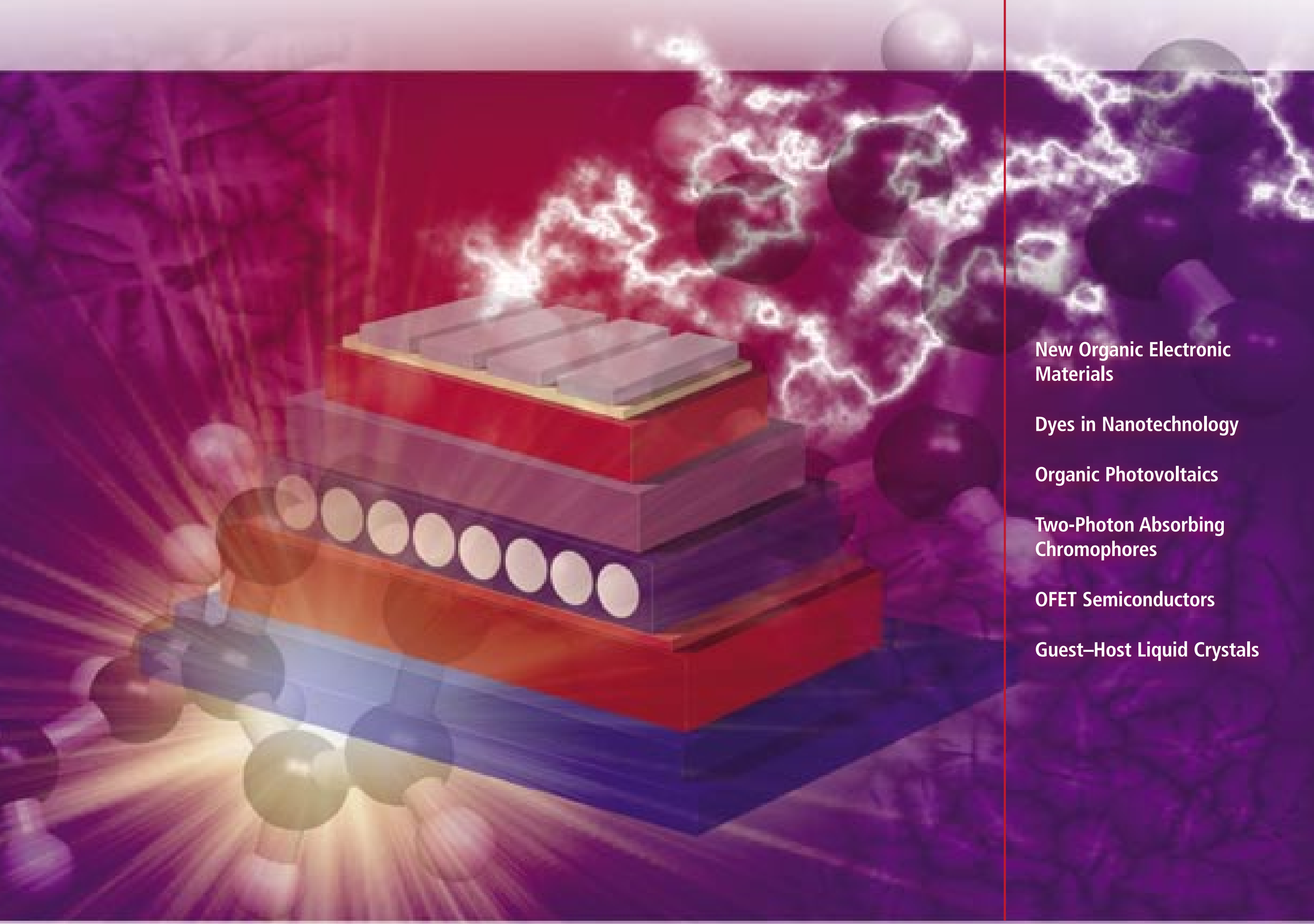
ChemFiles

Vol. 5 No. 8

Organic Electronic Materials



- New Organic Electronic Materials
- Dyes in Nanotechnology
- Organic Photovoltaics
- Two-Photon Absorbing Chromophores
- OFET Semiconductors
- Guest–Host Liquid Crystals

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Introduction

Welcome to Sigma-Aldrich's product guide, **Organic Electronic Materials**. Customers familiar with our materials science *ChemFiles* brochures may have noticed a new feel starting this year with **Nanomaterials for Advanced Applications**. In addition to our product and property tables and our featured new products, we include reviews from researchers in relevant technological fields. Our mission at Sigma-Aldrich is to inspire and advance your research. I hope that by highlighting the innovations of authors featured in this *ChemFiles*, you can generate the next ideas to significantly impact the field of organic electronics.

