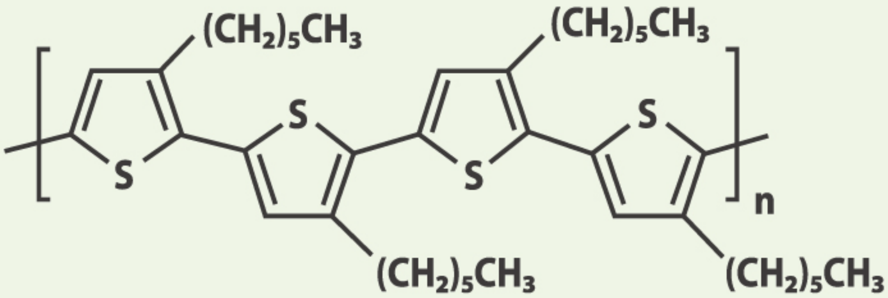


donor-acceptor (D-A)-type semiconducting polymer

References

H. Mori, M. Suetsugu, S. Nishinaga, N. Chang, H. Nonobe, Y. Okuda, Y. Nishihara, *J. Polym. Sci., Part A: Polym. Chem.* **2015**, *53*, 709.
Y. Nishihara, M. Kinoshita, K. Hyodo, Y. Okuda, R. Eguchi, H. Goto, S. Hamao, Y. Takabayashi, Y. Kubozono, *RSC Adv.* **2013**, *3*, 19341.
Y. Nishihara, ADEKA CORP., Jpn. Kokai Tokkyo Koho 2014-240483, **2014.**

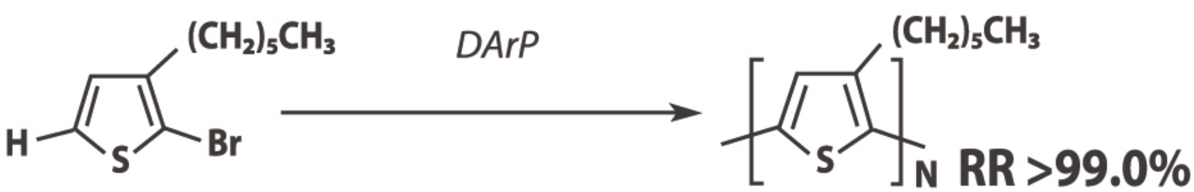
Organic Semiconducting Polymer Highly Regioregular P3HT



P3HT (regioregular) [for organic electronics]
100mg / 500mg
[P2513]

Advantages
- **High regioregularity (RR) >99.0%**
- **Number average molecular weight : M*n* = 27,000 - 45,000**
- **Electronic material grade: High purity, low metal (Pd <100 ppm)**
- **Highly soluble, excellent to film**

Synthesis of P3HT by direct arylation polymerization (DArP) and physical properties[1,2)]



DArP = Direct Arylation Polymerization

[P2513]

The data is extracted from Ref. 2)

Method	M_n (PDI)	RR / %	T_m (°C)	μ_{max} (cm²/V·s)
DArP	33,000 (1.8)	99.5	237	0.19
Rieke	25,000 (1.3)	95.5	224	0.02
GRIM	88,000 (1.5)	98.0	234	0.11

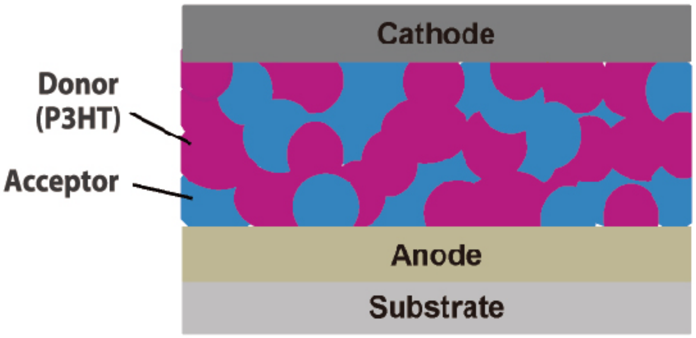
References

1) Q. Wang, R. Takita, Y. Kikuzaki, F. Ozawa, *J. Am. Chem. Soc.* **2010**, *132*, 11420.
2) J.-R. Pouliot, M. Wakioka, F. Ozawa, Y. Li, M. Leclerc, *Macromol. Chem. Phys.* **2016**, *217*, 1493.

This product was commercialized under instruction by Prof. Fumiyuki Ozawa.

Applications

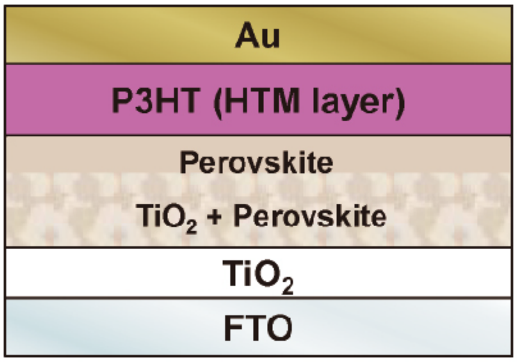
Organic Photovoltaics (OPV)[1)]



P3HT: Donor material

Usable for a solution processable OPV device Fabricates a bulk heterojunction (BHJ) with a highly soluble donor and acceptor

Perovskite Solar Cell (PSC)[2)]



P3HT: Hole transport material (HTM)

Usable for a solution processable PSC device Realizes high power conversion efficiency

Organic Transistor (OFET)[3)]

P3HT: p-Type semiconductor

Usable for a solution processable OFET device

References

1) OPV:

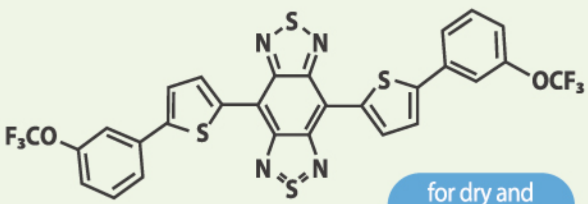
a) E. L. Lim, C. C. Yap, M. A. M. Teridi, C. H. Teh, A. R. M. Yuso, M. H. H. Jumali, *Org. Electron.* **2016**, *36*, 12.

b) A. Marrocchi, D. Lanari, A. Facchetti, L. Vaccaro, *Energy Environ. Sci.* **2012**, *5*, 8457.

2) PSC: L. Calió, S. Kazim, M. Grätzel, S. Ahmad, *Angew. Chem. Int. Ed.* **2016**, *55*, 14522.

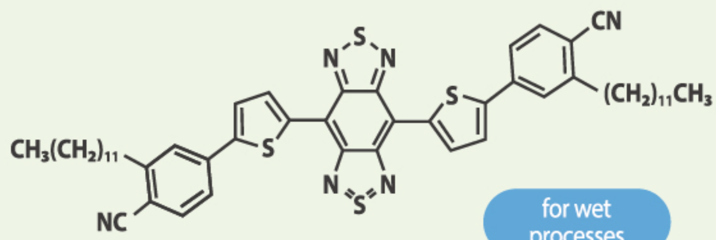
3) OFET: H. Sirringhaus, *Adv. Mater.* **2014**, *26*, 1319.

High Mobility n-Type Organic Semiconductors TU-1, TU-3



for dry and wet processes

TU-1
100mg / 250mg
[T3922]



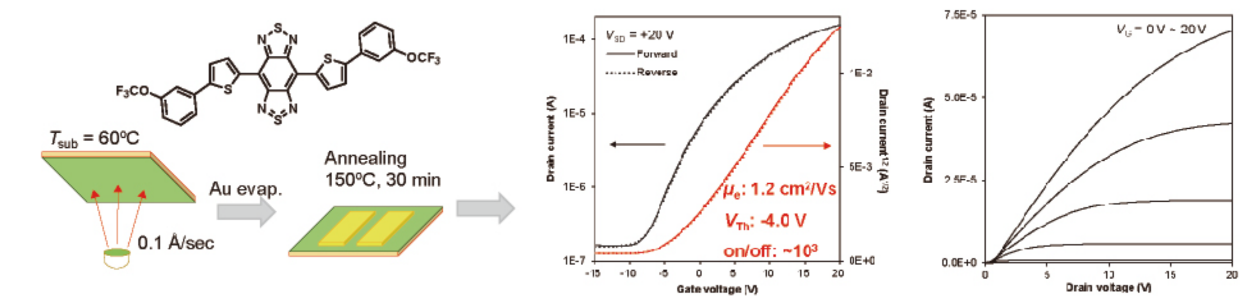
for wet processes

TU-3
100mg / 250mg
[T3924]

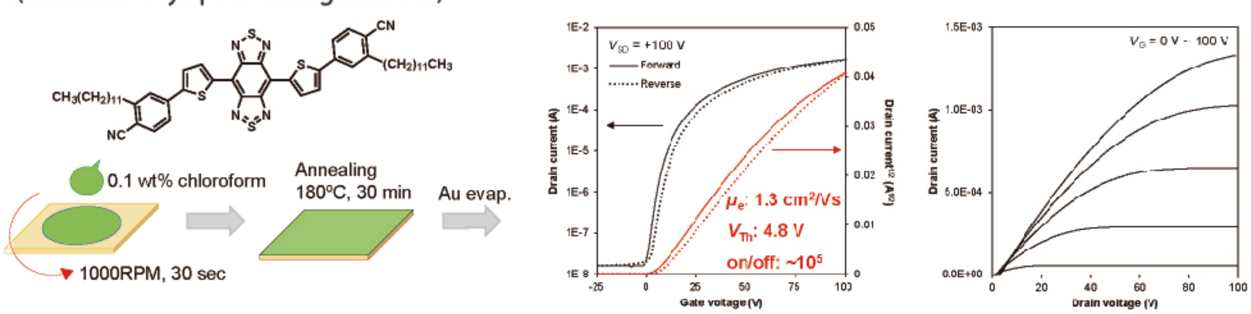
Advantages
- **Electron mobility >1 cm²/Vs**
- **Applicable to dry and/or wet processes**

Performance evaluation of TU-1 and TU-3

TU-1 [T3922]-based device
(fabricated by vacuum deposition method)



TU-3 [T3924]-based device
(fabricated by spin coating method)

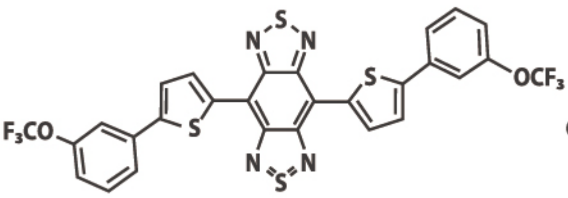


Previous research examples : 1) M. Mamada *et al., Chem. Mater.* **2015**, *27*, 141. DOI: https://doi.org/10.1021/cm503579m
2) Y. Takeda *et al, Sci. Rep.* **2016**, *6*, 25714. DOI: https://doi.org/10.1038/srep25714

TCI has evaluated and ensured semiconductor performance of OFET devices using our in-house equipment.

TU-1 and TU-3 are commercialized with the cooperation and help from Future Ink Corporation

Quality assurance by OFET mobility

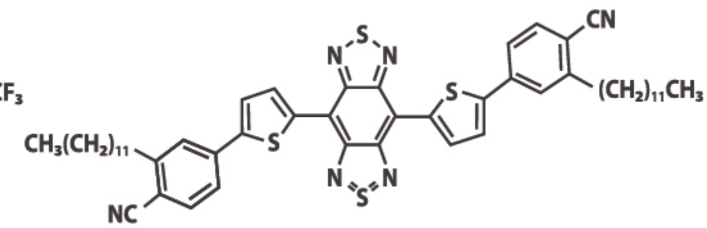


TU-1

[T3922]

Electron mobility : >0.50 cm^2/Vs (specification)

(SiO_2 / ODTS substrate)



TU-3

[T3924]

Electron mobility : >0.50 cm^2/Vs (specification)

(SiO_2 / cPVP substrate)

OFET characteristics of the TU-1, TU-3-based devices

compound	Insulator	V_{SD}[V]	$\mu_{avg.}$[cm^2/Vs]	$\mu_{max.}$[cm^2/Vs]	V_{Th}[V]	on/off
TU-1 (vacuum deposition)	SiO_2	20	0.31 (0.01)	0.33	6.5 (0.2)	~10^6
	SiO_2	40	0.45 (0.01)	0.46	9.6 (0.1)	~10^7
	SiO_2 / ODTS	20	0.88 (0.18)	1.18	-1.1 (2.6)	~10^3
TU-3 (spin coating)	SiO_2	20	0.21 (0.03)	0.26	11.9 (0.4)	~10^5
	SiO_2 / cPVP	20	0.51 (0.03)	0.55	5.0 (0.1)	~10^3
	SiO_2 / cPVP	100	1.03 (0.14)	1.25	5.3 (1.3)	~10^5

The values in parentheses are standard deviations., cPVP: cross-linked polyvinylphenol

TU-1 and TU-3 have product specifications for the electron mobilities (>0.50 cm^2/Vs) on OFET devices.

Related Products

High-quality p-type organic semiconductor

Ph-BTBT-10 100mg / 250mg / 1g **[D5491]**

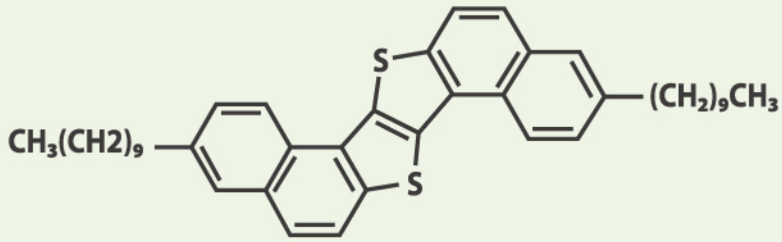
Surface treatment agents

Octadecyltrichlorosilane (=ODTS) (>99.0%) 1g **[T3815]**

***n*-Octyltrichlorosilane (=OTS)** 25g / 250g **[O0168]**

1,1,1,3,3,3-Hexamethyldisilazane (=HMDS) 25mL / 100mL/ 500mL **[H0089]**

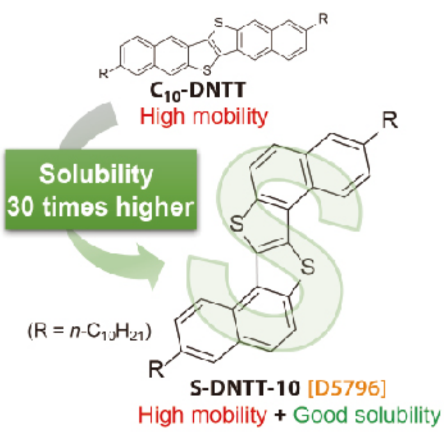
High Performance
S-shaped Organic Semiconductor
S-DNTT-10



S-DNTT-10 [for organic electronics]
100mg / 250mg
[D5796]

Advantages
- **High hole mobility > 10 cm²/Vs (Dip-coating method)**
- **Applicable to both dry and wet processes**
- **High durability**

Device Characteristics



Performance of Dip-Coated OFETs Based on S-DNTT-10 [D5796]

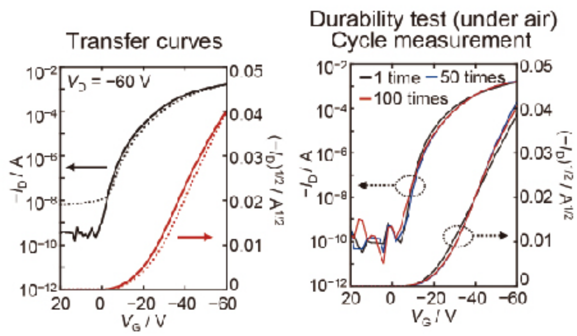
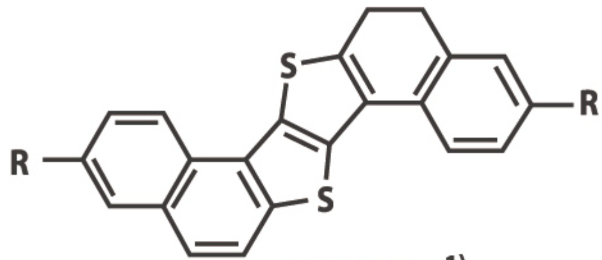


Table 1. Characteristics of OFETs based on **S-DNTT-10** [D5796]

Fabrication method	Surface modification Si/SiO_2 substrate	Maximum mobility (cm²/Vs)	Threshold voltage (V)	on/off
Wet (Dip-coating)	w/o (bare)	11	-17	10^7
Vacuum deposition	w/o (bare)	3.5	-8	10^7

Reference
Y. Yamaguchi, Y. Kojiguchi, S. Kawata, T. Mori, K. Okamoto, M. Tsutsui, T. Koganezawa, H. Katagiri, T. Yasuda, *Chem. Mater.* **2020**, *32*, 5350–5360.
DOI: https://doi.org/10.1021/acs.chemmater.0c01740

Characteristics



S-DNTT-*n*[1]
(*n* = 4, 6, 8, 10)

R = $-(CH_2)_3CH_3$ **(*n* = 4)**

R = $-(CH_2)_5CH_3$ **(*n* = 6)**

R = $-(CH_2)_7CH_3$ **(*n* = 8)**

R = $-(CH_2)_9CH_3$ **(*n* = 10)**

Table 2. Physical property data[1]

Compound	Solubility[a] (mmol/L)	HOMO (eV)	Mobility (cm^2/Vs)	
			Vacuum deposition[b]	Wet process
S-DNTT-4	19.4	−5.3	0.16	3.5[c]
S-DNTT-6	9.7	−5.3	1.6×10^{-3}	6.8[c]
S-DNTT-8	8.0	−5.3	2.7	5.7[c]
S-DNTT-10 **[D5796]**	3.7	−5.3	3.5	11[c]
C10-DNTT[2]	~0.12[2]	~4.9[3]	3.7[2]	11[4]

[a]Data obtained in toluene at 60 °C. [b]Data obtained using Si/SiO_2 (bare) substrates. [c]Dip-coating method.

References

1) Y. Yamaguchi, Y. Kojiguchi, S. Kawata, T. Mori, K. Okamoto, M. Tsutsui, T. Koganezawa, H. Katagiri, T. Yasuda, *Chem. Mater.* **2020**, *32*, 5350–5360.

2) M. J. Kang, I. Doi, H. Mori, E. Miyazaki, K. Takimiya, M. Ikeda, H. Kuwabara, *Adv. Mater.* **2011**, *23*, 1222–1225.

3) K.Takimiya, I. Osaka, T. Mori, M. Nakano, *Acc. Chem. Res.* **2014**, *47*, 1493–1502.

4) K. Nakayama, Y. Hirose, J. Soeda, M. Yoshizumi, T. Uemura, M. Uno, W. Li, N. J. Kang, M. Yamagishi, Y. Okada, E. Miyazaki, Y. Nakazawa, A.Nakao, K. Takimiya, J. Takeya, Adv. Mater. 2011, 23, 1626–1629.

DNTT-10 has a product specification for the hole mobility of > 3.0 cm^2/Vs (vacuum deposition method, bare substrate) on OFET devices.

Related Products

High-performance p-type organic semiconductor

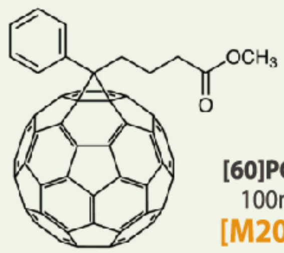
Ph-BTBT-10 [for organic electronics] 100mg / 250mg **[D5491]**

High-performance n-type organic semiconductor

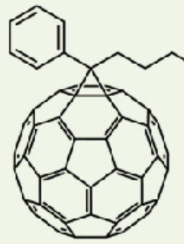
TU-1 [for organic electronics] 100mg / 250mg **[T3922]**

TU-3 [for organic electronics] 100mg / 250mg **[T3924]**

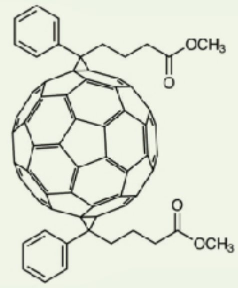
n-Type Organic Semiconductors
Soluble Fullerene Derivatives



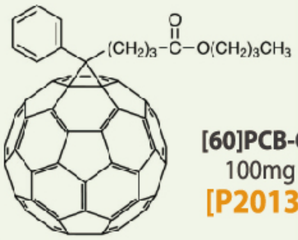
[60]PCBM
100mg
[M2088]



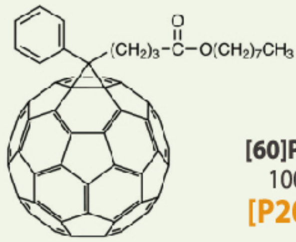
[60]PCBM
[for organic electronics]
100mg
[P2682]



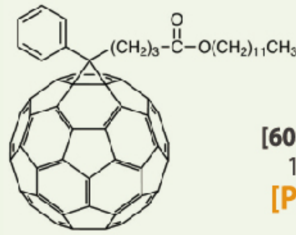
Bis-PCBM
50mg
[B4576]



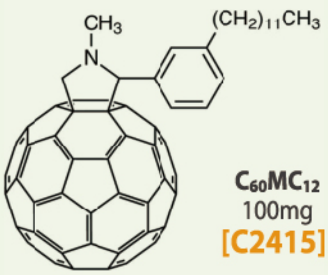
[60]PCB-C_4
100mg
[P2013]



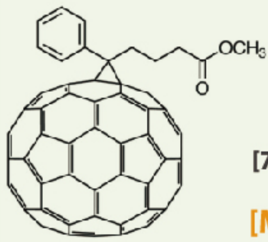
[60]PCB-C_8
100mg
[P2014]



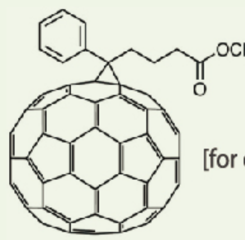
[60]PCB-C_{12}
100mg
[P2015]



$C_{60}MC_{12}$
100mg
[C2415]



[70]PCBM
100mg
[M2550]



[70]PCBM
[for organic electronics]
100mg
[P2683]

In comparison with traditional n-type organic semiconductor materials, these fullerene derivatives have high solubility in organic solvents and exhibit excellent basic properties. They are used as coatable materials for organic electronics research.

References

Organic Photovoltaic Cell (OPV)

[M2088] Appl. Phys. Lett. 2001, 79, 2996; *Nat. Mater.* **2005,** *4*, 864.
[P2013] Solar Ener. Mater. Solar Cells, 2008, 92, 397; *J. Phys. Chem. B*, **2004**, *108*, 11921.
[P2014] Solar Ener. Mater. Solar Cells, 2010, 94, 537; *J. Phys. Chem. B*, **2004**, *108*, 11921.
[P2015] Synth. Metals 2003, 135, 827; *J. Phys. Chem. B*, **2004**, *108*, 11921.

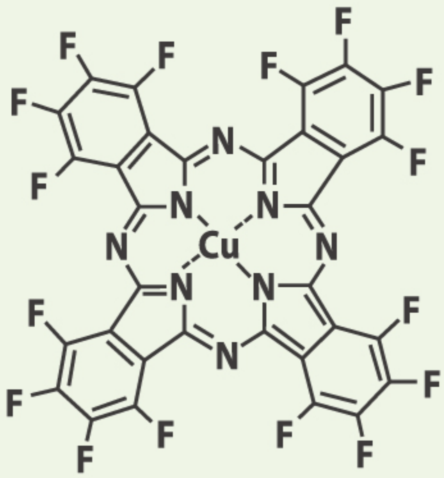
Organic Field-Effect Transistor (OFET)

[M2088] Appl. Phys. Lett. 2004, 85, 4205; *Synth. Metals.* **2008**, *158*, 468.
[C 2415] Appl. Phys. Express 2010, 3, 101601; *Appl. Phys. Lett.* **2005**, *87*, 203504

Organic Light-Emitting Diode (OLED)

[M2088] J. Phys. Chem. C, 2009, 113, 14500; *Macromolecules*, **2006**, *39*, 177.

Highly-purified n-Type Organic Semiconductor $F_{16}CuPc$

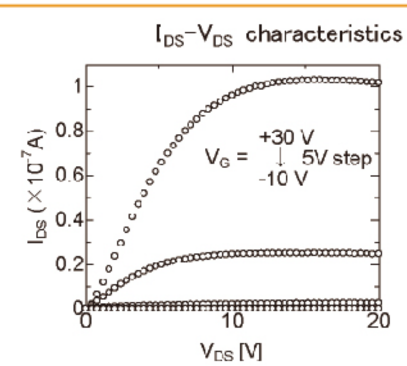


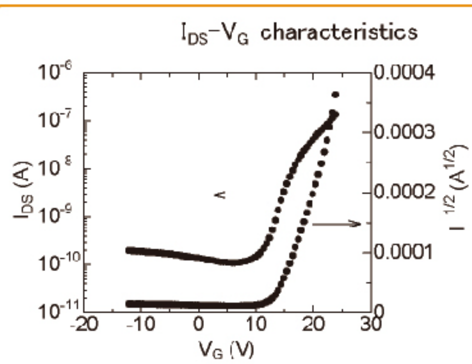
$F_{16}CuPc$ (purified by sublimation)
100mg / 1g
[H1194]

TCI's unique purification technology produces highly-purified semiconducting materials. We will ensure a stable supply of "$F_{16}CuPc$" being used as an organic semiconductor with high electron mobility.

Transistor Characteristics

The FET device made using our $F_{16}CuPc$ as an n-type semiconductor shows good characteristics.



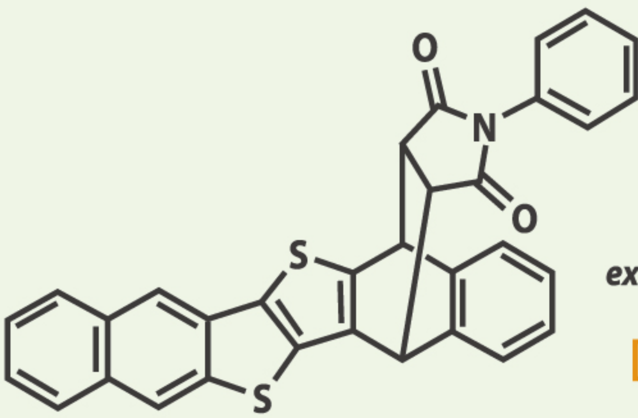


The characteristics above are presented by Dr. Yasuyuki Watanabe.

Related Products

F_8CuPc (purified by sublimation)	100mg / 1g	[C2427]
Pentacene (99.999%, trace metals basis) (purified by sublimation)	100mg / 1g	[P2524]
DPh-BTBT (purified by sublimation)	100mg	[D3526]
Ph-BTBT-10	100mg / 250mg / 1g	[D5491]

Organic Transistor Reagent
Soluble DNTT Precursor

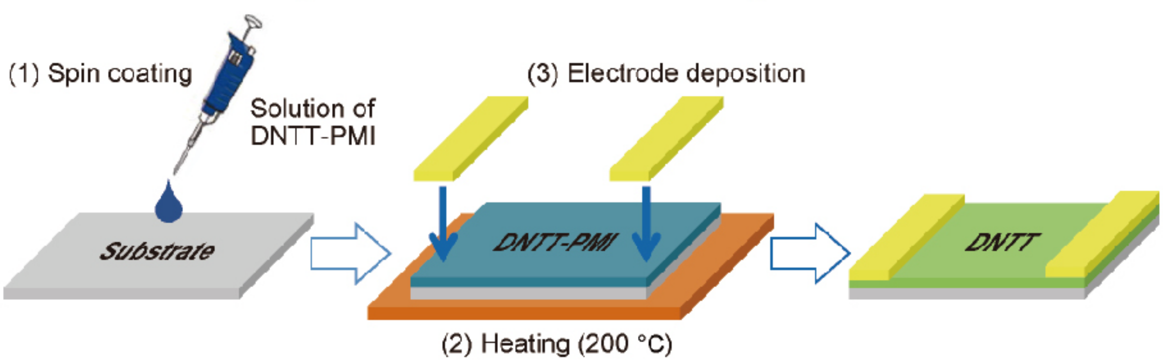


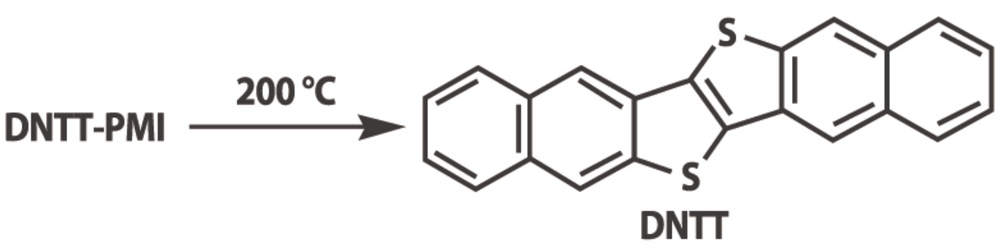
exo-DNTT-PMI
50mg
[D5154]

Advantages
- **Solution-processable DNTT precursor**
- **Thermally convertible to DNTT in thin-film**
- **Applicable to organic transistor and memory devices**

Application

Solution processed OFETs using DNTT-PMIs





References
(a) *J. Am. Chem. Soc.* **2007**, *129*, 2224. (b) *Adv. Mater.* **2015,** *27*, 727. (c) *Adv. Mater.* **2015**, *27*, 6606.
(d) *Organic Electronics* **2013**, *14*, 1211. (e) *Appl. P hys. Express* **2015**, *8*, 101601. (f) Y. Ikeda, T. Shiro, K. Takimiya, Patent JP5269825.