Organic electronics is the study of how semiconducting small molecules and polymers can be engineered to replace electronic components in micro- and nanoelectronic devices. A key driver for this activity is that, unlike traditional inorganic semiconducting materials, organic electronic materials may be processed at low temperatures with techniques such as ink-jet printing, solution phase processing, or vacuum deposition. Imagine a computer being printed on a thin flexible surface, this is the ultimate goal of organic electronics research. In addition, organic electronic components may have physical properties tailored through the chemistry of the material, avoiding multiple processing steps of current semiconductor manufacturing. Because of Sigma-Aldrich's expertise in dye technology, we offer a wide range of products and services to meet your needs.

Products in this brochure may be used for research in organic field effect transistor (OFET) research, photovoltaic applications, photonics, non-linear optics, IR shielding, displays, and molecular electronics. This brochure may be used in conjunction with *ChemFiles* Vol 4. No. 6 for our complete line of organic semiconducting products. For your convenience, when you find the product you need, simply go to **sigma-aldrich.com/matsci** for pricing, availability, and more details.

I would like to thank the contributors to this issue for their excellent reviews: **Prof. Ghassan Jabbour** of the Flexible Display Center at Arizona State University; **Prof. Seth Marder**, Director, Center for Organic Photonics and Electronics, Georgia Institute of Technology; **Prof. Dan Frisbie**, Department of Chemical Engineering and Materials Science, University of Minnesota; and **Dr. Bahman Taheri** of AlphaMicron Inc.

Sincerest Regards,

Sean D Dingman

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Product Manager, Materials Science
Sigma-Aldrich Corporation

Organic Semiconductors:

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With over 1000 products and over 50 years of experience in small-molecule and dye chemistry, we can advance your materials science research with:

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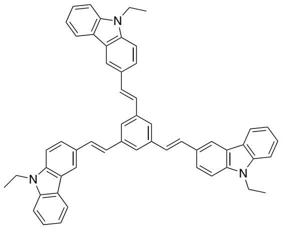
Contact the Materials Science Team at **matsci@sial.com**.

New Products for Organic Electronics

1,3,5-Tris(2-(9-ethylcabazyl-3)ethylene)benzene NEW

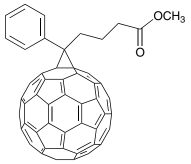
TECEB
$C_{54}H_{45}N_3$
FW: 735.95
[*848311-04-6*]
$\lambda^{max}_{(abs)}$: ~350 nm
A single-source white-light emitting molecule for OLED/lighting applications.[1]



661732-500MG	500 mg

(6,6)-Phenyl-C61 butyric acid methyl ester NEW

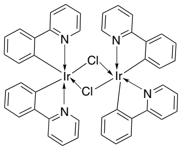
PCBM
$C_{72}H_{14}O_2$
FW: 910.88
[*161196-25-4*]
A key *n*-channel semiconducting material.[2]



659169-100MG	100 mg

Dichlorotetrakis(2-(2-pyridinyl)phenyl)diiridium(III) NEW

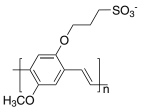
$Ir_2Cl_2(ppy)_4$
$C_{44}H_{32}Cl_2Ir_2N_4$
FW: 1072.09
[*92220-65-0*]
A precursor to several iridium-containing triplet-emitting molecules.[3]



658383-100MG	100 mg
658383-500MG	500 mg

Poly[5-methoxy-2-(3-sulfopropoxy)-1,4-phenylene-vinylene], Potassium salt solution, 0.25 wt. % in water NEW

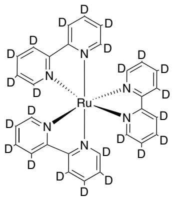
MPS-PPV
$(C_{12}H_{13}KO_5S)_n$
A water-soluble PPV



659894-10ML	10 mL

Tris(2,2'-bipyridyl-d$_8$)ruthenium(II) hexafluoro-phosphate, 95% NEW

$C_{30}D_{24}F_{12}N_6P_2Ru$
FW: 883.7
[*67573-02-8*]
$\lambda^{max}_{(abs)}$: 285 nm
A high-efficiency triplet emitter



652407-100MG	100 mg
652407-500MG	500 mg

References

(1) Yan, J.; Liu, D.; Ma, C.; Lengyel, O.; Lee, C.; Tung, C.; Lee, S. *Adv. Mater.* **2004**, *16*, 1538.