These product was commercialized with the cooperation of TEIJIN LIMITED.

Measurement of OFETs fabricated by using DNTT-PMI

Device fabrication (*endo*-DNTT-PMI)

(1) Mix endo-DNTT-PMI and polystyrene in 2:1 weight ratio

(2) Dissolve mixed powder in $CHCl_3$ to prepare 1wt% solution

(3) Spin-coat the solution onto cleaned- and UV/O_3 treated- n^+-Si/SiO_2 substrate

(4) Anneal substrates at 200 ºC for 10 min under air for converting the precursor to DNTT thin film

(5) Fabricate source and drain electrodes by vacuum deposition of Au

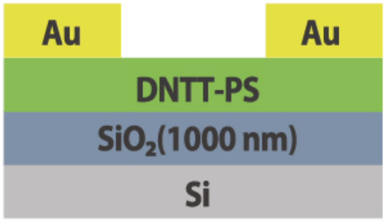


Figure 1. Device structure

Thin-film and OFET properties

Figure 2 shows polarized optical microscopy (POM) image of DNTT thin film prepared from DNTT-PMI. Image clearly shows polycrystalline film morphology. As shown in Figure 3, fabricated devices show typical p-type characteristics.
Maximum carrier mobility 0.86 cm²/Vs was observed when channel length was 200 μm. Carrier mobility was greatly improved to 2.33 cm²/Vs when the channel length was shortened to 20 μm. This high mobility can be assumed to be as following: the source and drain channels were completely filled in single grain, so the carrier transportation barrier caused by grain boundaries reduced.

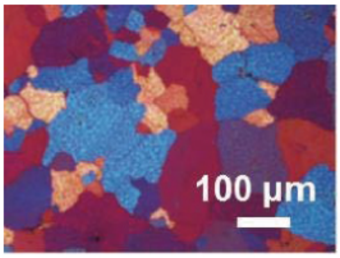


Figure 2. POM image of DNTT thin film.

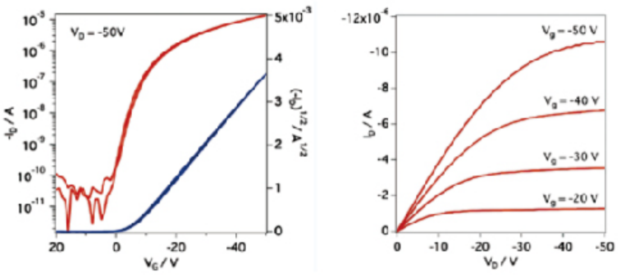


Figure 3. Transfer (left) and output (right) curves of OFET device prepared from endo-DNTT-PMI.

Device	Anneal. Temp. (°C)	Channel Length (μm)	Mobility (cm^2/Vs)	on/off	V_{th} (V)
1	200	200	0.86	4.8×10^6	-5.5
2	210	200	0.85	4.6×10^5	-0.9
3	210	20	2.33	1.1×10^7	-3.1

Table 1. Summary of OFET properties of DNTT prepared from *endo*-DNTT-PMI.

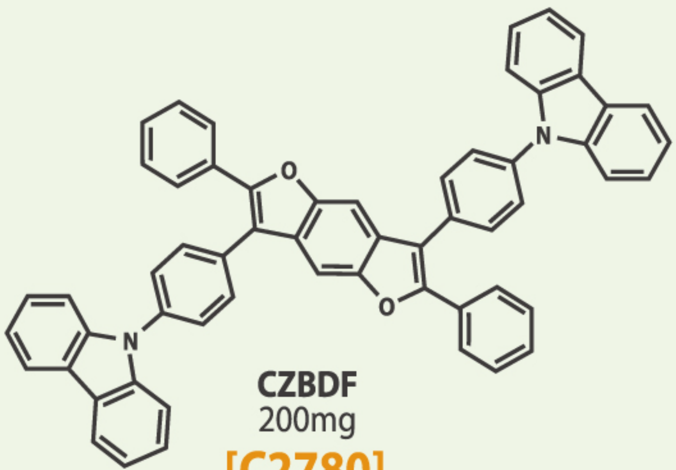
Other notices of DNTT-PMIs

Solubility : exo-DNTT-PMI **[D5154]** (0.2wt% in $CHCl_3$)

Condition to Store : Store in the dark because the color of exo-DNTT-PMI gradually turns to redu under light irradiation

Ambipolar Organic Semiconductor : CZBDF

-Organic material with well-balanced high hole and electron mobility-



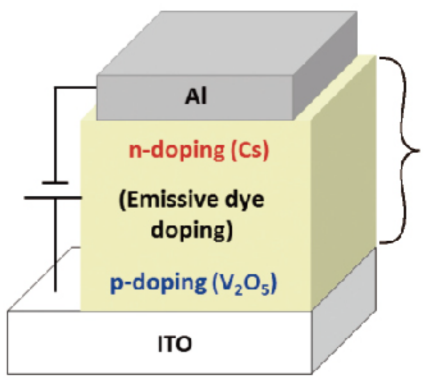
CZBDF
200mg
[C2780]

Advantages

- **Well-balanced high hole and electron**
- **mobility (Hole : 3.7 × 10^{-3} cm^2/Vs,**
- **Electron: 4.4 × 10^{-3} cm^2/Vs; Amorphous, TOF technique)**
- **High glass-transition temperature (T_g = 162 °C)**
- **Wide band gap (3.3 eV)**
- **Serves as a host material for fluorescent and red phosphorescent dopants.**

Application

Host material for homojunction OLED



Single matrix of CZBDF

EQE: up to 4.2% (C545T as an emission dopant)

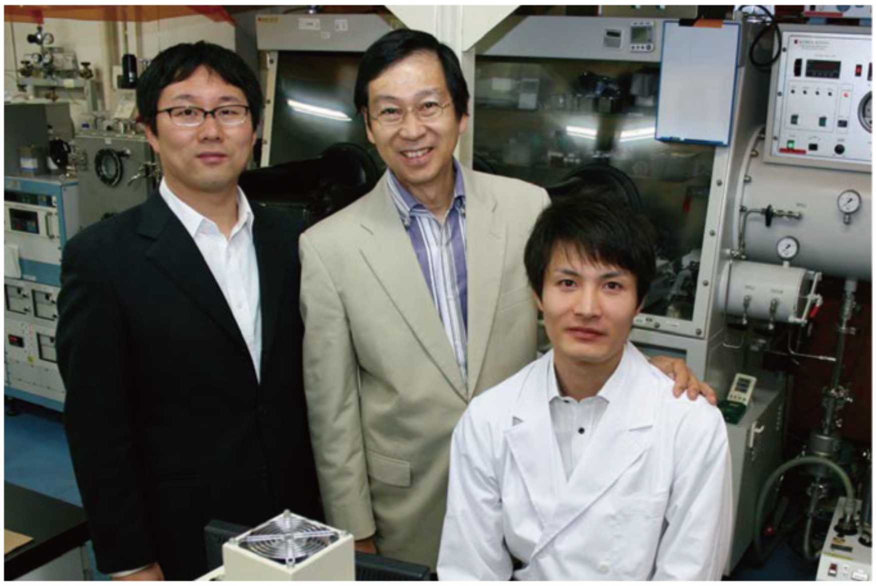
Reference H. Tsuji, C. Mitsui, Y. Sato, E. Nakamura, *Adv. Mater.* **2009,** *21*, 3776. DOI: https://doi.org/10.1002/adma.200900634

Related Products

Coumarin 545T (= C545T)	200mg	[B4257]
2,5,8,11-Tetra-*tert*-butylperylene (= TBP)	100mg	[T3053]
Rubrene (purified by sublimation)	250mg / 1g	[T2233]
Ir(piq)$_3$ (purified by sublimation)	100mg	[T2685]
Alq$_3$ (purified by sublimation)	5g	[T2238]
***N,N'*-Di-1-naphthyl-*N,N'*-diphenylbenzidine (= α-NPD)** (purified by sublimation)	1g / 5g	[D3970]

Introduction of the researcher

Physical Organic Chemistry Laboratory (Nakamura Group), Department of Chemistry, University of Tokyo

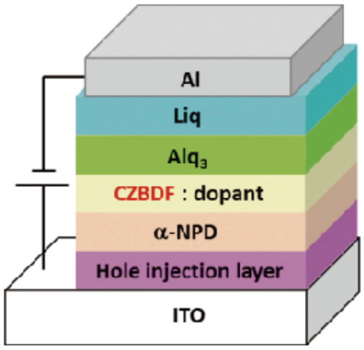


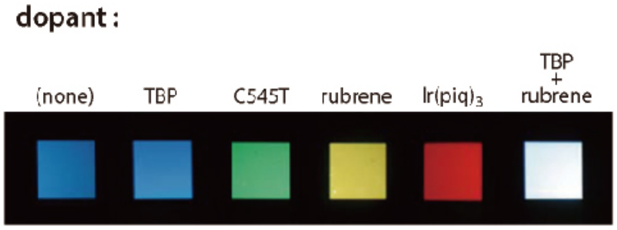
From left : Associate Prof. Dr. Hayato Tsuji, Prof. Dr. Eiichi Nakamura, Dr. Chikahiko Mitsui

Contents of the research

The Nakamura group has pioneered organic chemistry spreading to various research fields based on their manufacturing by synthetic organic chemistry. Their studies involve development of a C-H activation reaction using an iron catalyst, organic electronics materials useful for organic solar cells, organic light-emitting diodes (OLED) and molecular transistors as well. They also research on a novel cure method by introducing a gene. Recently, their study on an electron microscope enabled us to directly observe various motions and crystal growths of individual molecules.

Host material for heterojunction OLED

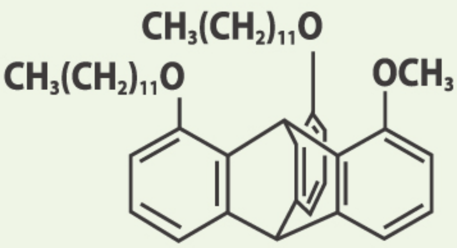




Full-color emission using CZBDF as a host material

Reference C. Mitsui, H. Tsuji, Y. Sato, E. Nakamura, *Chem. Asian J.* **2012,** *7*, 1443. DOI: https://doi.org/10.1002/asia.201200062

Triptycene-type SurfaceTreatment Agent for Completely Orientated Molecular Film



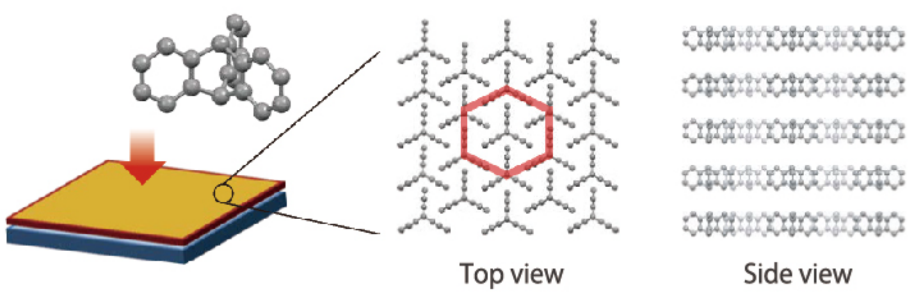
Trip-C12'
100mg
[D5881]

Advantages

- **Forms completely oriented molecular thin films on any substrate layer.**
- **Applicable to dry and wet processes**
- **Enables the improvement of OFET performance by inserting its film under an active layer**

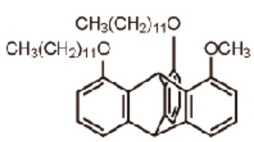
Self-assembly of Triptycene on a substrate [1~4)]

A propeller-shaped molecular structure consisting of three phenylene rings



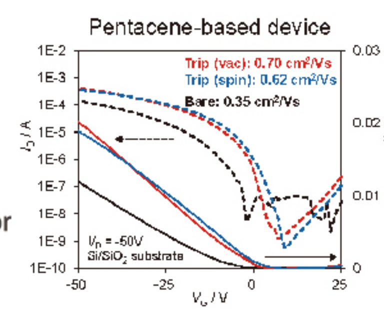
Forming of a 2D nested hexagonal packing sheet and 1D layer stacking structure

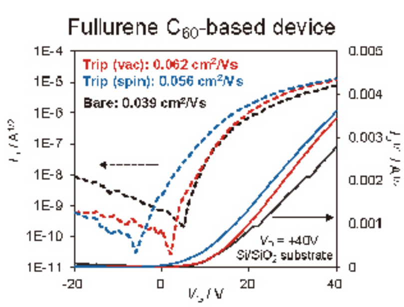
Surface Modification using Trip-C12' for the Improvement of OFET Performance



Trip-C12' [D5881]

deposited by vacuum-evaporation or spin-coating on Si/SiO_2 substrate.





The OFET mobilities increased by inserting the Trip-C12' layers

This product is commercialized under the license agreement based on the patents (No. JP6219314B2 and No. JP6272242B2) invented by Prof. Takanori Fukushima.