(2) Meijer, E.; De Leeuw, D.; Setayesh, S.; van Veenendaal, E.; Husimanm B.; Blom. P.; Hummelen, J.; Scherf, U.; Klapwijk, T. *Nat. Mater.* **2003**, *2*, 678.

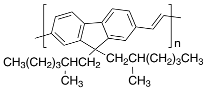
(3) Lowry, M.; Hudson, W.; Pascal, R.; Bernhard, S. *J. Am. Chem. Soc.* **2004**, *126*, 14129.

NEW High Efficency Blue-Green Light Emitting Polymers

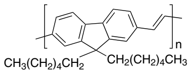
Sigma-Aldrich is pleased to introduce these new light-emitting polymers, first described by Jin.[1] The polyfluorene-vinylenes (PFVs) exhibit blue luminescence with red shifting due to the addition of the vinylene and MEHPV units. The co-polymers exhibit a very high brightness and luminescence efficiency. The table below shows the percent composition of the polymers and co-polymers with their optical properties. To learn more, visit **sigma-aldrich.com/matsci**.

(1) Jin, S.; Kang, S.; Kim, M.; Chan, Y.; Kim, J.; Lee, K.; Gal, Y. *Macromolecules* **2003**, *36*, 3841.

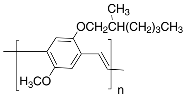
Name	**Abbr.**	**DEH-PFV**	**DH-PFV**	**MEH-PPV**	$\lambda^{max}_{(abs)}$ **nm**	$\lambda^{max}_{(emm)}$ **nm solu.**	$\lambda^{max}_{(emm)}$ **nm film**	T_g	**Cat. No.**
Poly(9,9-(di-2-ethylhexyl)-9*H*-fluorene-2,7-diyl)	DEH-PFV	100			417	463	507	173	656267-500MG
Poly(9,9-(di-2-ethylhexyl)-9*H*-fluorene-2,7-diyl)-co-(1-methoxy-4-(2-ethylhexyloxy)-2,5-phenylenevinylene)]	DEH-PFV MEH-PPV	95		5	415	463	576	176	656224-500MG
Poly(9,9-(di-2-ethylhexyl)-9*H*-fluorene-2,7-diyl)-co-(1-methoxy-4-(2-ethylhexyloxy)-2,5-phenylenevinylene)]	DEH-PFV MEH-PPV	90		10	418	463	580	170	656232-500MG
Poly(9,9-(dihexyl)-9*H*-fluorene-2,7-diyl)-co-(1-methoxy-4-(2-ethylhexyloxy)-2,5-phenylenevinylene)]	DH-PFV MEH-PPV		95	5	—	—	—	—	656208-500MG
Poly(9,9-(dihexyl)-9*H*-fluorene-2,7-diyl)-co-(1-methoxy-4-(2-ethylhexyloxy)-2,5-phenylenevinylene)]	DH-PFV MEH-PPV		90	10	—	—	—	—	656194-500MG



DEH-PFV



DH-PFV



MEH-PPV

Dyes in Nanotechnology

Sean Dingman, Ph.D.
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Milwaukee, Wisconsin

Dye technology dates back to ancient China, while medieval European alchemists used gold colloids for their mystical endeavors. These technologies create exciting and innovative science today. A review of recent literature shows that combinations of dyes and nanomaterials give material properties that are more than the sum of their parts.

Ichinose describes a process for making nano-scaled strands of cadmium hydroxide that exhibit a large positive surface charge. The nanostrands interact with anionic dyes like Evans Blue (**206334**), Congo Red (**318825**), Direct Yellow 50 (**201898**), and DATS (**5021**). The interaction leads to the spontaneous formation of a nanocomposite, where the dyes act as *molecular fasteners* between the $Cd(OH)_2$ and the strand.[1] The dyes take the place of surfactants typically used to separate and disperse nano-scaled materials. Since the dyes are polyanionic, several nanostrands are attracted together and linked by the dyes, providing for the formation of multilayered nanofibers with interesting optical properties.