Film deposition procedure of Trip-C12′

Deposition method	Vacuum-evaporation[2]	Blade-coating[3]	Spin-coating[1]
Substrate, Insulator	SiO_2, AlO_x, Polyimide, Parylene	Parylene	Silicon wafer
Deposition condition	Thickness : 5nm Without substrate heating during deposition	0.5mM Mesitylene solution Blade speed : 40~50 µm/sec Substrate temperature : 50~60ºC	5mM Toluene solution Rotation speed : 2000RPM
Annealing	120ºC, 1 hour, N_2	120ºC, 1 hour, vacuum (~100Pa)	120ºC, 1 hour

References

1) N. Seiki, Y. Shoji, T. Kajitani, F. Ishiwari A. Kosaka T. Hikima, M. Takata, T. Someya, T. Fukushima, *Science* **2015**, *348*, 1122.
DOI: https://doi.org/10.1126/science.aab1391
2) T. Yokota, T. Kajitani, R. Shidachi, T. Tokuhara, M. Kaltenbrunner, Y. Shoji, F. Ishiwari, T. Sekitani, T. Fukushima, T. Someya, *Nat. Nanotechnol.* **2018**, *13*, 139.
DOI: https://doi.org/10.1038/s41565-017-0018-6
3) M. Kondo, T. Kajitani, T. Uemura, Y. Noda, F. Ishiwari, Y. Shoji, T. Araki, S. Yoshimoto, T. Fukushima, T. Sekitani, *Sci. Rep.* **2019**, *9*, 9200.
DOI: https://doi.org/10.1038/s41598-019-45559-4
4) M. Kondo, T. Uemura, F. Ishiwari, T. Kajitani, Y. Shoji, M. Morita, N. Namba, Y. Inoue, Y. Noda, T. Araki, T. Fukushima, T. Sekitani, *ACS Appl. Mater. Interface* **2019**, *11*, 41561.
DOI: https://doi.org/10.1021/acsami.9b13056

Related Products

Trip-C12′ precursor

1,8,13-Trihydroxytriptycene 500mg [D5823]

High-quality organic semiconductors

Pentacene 100mg / 1g [P2524]
Fullerene C_{60} 100mg [F1232]
Ph-BTBT-10 100mg / 250mg / 1g [D5491]
S-DNTT-10 100mg / 250mg [D5796]
TU-1 [for organic electronics] 100mg / 250mg [T3922]
TU-3 [for organic electronics] 100mg / 250mg [T3924]

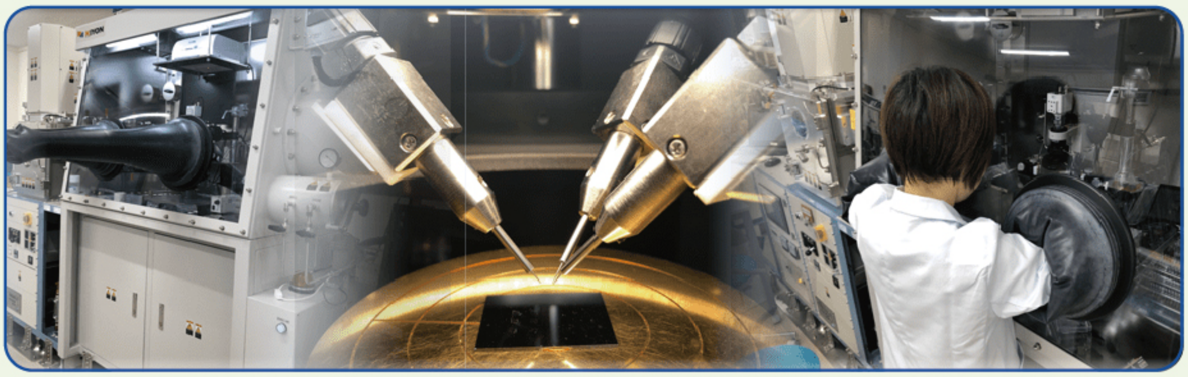
Surface treatment agent

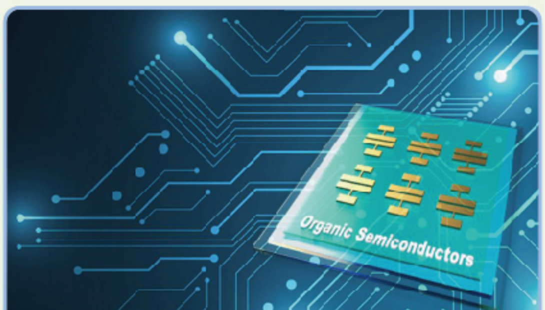
Trichlorooctadecylsilane (>99.0%) 1g [T3815] memo

Details of Representative TCI's Products

▪ Organic Transistor

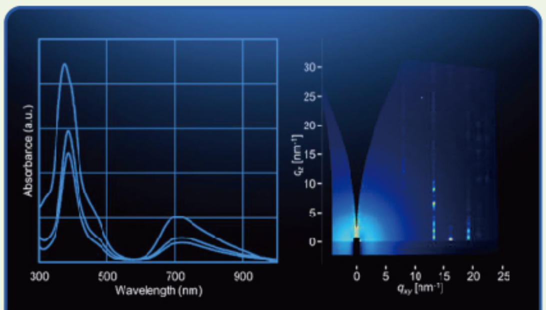
TCI has begun in-house fabrication and assessment of organic transistors by using our products. The results of device performance and its functionality provide us the feedback on synthesis and its purification processes to improve our technology and skill. This helps us to provide more reliable reagents to our customers. In addition, we also release several useful physical properties of our products (e.g. UV-Vis spectra and 2D-GIXD data).





Device Fabrication and Evaluation >

Details of device fabrication methods and device characteristics.

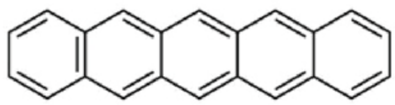


Physical Properties >

Physical property data (e.g. UV-Vis spectra and 2D-GIXD).

Scan the QR code and visit to website for more OFET products.

Fabrication and Evaluation of Organic Field-Effect Transistors (OFETs) : Pentacene



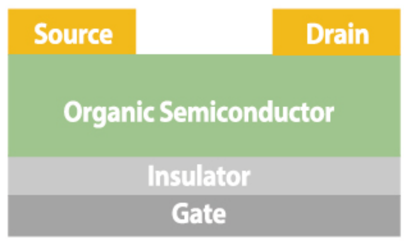
Pentacene (99.999%, trace metals basis) (purified by sublimation)

CAS RN : 135-48-8

Product Number : **P2524**

Performance of Pentacene [P2524]-based OFETs

Vacuum Deposition Method



Top-Contact Bottom-Gate Type (TCBG)

Table. OFETs Characteristics of Pentacene [P2524]-based OFETs

Entry	Fabrication Method	Device Configuration	SAM Treatment	T_{sub}(°C)	Polarity	μ ($cm^2 V^{-1} s^{-1}$)	V_{th} (V)	I_{on}/I_{off}
1	Vacuum deposition	TCBG	w/o Bare	RT	p	0.33	−15	10^5
2	Vacuum deposition	TCBG	OTS	RT	p	1.2	−7.0	10^6

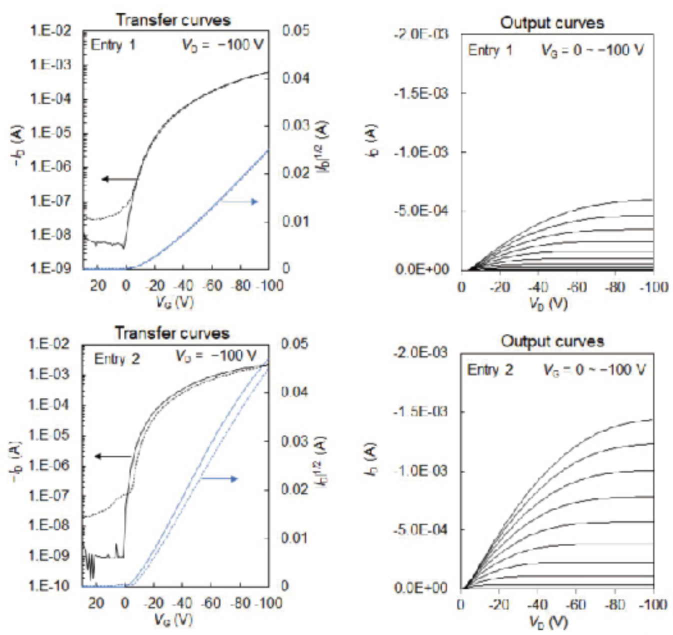


Figure. Transfer curves in the saturated region and output curves at different gate voltages

Experimental details

Fabrication and evaluation of vacuum-deposited Pentacene **[P2524]**-based OFETs

< Substrate >

- Bare Si/SiO_2 (thickness of SiO_2 : 200 nm)
- OTS-treated Si/SiO_2 (thickness of SiO_2 : 200 nm)

< Self-Assembly Monolayer (SAM) Treatment >

- *n*-Octyltrichlorosilane (OTS) **[O0168]**
  1. Piranha etching (H_2SO_4:H_2O_2=4:1, 80ºC, 2h)
  2. Ultrasonication (Deionized water, Acetone, IPA, 10 min each)
  3. Exposure to vapor (IPA, 3min)
  4. UV/O_3 treatment (1h)
  5. Immersion in OTS solution (0.01 M toluene, 16h, N_2)
  6. Ultrasonication (Toluene, Acetone, IPA, 10 min each)

< Vacuum Deposition >

- Deposition rate of Pentacene **[P2524]** : 0.1 Å/s (under a pressure of ~10^{-5} Pa)
- Substrate temperature during deposition : RT
- Deposition rate of Au : 0.3 Å/s, (under a pressure of ~10^{-4} Pa)

< Device Configuration >

- [n^+-Si/SiO_2 (200 nm) / Pentacene **[P2524]** (60 nm) / Au (60 nm)]
- Top-Contact Bottom-Gate Type (TCBG)
- Channel Length : 50 µm
- Channel width : 1.5 mm: 1.5 mm

< Evaluation Condition >

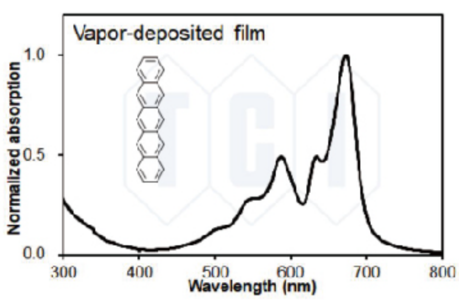
- Under N_2
- Field-effect mobilities (μ) were determined from the transfer curves in the saturation regime using the following equation: $I_D = (W/2L)\, \mu\, Ci\, (V_G - V_{th})^2$

TCI products used in this experiment

[P2524] Pentacene (99.999%, trace metals basis) (purified by sublimation)

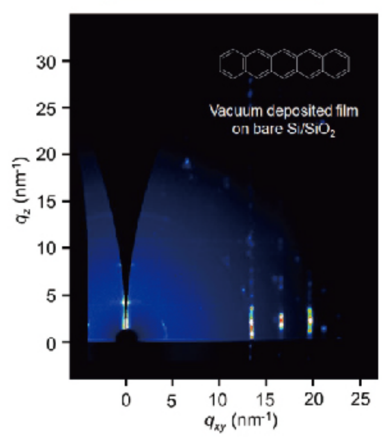
[O0168] *n*-Octyltrichlorosilane (OTS)

UV-Vis Spectrum Data

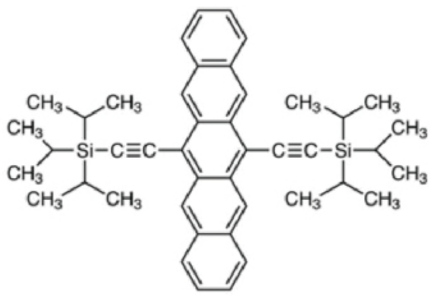


λ_{peak}(nm): 673, λ_{edge}(nm): 699

2D-GIXD Data



Fabrication and Evaluation of Organic Field-Effect Transistors (OFETs) : TIPS Pentacene



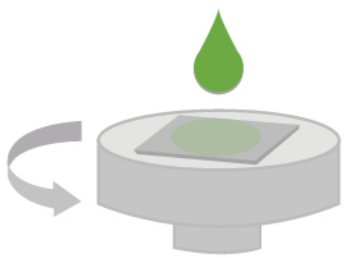
6,13-Bis(triisopropylsilylethynyl)pentacene
(This product is unavailable in the U.S.)
[for organic electronics]

TIPS Pentacene

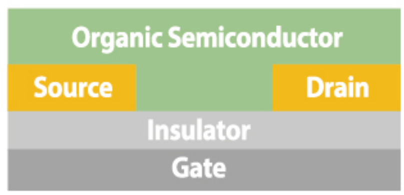
CAS RN : 373596-08-8

Product Number : **B5942**

Performance of TIPS Pentacene [B5942]-based OFETs



Spin-Coating Method



Bottom-Contact Bottom-Gate Type (BCBG)

Table. OFETs Characteristics of TIPS Pentacene [B5942]-based OFETs

Entry	Fabrication Method	Device Configuration	SAM Treatment	Polarity	μ ($cm^2 V^{-1} s^{-1}$)	V_{th} (V)	I_{on}/I_{off}
1	Spin-coating	BCBG	HMDS (SiO_2) PFBT (Au)	p	0.12	−1.2	10^5

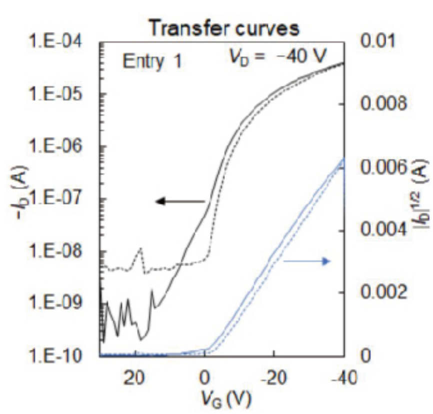


Figure. Transfer curves in the saturated region

Experimental details

Fabrication and evaluation of vacuum-deposited TIPS Pentacene [B5942]-based OFETs

< Substrate >

- HMDS-treated Si/SiO_2 (thickness of SiO_2 : 200 nm) + with PFBT-treated Au electrodes (thickness of Au : 40 nm)

< Vacuum Deposition >

- Deposition rate of Au : 0.2 Å/s, (under a pressure of ~10^{-4} Pa)

< Vacuum Deposition >

- PFBT [P0861] (For Au surface treatment) + HMDS [H0089] (For Si/SiO_2 surface treatment)
  1. UV/O_3 treatment (20 min)
  2. Immersion in PFBT [P0861] solution (0.01 M toluene, 3 min, Air)
  3. Exposure to vapor (IPA, 1 min)
  4. Spin-coating of HMDS [H0089] (4000 RPM, 40 sec, Air)
  5. Exposure to vapor (IPA, 1 min)

< Spin-coating >

- TIPS Pentacene [B5942], 1 mg/mL toluene
- Spin-coating condition : 1000 RPM, 60sec, N_2

< Device configuration >

- [n^+-Si/SiO_2 (200 nm) / Au (40 nm) / TIPS Pentacene [B5942] (15 nm)]
- Bottom-Contact Bottom-Gate Type (BCBG)
- Channel Length : 50 μm
- Channel width : 1.5 mm

< Evaluation condition >

- Under N_2
- Field-effect mobilities (μ) were determined from the transfer curves in the saturation regime using the following equation : $I_D = (W/2L)\,\mu\, Ci\,(V_G - V_{th})^2$

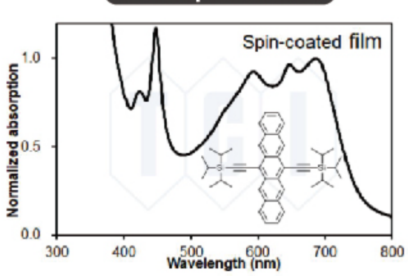
TCI products used in this experiment

[B5942] 6,13-Bis(triisopropylsilylethynyl)pentacene (This product is unavailable in the U.S.) [for organic electronics]

[P0861] Pentafluorobenzenethiol

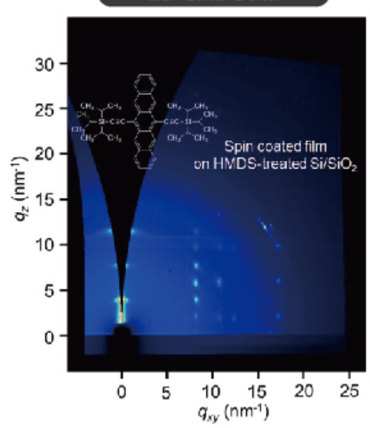
[H0089] 1,1,1,3,3,3-Hexamethyldisilazane

UV-Vis Spectrum Data

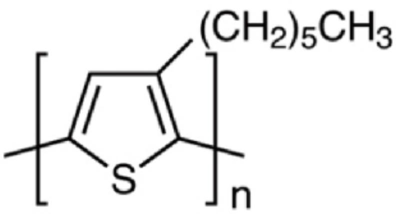


λ_{peak}(nm): 686, λ_{edge}(nm): 748

2D-GIXD Data



Fabrication and Evaluation of Organic Field-Effect Transistors (OFETs) : P3HT



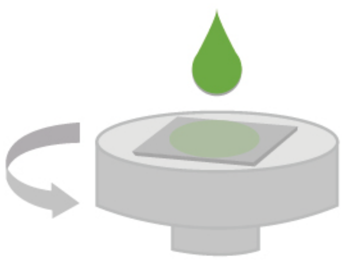
Poly(3-hexylthiophene-2,5-diyl) (regioregular)

P3HT

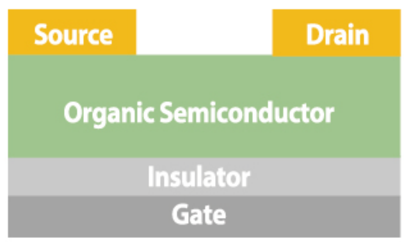
CAS RN : 125321-66-6

Product Number : **P2513**

Performance of P3HT (regioregular) [P2513]-based OFETs



Spin-Coating Method



Top-Contact Bottom-Gate Type (TCBG)

Table. OFETs Characteristics of P3HT (regioregular) **[P2513]**

Entry	Fabrication Method	Device Configuration	SAM Treatment	Annealing Temp.[a] (°C)	Polarity	μ ($cm^2 V^{-1} s^{-1}$)	V_{th} (V)	I_{on}/I_{off}
1	Spin-coating	TCBG	OTS	100	p	0.12	9.9	10^3

[a]Post-annealing temperature.

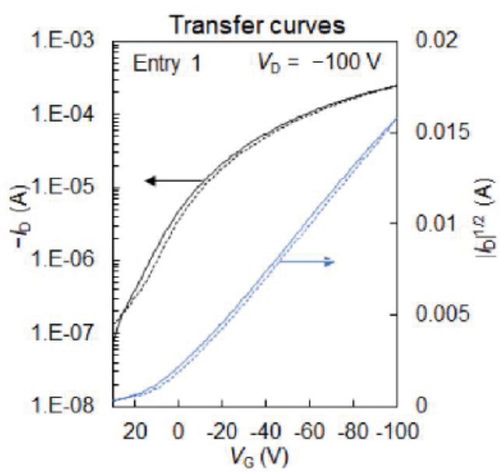


Figure. Transfer curves in the saturated region

Experimental details

Fabrication and evaluation of spin-coated P3HT (regioregular) [P2513]-based OFETs

< Substrate >

- OTS-treated Si/SiO_2 (thickness of SiO_2 : 300 nm)

< Self-Assembly Monolayer (SAM) Treatment >

- *n*-Octyltrichlorosilane (OTS) **[O0168]**
  1. Piranha etching (H_2SO_4:H_2O_2=4:1, 80°C, 2h)
  2. Ultrasonication (Deionized water, Acetone, IPA, 10 min each)
  3. Exposure to vapor (IPA, 3 min)
  4. UV/O_3 treatment (1 h)
  5. Immersion in OTS solution (0.01 M toluene, 16 h, N_2)
  6. Ultrasonication (Toluene, Acetone, IPA, 10 min each)

< Spin-Coating >

- P3HT (regioregular) [P2513] 10 mg/mL, 1,2,4-Trichlorobenzene : Chloroform (2:98) mixed solvent
- Spin-coating condition : 1500 RPM, 60 sec, N_2

< Vacuum Deposition >

- Deposition rate of Au : 0.2 Å/s (under a pressure of ~ 10^{-4} Pa)

< Post-Annealing Treatment >

- Annealing condition : 100 °C, 30 min, N_2

< Device Configuration >

- [n^+-Si/SiO_2 (300 nm) / P3HT (regioregular) **[P2513]** (100 nm) / Au (40 nm)]
  Bottom-Contact Bottom-Gate Type (TCBG)
  Channel Length : 50 μm
  Channel width : 1.5 mm

< Evaluation Condition >

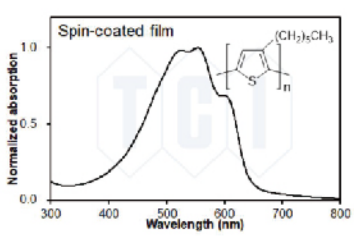
- Under N_2
- Field-effect mobilities (μ) were determined from the transfer curves in the saturation regime using the following equation : $I_D = (W/2L)\, \mu\, Ci\, (V_G - V_{th})^2$

TCI products used in this experiment

[P2513] Poly(3-hexylthiophene-2,5-diyl) (regioregular)

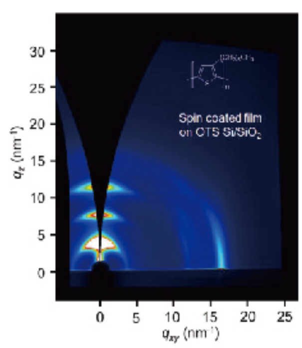
[O0168] *n*-Octyltrichlorosilane (OTS)

UV-Vis Spectrum Data

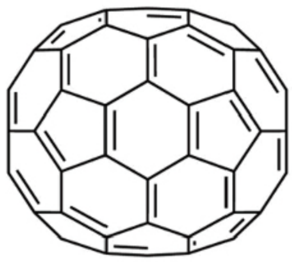


λ_{peak}(nm): 554, λ_{edge}(nm): 543

2D-GIXD Data



Fabrication and Evaluation of Organic Field-Effect Transistors (OFETs) : Fullerene C70



Fullerene C70 (purified by sublimation) [for organic electronics]

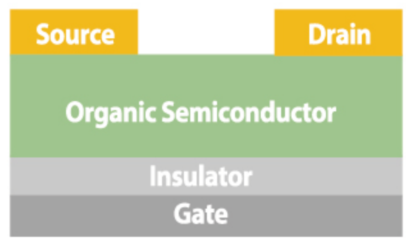
Fullerene C70

CAS RN: 115383-22-7

Product Number : **F1233**

Performances of C70 [F1233]-based OFETs

Vacuum Deposition Method



Top-Contact Bottom-Gate Type (TCBG)

Table. OFETs Characteristics of Fullerene C70 [F1233]-based OFETs

Entry	Fabrication Method	Device Configuration	SAM Treatment	T_{sub}(°C)	Polarity	μ ($cm^2 V^{-1} s^{-1}$)	V_{th} (V)	I_{on}/I_{off}
1	Vacuum deposition	TCBG	HMDS	RT	n	0.52	6.7	10^6
2	Vacuum deposition	TCBG	OTS	RT	n	0.55	8.3	10^6

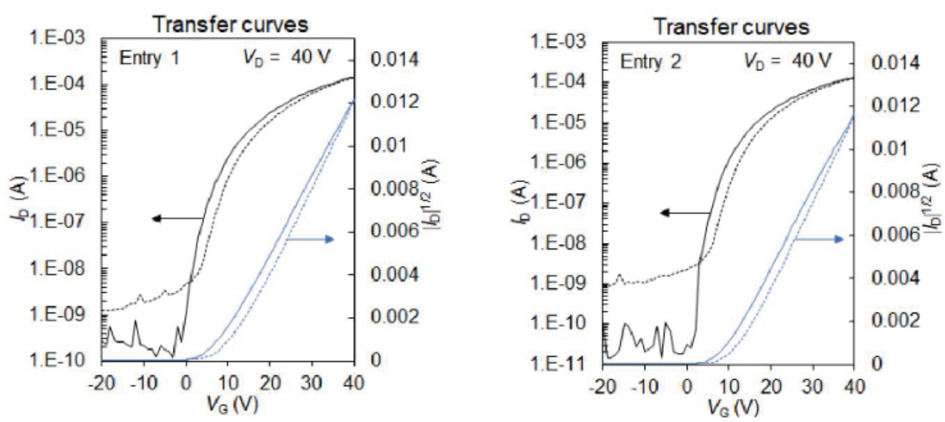


Figure. Transfer curves in the saturated region

Experimental details

Fabrication and evaluation of vacuum-deposited Fullerene C70 [F1233]-based OFETs

< Substrate >

- HMDS-treated Si/SiO_2 (thickness of SiO_2 : 200 nm)
- OTS-treated Si/SiO_2 (thickness of SiO_2 : 200 nm)

< Self-Assembly Monolayer (SAM) Treatment >

- 1,1,1,3,3,3-Hexamethyldisilazane (HMDS) [H0089]
  1. Piranha etching (H_2SO_4:H_2O_2=4:1, 80ºC, 2h)
  2. Ultrasonication (Deionized water, Acetone, IPA, 10 min each)
  3. Exposure to vapor (IPA, 3 min)
  4. UV/O_3 treatment (1 h)
  5. Immersion in HMDS (16 h, N_2)
  6. Ultrasonication (Toluene, Acetone, IPA, 10 min each)
- n-Octyltrichlorosilane (OTS) [O0168]
  1. Piranha etching (H_2SO_4:H_2O_2=4:1, 80ºC, 2h)
  2. Ultrasonication (Deionized water, Acetone, IPA, 10 min each)
  3. Exposure to vapor (IPA, 3 min)
  4. UV/O_3 treatment (1 h)
  5. Immersion in OTS solution (0.01 M toluene, 16 h, N_2)
  6. Ultrasonication (Toluene, Acetone, IPA, 10 min each)

< Vacuum Deposition >

- Deposition rate of C70 [F1233] 0.2 Å/s (under a pressure of ~10^{-5} Pa)
- Substrate temperature during deposition: RT
- Deposition rate of Au : 0.2 Å/s (under a pressure of ~10^{-5} Pa)

< Device configuration >

- [n^+-Si/SiO_2 (200 nm) / C70 [F1233] (40 nm) / Au (40 nm)]
- Top-Contact Bottom-Gate Type (TCBG)
- Channel Length : 50 μm
- Channel width : 1.5 mm

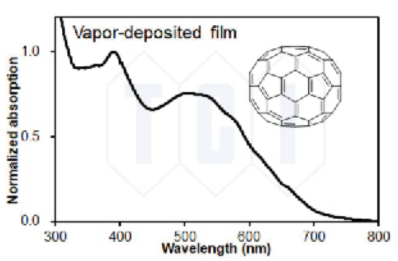
< Evaluation condition >

- Under N_2
- Field-effect mobilities (μ) were determined from the transfer curves in the saturation regime using the following equation : $I_D = (W/2L)\,\mu\, Ci\,(V_G - Vth)^2$

TCI products used in this experiment

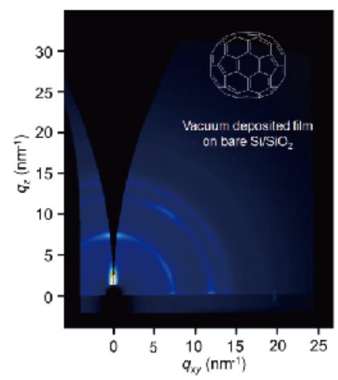
[F1233] Fullerene C70 (purified by sublimation) [for organic electronics]
[H0089] 1,1,1,3,3,3-Hexamethyldisilazane (HMDS)
[O0168] n-Octyltrichlorosilane (OTS)

UV-Vis Spectrum Data

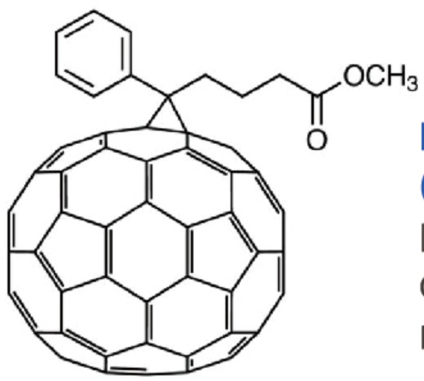


λ_{peak}(nm): 390, λ_{edge}(nm): 715

2D-GIXD Data



Fabrication and Evaluation of Organic Field-Effect Transistors (OFETs) : [70]PCBM



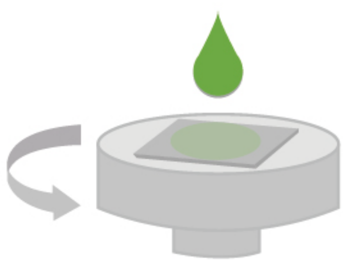
[6,6]-Phenyl-C71-butyric Acid Methyl Ester (mixture of isomers)[for organic electronics]

[70]PCBM (mixture of isomers)

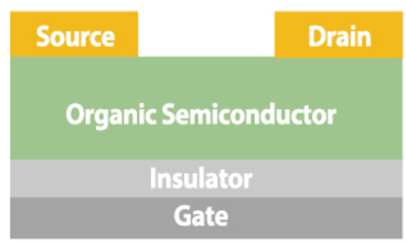
CAS RN : 609771-63-3

Product Number : **P2683**

Performance of [70]PCBM[P2683]-based OFETs



Spin-Coating Method



Top-Contact Bottom-Gate Type (TCBG)

Table. OFETs Characteristics of [70]PCBM[P2683]-based OFETs

Entry	Fabrication Method	Device Configuration	SAM Treatment	Polarity	μ (cm^2 V^{-1} s^{-1})	V_{th} (V)	I_{on}/I_{off}
1	Spin-coating	TCBG	HMDS	n	2.5×10^{-2}	8.8	10^4

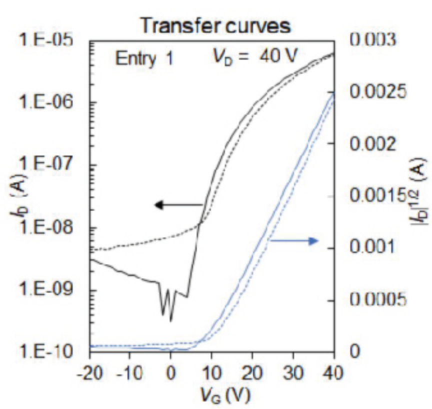


Figure. Transfer curves in the saturated region

Experimental details

Fabrication and evaluation of spin-coated [70]PCBM[P2683]-based OFETs

< Substrate >

- HMDS-treated Si/SiO_2 (thickness of SiO_2 : 200 nm)

< Self-Assembly Monolayer (SAM) Treatment >

- 1,1,1,3,3,3-Hexamethyldisilazane (HMDS) **[H0089]**

1. Piranha etching (H_2SO_4:H_2O_2=4:1, 80°C, 2h)
2. Ultrasonication (Deionized water, Acetone, IPA, 10 min each)
3. Exposure to vapor (IPA, 3 min)
4. UV/O_3 treatment (1 h)
5. Immersion in HMDS (16 h, N_2)
6. Ultrasonication (Toluene, Acetone, IPA, 10 min each)

< Spin-Coating >

- [70]PCBM**[P2683]**, 15 mg/mL, Chloroform
- Spin-coating condition : 2000 RPM, 60 sec, N_2

< Vacuum Deposition >

- Deposition rate of Au : 0.2 Å/s (under a pressure of ~10^{-4} Pa)

< Device configuration >

- [n^+-Si/SiO_2 (200 nm) / [70]PCBM**[P2683]** / Au (40 nm)]
- Top-Contact Bottom-Gate Type (TCBG)
- Channel Length : 50 μm
- Channel width : 1.5 mm

< Evaluation condition >

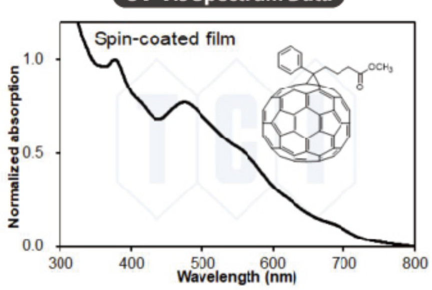
- Under N_2
- Field-effect mobilities (μ) were determined from the transfer curves in the saturation regime using the following equation: $I_D = (W/2L)\, \mu\, Ci\, (V_G - V_{th})^2$

TCI products used in this experiment

[P2683] [70]PCBM (mixture of isomers)

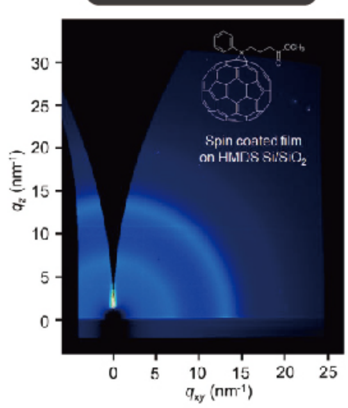
[H0089] 1,1,1,3,3,3-Hexamethyldisilazane (HMDS)

UV-Vis Spectrum Data

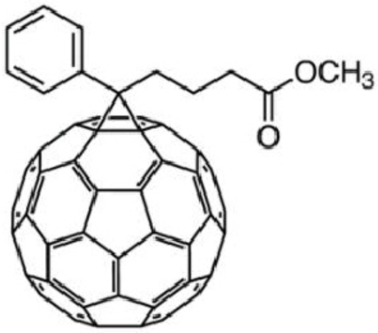


λ_{peak}(nm): 377, λ_{edge}(nm): 737

2D-GIXD Data



Fabrication and Evaluation of Organic Field-Effect Transistors (OFETs) : [60]PCBM



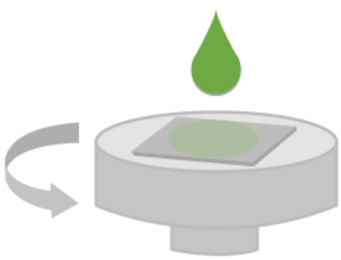
[6,6]-Phenyl-C61-butyric Acid Methyl Ester [for organic electronics]

[60]PCBM

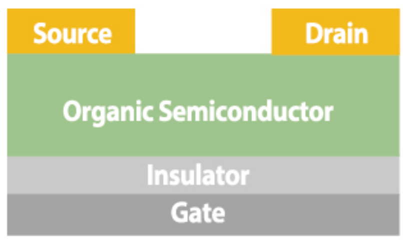
CAS RN : 115383-22-7

Product Number : **P2682**

Performance of [60]PCBM [P2682]-based OFETs



Spin-Coating Method



Top-Contact Bottom-Gate Type (TCBG)

Table. OFETs Characteristics of [60]PCBM **[P2682]**-based OFETs

Entry	Fabrication Method	Device Configuration	SAM Treatment	T_{sub}(°C)	Polarity	μ ($cm^2 V^{-1} s^{-1}$)	V_{th} (V)	I_{on}/I_{off}
1	Spin-coating	TCBG	HMDS	RT	n	2.4×10^{-2}	6.7	10^4

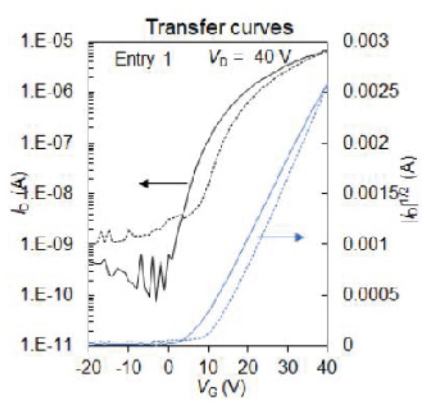


Figure. Transfer curves in the saturated region

Experimental details

Fabrication and evaluation of spin-coated [60]PCBM [P2682]-based OFETs

< Substrate >

- HMDS-treated Si/SiO_2 (thickness of SiO_2 : 200 nm)

< Self-Assembly Monolayer (SAM) Treatment >

- 1,1,1,3,3,3-Hexamethyldisilazane (HMDS) **[H0089]**

1. Piranha etching (H_2SO_4:H_2O_2=4:1, 80°C, 2h)
2. Ultrasonication (Deionized water, Acetone, IPA, 10 min each)
3. Exposure to vapor (IPA, 3 min)
4. UV/O_3 treatment (1 h)
5. Immersion in HMDS (16 h, N_2)
6. Ultrasonication (Toluene, Acetone, IPA, 10 min each)

< Spin-Coating >

- [60]PCBM **[P2682]**, 15 mg/mL, Chloroform
- Spin-coating condition : 3000 RPM, 60 sec, N_2

< Vacuum Deposition >

- Deposition rate of Au : 0.2 Å/s (under a pressure of ~10^{-4} Pa)

< Device configuration >

- [n^+-Si/SiO_2 (200 nm) / [60]PCBM **[P2682]** / Au (40 nm)]
- Top-Contact Bottom-Gate Type (TCBG)
- Channel Length : 50 µm
- Channel width : 1.5 mm

< Evaluation condition >

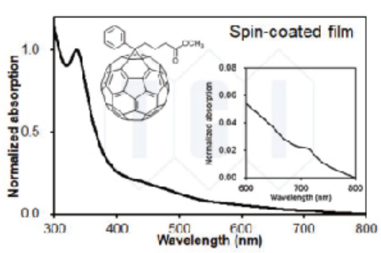
- Under N_2
- Field-effect mobilities (μ) were determined from the transfer curves in the saturation regime using the following equation: $I_D = (W/2L)\, \mu\, Ci\, (V_G - V_{th})^2$

TCI products used in this experiment

[P2682] **[60]PCBM**

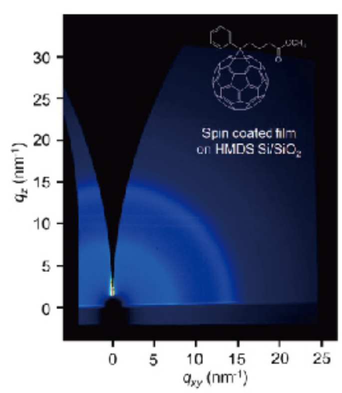
[H0089] **1,1,1,3,3,3-Hexamethyldisilazane (HMDS)**

UV-Vis Spectrum Data



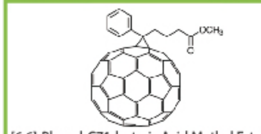
λ_{peak}(nm): 336 λ_{edge}(nm): 755

2D-GIXD Data



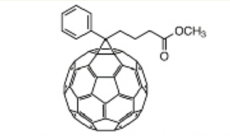
High-Quality Organic Semiconductor Materials

P2683 100mg



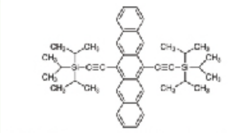
[6,6]-Phenyl-C71-butyric Acid Methyl Ester (mixture of isomers) [for organic electronics]
CAS RN : 609771-63-3

P2682 100mg



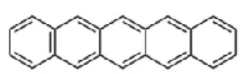
[6,6]-Phenyl-C61-butyric Acid Methyl Ester [for organic electronics]
CAS RN : 160848-22-6

B5942 100mg



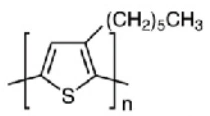
6,13-Bis(triisopropylsilylethynyl)pentacene [for organic electronics]
CAS RN : 373596-08-8

P2524 100mg / 1g



Pentacene (99.999%, trace metals basis) (purified by sublimation) [for organic electronics]
CAS RN : 135-48-8

P2513 100mg / 500mg



Poly(3-hexylthiophene-2,5-diyl) (regioregular)[for organic electronics]
CAS RN : 110134-47-9

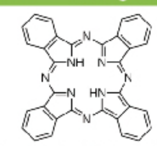
F1233 100mg

Fullerene C70 (purified by sublimation) [for organic electronics]
CAS RN : 115383-22-7

F1232 100mg

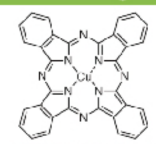
Fullerene C60 (purified by sublimation) [for organic electronics]
CAS RN : 99685-96-8

P2734 100mg / 500mg



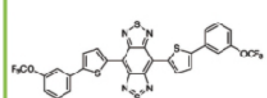
Phthalocyanine (purified by sublimation) [for organic electronics]
CAS RN : 574-93-6

C3645 100mg / 500mg



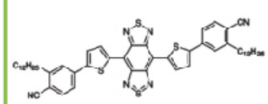
Copper(II) Phthalocyanine (purified by sublimation)[for organic electronics]
CAS RN : 147-14-8

T3922 100mg / 250mg



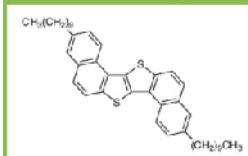
TU-1 [for organic electronics]
CAS RN : 1458041-70-7

T3924 100mg / 250mg



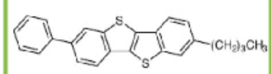
TU-3 [for organic electronics]
CAS RN : 1681007-44-2

D5796 100mg / 250mg



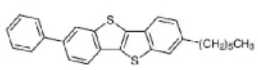
S-DNTT-10 [for organic electronics]

B6248 100mg / 250mg / 1g



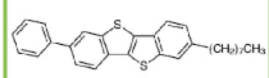
2-Butyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1781261-91-3

H1769 100mg / 250mg / 1g



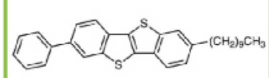
2-Hexyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1781261-93-5

O0576 100mg / 250mg / 1g



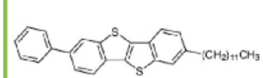
2-Octyl-7-phenyl-benzo[d][1]benzothieno[3,2-b]thiophene [for organic electronics]
CAS RN : 1781261-95-7

D5491 100mg / 250mg / 1g



2-Decyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1398395-83-9

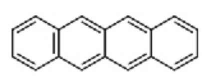
D5910 100mg / 250mg / 1g



2-Dodecyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1627606-00-1

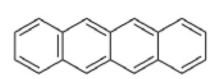
p-Type Organic Semiconductors

N0001 100mg / 1g / 5g



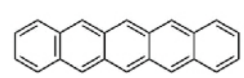
Naphthacene
CAS RN : 92-24-0

N0951 200mg / 1g



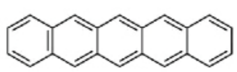
Naphthacene (purified by sublimation)
CAS RN : 92-24-0

P0030 100mg / 1g



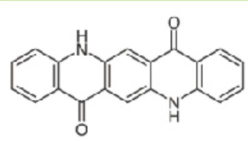
Pentacene (purified by sublimation)
CAS RN : 135-48-8

P2524 100mg / 1g



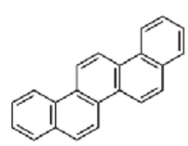
Pentacene (99.999%, trace metals basis) (purified by sublimation) [for organic electronics]
CAS RN : 135-48-8

Q0083 1g



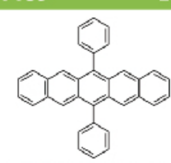
Quinacridone (purified by sublimation)
CAS RN : 1047-16-1

P2207 100mg / 500mg



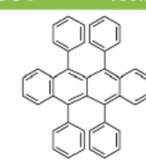
Picene (purified by sublimation) (>99.9%)
CAS RN : 213-46-7

D4469 200mg



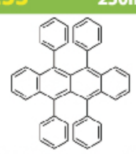
6,13-Diphenylpentacene
CAS RN : 76727-11-2

T0561 100mg / 1g



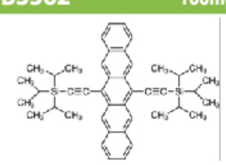
5,6,11,12-Tetraphenylnaphthacene
CAS RN : 517-51-1

T2233 250mg / 1g



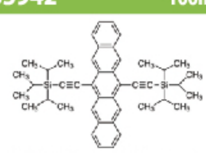
5,6,11,12-Tetraphenylnaphthacene (purified by sublimation)
CAS RN : 517-51-1

B3562 100mg



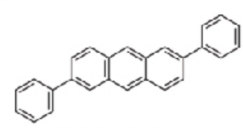
6,13-Bis(triisopropylsilylethynyl)pentacene
CAS RN : 373596-08-8

B5942 100mg



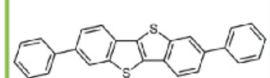
6,13-Bis(triisopropylsilylethynyl)pentacene[for organic electronics]
CAS RN : 373596-08-8

D5152 100mg



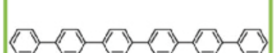
2,6-Diphenylanthracene (purified by sublimation)
CAS RN : 95950-70-2

D3526 100mg



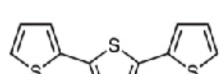
2,7-Diphenyl[1]benzothieno[3,2-b][1]benzothiophene (purified by sublimation)
CAS RN : 900806-58-8

S0220 100mg / 1g



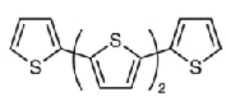
p-Sexiphenyl
CAS RN : 4499-83-6

T1196 1g / 5g



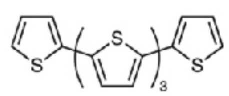
2,2':5',2''-Terthiophene (purified by sublimation)
CAS RN : 1081-34-1

Q0078 100mg



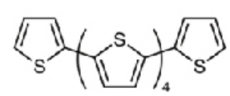
α-Quaterthiophene
CAS RN : 5632-29-1

Q0079 100mg / 500mg



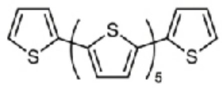
α-Quinquethiophene
CAS RN : 5660-45-7

S0504 100mg / 1g



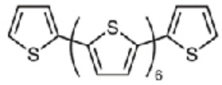
α-Sexithiophene (purified by sublimation)
CAS RN : 88493-55-4

S0505 100mg



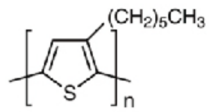
α-Septithiophene
CAS RN : 86100-63-2

O0313 100mg



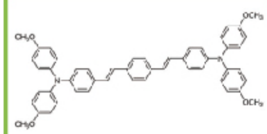
α-Octithiophene
CAS RN : 113728-71-5

P2513 100mg / 500mg



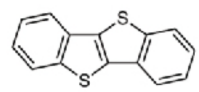
Poly(3-hexylthiophene-2,5-diyl) (regioregular)[for organic electronics]
CAS RN : 110134-47-9

B5672 1g / 5g / 25g



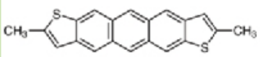
((E,E)-1,4-Bis[4-[bis(4-methoxyphenyl) amino]B5672styryl]benzene
CAS RN : 872466-50-7

B5551 200mg / 1g



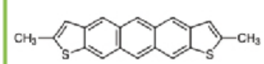
Benzo[b]benzo[4,5]thieno[2,3-d] thiophene
CAS RN : 248-70-4

D4617 100mg



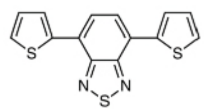
2,8-Dimethylanthra[2,3-b:6,7-b'] dithiophene(purified by sublimation)
CAS RN : 1019983-99-3

D4618 100mg



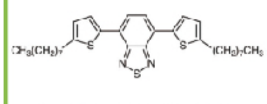
2,8-Dimethylanthra[2,3-b:7,6-b'] dithiophene(purified by sublimation)
CAS RN : 1392416-39-5

D4487 200mg / 1g



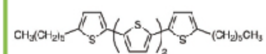
4,7-Di(2-thienyl)-2,1,3-benzothiadiazole
CAS RN : 165190-76-1

B4683 200mg



4,7-Bis(5-n-octyl-2-thienyl)-2,1,3-benzothiadiazole
CAS RN : 1171974-28-9

D4842 100mg

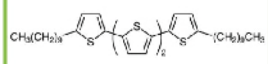


5,5'''-Dihexyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 132814-92-7

D4877 100mg

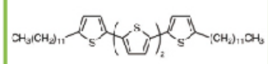
5,5'''-Di-n-octyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 882659-01-0

D4888 100mg



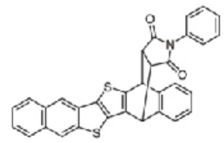
5,5'''-Didecyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 514188-77-3

D4889 100mg



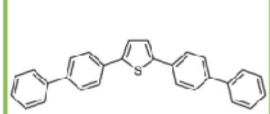
5,5'''-Didodecyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 153561-79-6

D5154 50mg



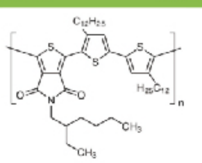
exo-DNTT-PMI (DNTT-Precursor)
CAS RN : 1269669-43-3

B3441 1g / 5g



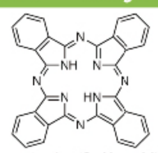
2,5-Bis(4-biphenylyl)thiophene
CAS RN : 56316-86-0

P2710 100mg



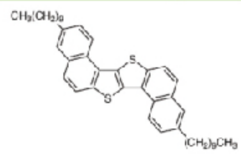
PBTTPD
CAS RN : 1240372-42-2

P2734 100mg / 500mg



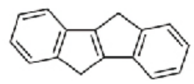
Phthalocyanine (purified by sublimation) [for organic electronics]
CAS RN : 574-93-6

D5796 100mg / 250mg



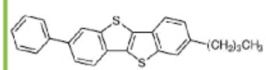
S-DNTT-10 [for organic electronics]

D3191 1g



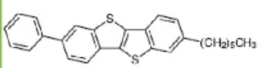
5,10-Dihydroindeno[2,1-a]indene
CAS RN : 6543-29-9

B6248 100mg / 250mg / 1g



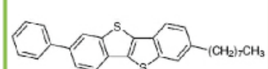
2-Butyl-7-phenyl[1]benzothieno[3,2-b][1] benzothiophene [for organic electronics]
CAS RN : 1781261-91-3

H1769 100mg / 250mg / 1g



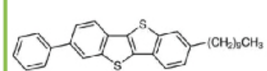
2-Hexyl-7-phenyl[1]benzothieno[3,2-b][1] benzothiophene [for organic electronics]
CAS RN : 1781261-93-5

O0576 100mg / 250mg / 1g



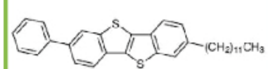
2-Octyl-7-phenyl-benzo[d][1]benzothieno [3,2-b]thiophene [for organic electronics]
CAS RN : 1781261-95-7

D5491 100mg / 250mg / 1g



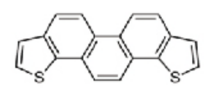
2-Decyl-7-phenyl[1]benzothieno[3,2-b][1] benzothiophene [for organic electronics]
CAS RN : 1398395-83-9

D5910 100mg / 250mg / 1g



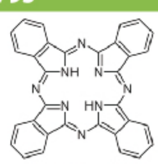
2-Dodecyl-7-phenyl[1]benzothieno [3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1627606-00-1

P2383 100mg



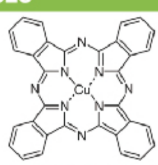
Phenanthro[1,2-b:8,7-b']dithiophene
CAS RN : 1491133-64-2

P1795 1g



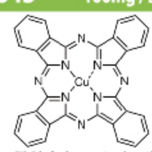
Phthalocyanine (purified by sublimation)
CAS RN : 574-93-6

P1628 1g



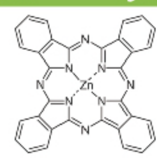
Pigment Blue 15 (purified by sublimation)
CAS RN : 147-14-8

C3645 100mg / 500mg



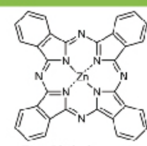
Copper(II) Phthalocyanine(purified by sublimation)[for organic electronics]
CAS RN : 147-14-8

P0767 1g / 5g / 25g



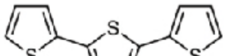
Zinc Phthalocyanine
CAS RN : 14320-04-8

Z0037 500mg



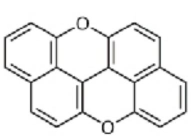
Zinc Phthalocyanine (purified by sublimation)
CAS RN : 14320-04-8

T1196 1g / 5g



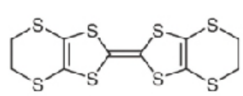
2,2':5',2''-Terthiophene (purified by sublimation)
CAS RN : 1081-34-1

X0083 1g



Xantheno[2,1,9,8-klmna]xanthene
CAS RN : 191-28-6

B1200 100mg / 1g /5g



Bis(ethylenedithio)tetrathiafulvalene
CAS RN : 66946-48-3

n-Type Organic Semiconductors

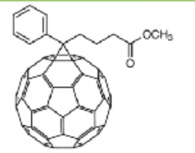
B1641 100mg / 500mg / 1g

Fullerene C60 (pure)
CAS RN : 99685-96-8

F1232 100mg

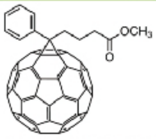
Fullerene C60 (purified by sublimation) [for organic electronics]
CAS RN : 99685-96-8

M2088 100mg



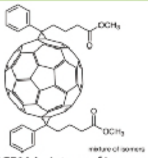
[6,6]-Phenyl-C61-butyric Acid Methyl Ester
CAS RN : 160848-22-6

P2682 100mg



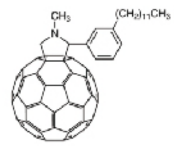
[6,6]-Phenyl-C61-butyric Acid Methyl Ester [for organic electronics]
CAS RN : 160848-22-6

B4576 50mg



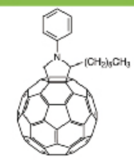
Bis-PCBM (mixture of isomers)
CAS RN : 1048679-01-1

C2415 100mg



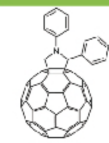
C60MC12
CAS RN : 403483-19-2

P2744 100mg



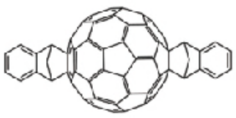
N-Phenyl-2-hexyl[60]fulleropyrrolidine
CAS RN : 1426332-00-4

D5757 100mg



N,2-Diphenyl[60]fulleropyrrolidine (contains 5% Hexane at maximum)
CAS RN : 1373934-14-5

I0900 50mg



ICBA
CAS RN : 1207461-57-1

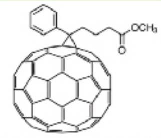
B1694 100mg

Fullerene C70
CAS RN : 115383-22-7

F1233 100mg

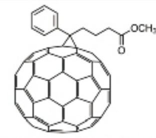
Fullerene C70 (purified by sublimation) [for organic electronics]
CAS RN : 115383-22-7

M2550 50mg



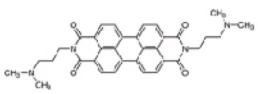
[6,6]-Phenyl-C71-butyric Acid Methyl Ester (mixture of isomers)
CAS RN : 609771-63-3

P2683 100mg



[6,6]-Phenyl-C71-butyric Acid Methyl Ester (mixture of isomers)[for organic electronics]
CAS RN : 609771-63-3

B5954 200mg / 1g

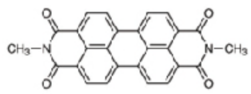


N,N'-Bis[3-(dimethylamino)propyl] perylene-3,4,9,10-tetracarboxylic Diimide
CAS RN : 117901-97-0

B4268 1g / 5g

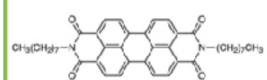
N,N'-Bis(2,6-diisopropylphenyl)-3,4,9,10-perylenetetracarboxylic Diimide
CAS RN : 82953-57-9

D4429 1g / 5g



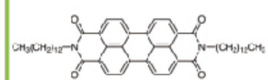
N,N'-Dimethyl-3,4,9,10-perylenetetracarboxylic Diimide
CAS RN : 5521-31-3

D4175 1g



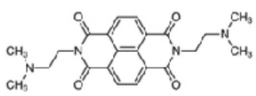
N,N'-Di-n-octyl-3,4,9,10-perylenetetracarboxylic Diimide
CAS RN : 78151-58-3

D3947 200mg / 1g



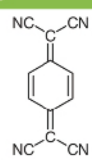
N,N'-Ditridecyl-3,4,9,10-perylenetetracarboxylic Diimide
CAS RN : 95689-92-2

B4583 200mg



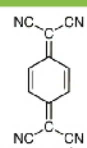
N,N'-Bis[2-(dimethylamino)ethyl]-1,8:4,5-naphthalenetetracarboxdiimide
CAS RN : 22291-04-9

T0078 5g / 25g



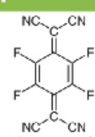
7,7,8,8-Tetracyanoquinodimethane
CAS RN : 1518-16-7

T3034 1g / 5g



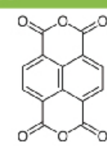
7,7,8,8-Tetracyanoquinodimethane (purified by sublimation)
CAS RN : 1518-16-7

T1131 100mg / 1g



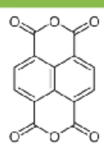
Tetrafluorotetracyanoquinodimethane (purified by sublimation) [Organic Electronic Material]
CAS RN : 29261-33-4

N0369 25g / 250g



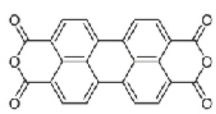
Naphthalene-1,4,5,8-tetracarboxylic Dianhydride
CAS RN : 81-30-1

N0755 1g / 5g



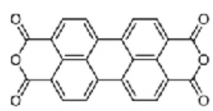
Naphthalene-1,4,5,8-tetracarboxylic Dianhydride(purified by sublimation)
CAS RN : 81-30-1

P0972 25g / 100g / 500g



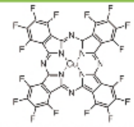
3,4,9,10-Perylenetetracarboxylic Dianhydride
CAS RN : 128-69-8

P2102 1g



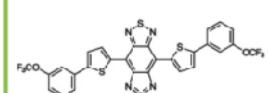
3,4,9,10-Perylenetetracarboxylic Dianhydride (purified by sublimation)
CAS RN : 128-69-8

H1194 100mg / 1g



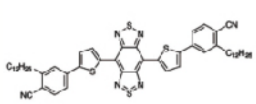
1,2,3,4,8,9,10,11,15,16,17,18,22,23,24,25-Hexadecafluorophthalocyanine Copper(II) (purified by sublimation)
CAS RN : 14916-87-1

T3922 100mg / 250mg



TU-1 [for organic electronics]
CAS RN : 1458041-70-7

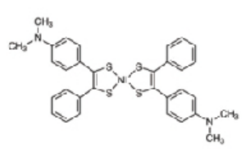
T3924 100mg / 250mg



TU-3 [for organic electronics]
CAS RN : 1681007-44-2

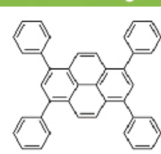
Ambipolar Semiconductors

B4361 1g



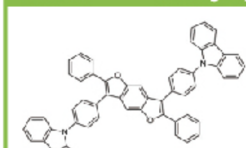
Bis(4-dimethylaminodithiobenzil)nickel(II)
CAS RN : 38465-55-3

T3042 50mg / 200mg



1,3,6,8-Tetraphenylpyrene
CAS RN : 13638-82-9

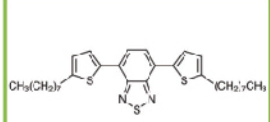
C2780 200mg / 1g



CZBDF
CAS RN : 1092578-51-2

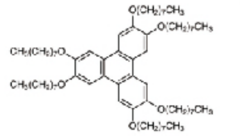
Liquid Crystalline Semiconductors

B4683 200mg



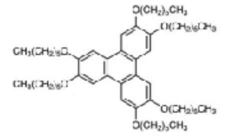
4,7-Bis(5-n-octyl-2-thienyl)-2,1,3-benzothiadiazole
CAS RN : 1171974-28-9

H1450 200mg / 1g



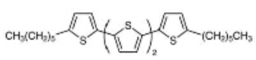
2,3,6,7,10,11-Hexakis[(n-octyl)oxy]triphenylene
CAS RN : 70351-87-0

H1449 200mg / 1g



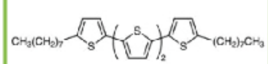
2,3,6,7,10,11-Hexakis(hexyloxy)triphenylene
CAS RN : 70351-86-9

D4842 100mg



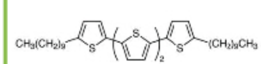
5,5'''-Dihexyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 132814-92-7

D4877 100mg



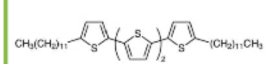
5,5'''-Di-n-octyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 882659-01-0

D4888 100mg



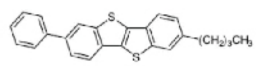
5,5'''-Didecyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 514188-77-3

D4889 100mg



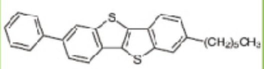
5,5'''-Didodecyl-2,2':5',2'':5'',2'''-quaterthiophene
CAS RN : 153561-79-6

B6248 100mg / 250mg / 1g



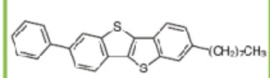
2-Butyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1781261-91-3

H1769 100mg / 250mg / 1g



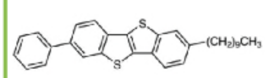
2-Hexyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1781261-93-5

O0576 100mg / 250mg / 1g



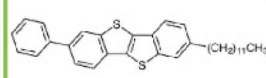
2-Octyl-7-phenyl-benzo[d][1]benzothieno[3,2-b]thiophene [for organic electronics]
CAS RN : 1781261-95-7

D5491 100mg / 250mg / 1g



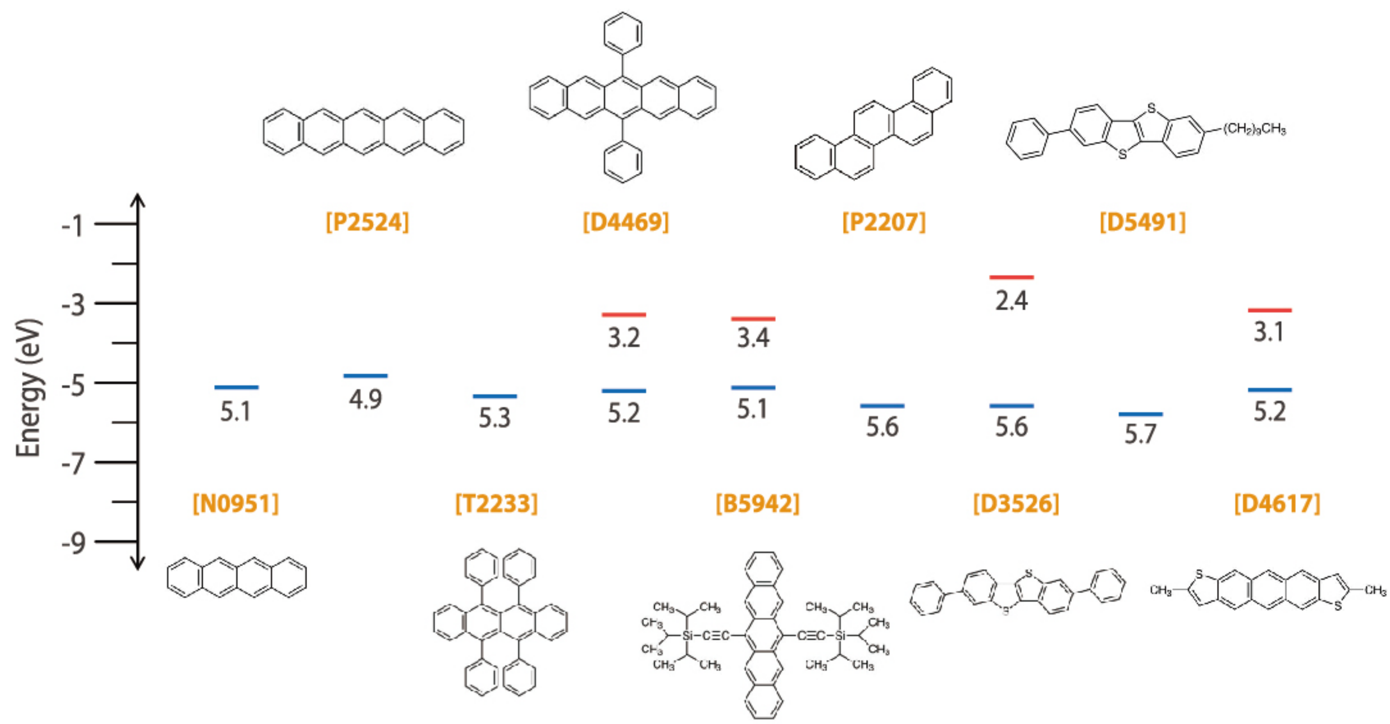
2-Decyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1398395-83-9

D5910 100mg / 250mg / 1g

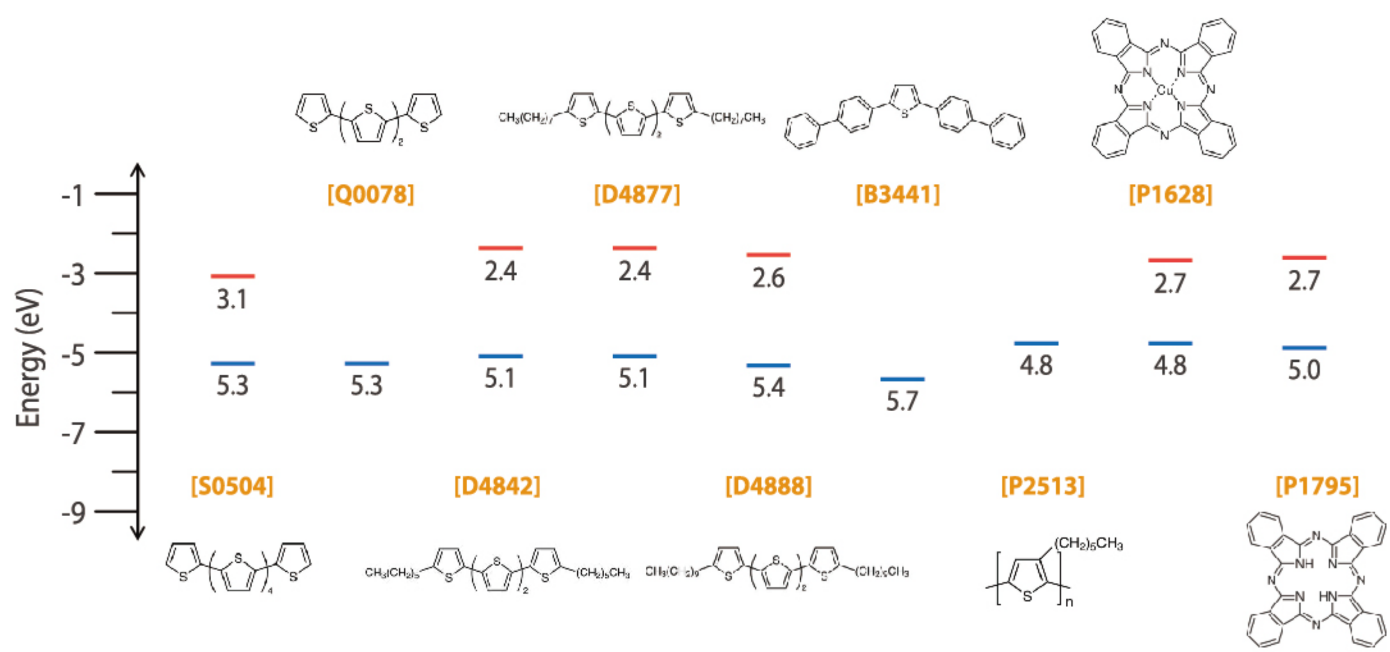


2-Dodecyl-7-phenyl[1]benzothieno[3,2-b][1]benzothiophene [for organic electronics]
CAS RN : 1627606-00-1

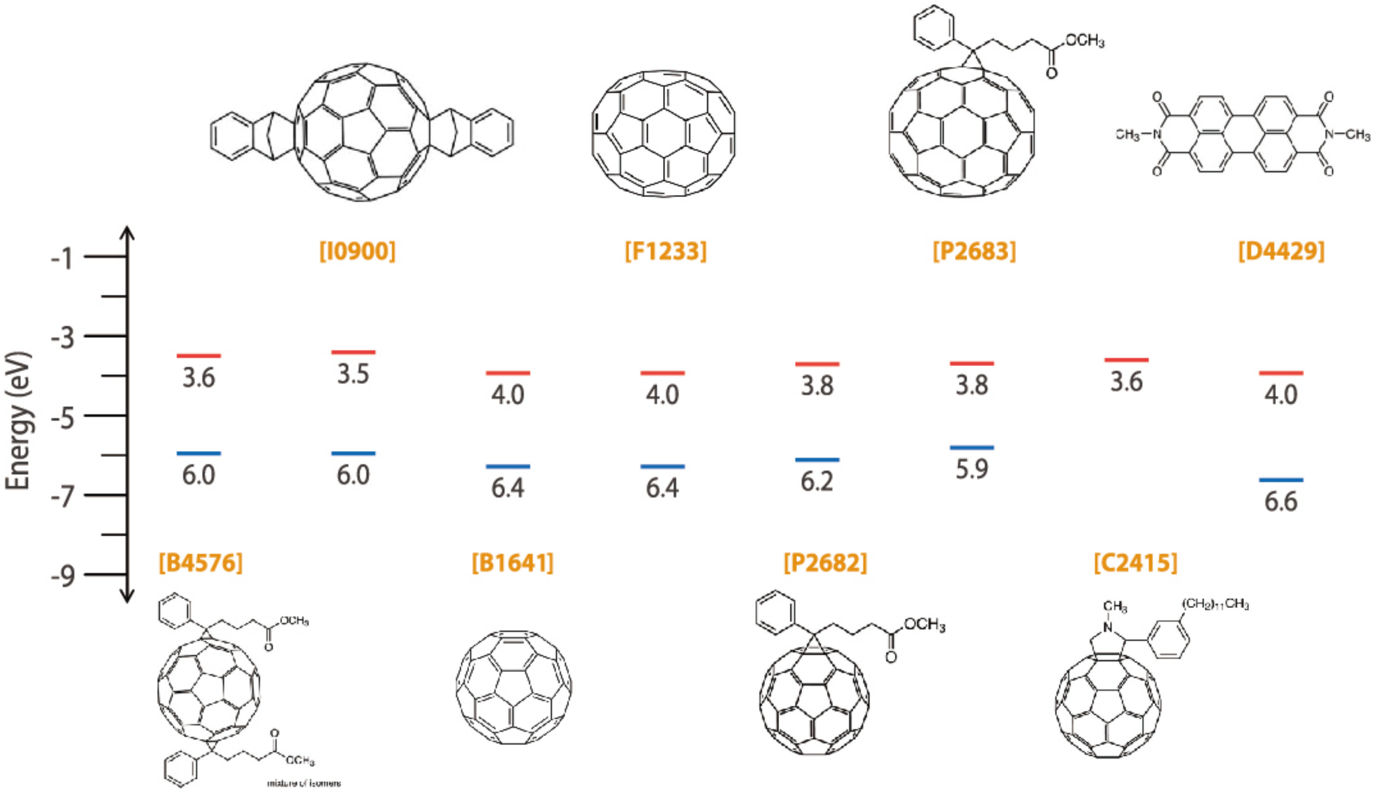
Energy level of materials (HOMO, LUMO)



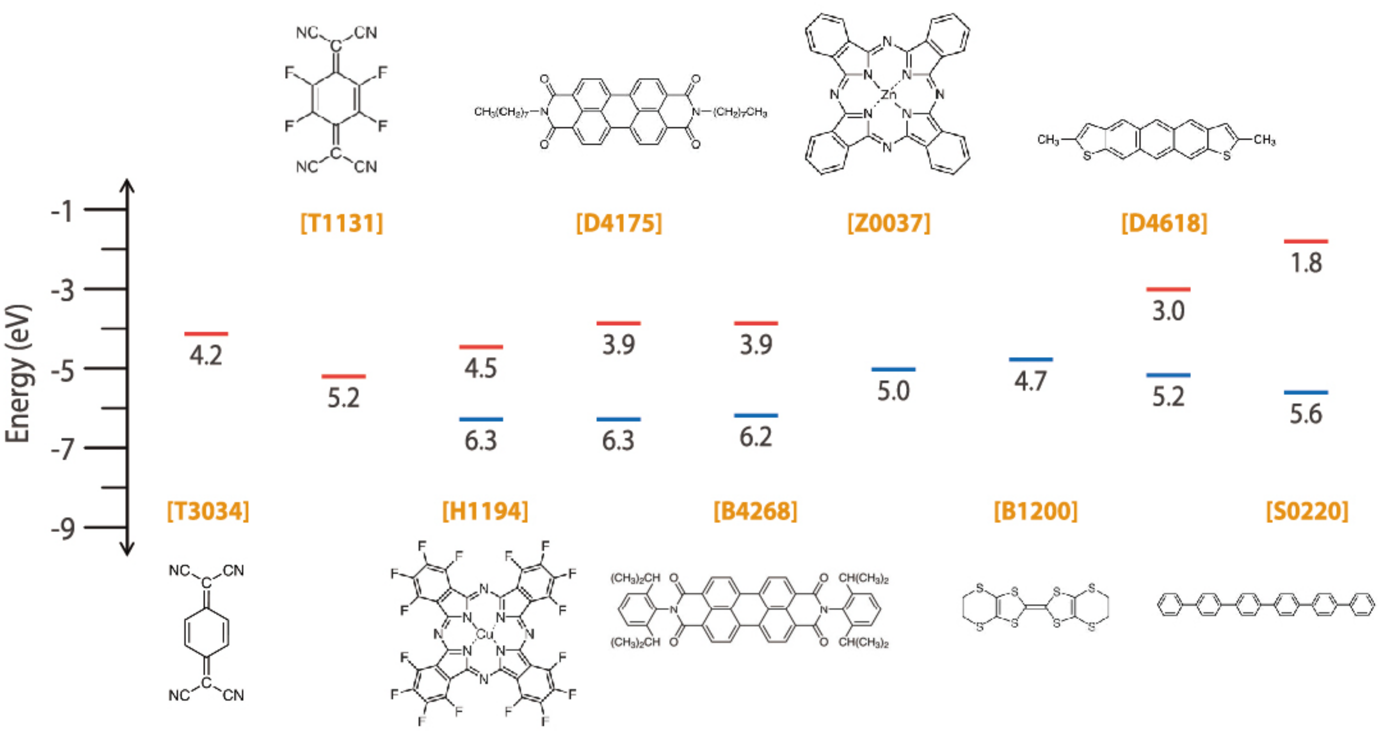
Energy level of materials (HOMO, LUMO)



Energy level of materials (HOMO, LUMO)



Energy level of materials (HOMO, LUMO)



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