Nolte[2] reports a method of constructing layers for liquid crystal-based solar cells and sensors. The technique involves self-assembly of molecules like phenyltriethoxysilane (**175609**) or 3-aminopropyltriethoxysilane (**440140**) on ITO substrates (e.g., **578274**). The self-assembled molecules are functionalized to contain a Lewis base moiety that coordinates to zinc-pthalocyanine dyes (**459720**), amplifying the ordering of the liquid crystal. Properties of the nano-layered structure are tuned by changing the height of the stacks.

No review of nanotechnology would be complete without including carbon nanotubes. Mao[3] and co-workers report the interaction of methylene blue (MB) dye (**M44907**) and single-walled carbon nanotubes (SWNT, **519308**). MB exhibits a flat, polyene structure and is attracted to the graphene structure of a SWNT through π–π interactions. The resulting composite exhibits charge-transfer properties where MB is the electron acceptor and the SWNT is the electron donor. Furthermore, the MB allows for the SWNT to become water-soluble without covalently functionalizing the nanotube. This processable, electrochemically active SWNT is ready for photovoltaic and biosensor applications.

Other dye/nano applications include dyes acting as molecular switches on semiconductor quantum dots[4] and dye/silica nanoparticles as non-toxic quantum dots for biofluorescence.[5] This review only scratches the surface of potential synergies of dye chemistry and nanotechnology. We at Sigma-Aldrich are eager to see your innovations in the literature soon.

References

(1) Luo, Y. H.; Huang, J.; Ichinose, I. *J. Am. Chem. Soc.* **2005**, *127*, 8296.

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(4) Zhu, L.; Zhu, M.; Hurst, J.; Li., A *J. Am. Chem. Soc.* **2005**, *127*, 8968.

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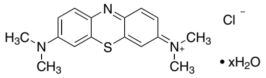
Methylene Blue Trihydrate

$C_{16}H_{18}ClN_3S \cdot 3H_2O$
FW: 373.90
[7220-79-3]
$\lambda^{max}_{(abs)}$: 661 nm



M44907-2G	2 g
M44907-100G	100 g
M44907-500G	500 g

Organic Photovoltaics

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Flexible Display Center
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Solar energy technology holds great promise for providing significant energy from the most prominent renewable source, the sun. The ongoing development and use of novel organic semiconductors enables the fabrication of relatively efficient photovoltaic devices, also known as solar cells. The use of organic semiconducting materials allows for manufacturing photovoltaics by low-cost, high-throughput fabrication techniques such as printing[1] and roll-to-roll manufacturing. Organic photovoltaics can also provide low-cost, lightweight, and even flexible devices, allowing them to be incorporated in a variety of places, such as window coatings, wallpapers,[2] and even fabric and clothing.

An organic solar cell functions via four key mechanisims: absorption of light, generation of free charges, transportation of these photogenerated charge carriers, and collection at the respective electrodes. While careful design and device engineering contribute greatly to the optimization of the cell, the overall efficiency is fundamentally dependent upon the amount of incident light that can be absorbed, driving the need for strongly absorbing dyes with broad spectral ranges. In addition to specifically tailored band gaps for absorption purposes, dye molecules may also be responsible for charge transport, either as the sole transport medium or as a dopant, increasing conductivity.

Studies of photovoltages in organic thin-films began in the 1950s. By the 1970s, significant progress was made toward developing organic solar cells. These first devices consisted of metal-insulator-semiconductor (MIS) or Schottky barrier structures, commonly incorporating squarylium or merocyanine dyes.[3] Anthracene, phthalocyanine, porphyrin, and perylene devices soon followed and, in 1986, C. W. Tang developed a cell with 1% power efficiency. The device possessed an organic bilayer structure using copper phthalocyanine (**CuPc, 546682**) and a perylene derivative, mimicking a *p-n* junction. Today phthalocyanines are among the most commonly utilized molecular materials for organic solar cells, often coupled with some sort of fullerene.

Dye-sensitized cells are a key technology derived from dye-based photovoltaics.[4] Currently these devices outperform their solid-state organic counterparts with power efficiencies of ~10%. The device structure is composed of a nanoporous oxide (such as TiO_2 or ZnO), coated with a monolayer of a sensitizing dye. The most common dye used is N3 dye, *cis*-$Ru(SCN)_2L_2$ (L = 2,2-bipyridyl-4,4-dicarboxylate). The dye is responsible for light absorption, injecting charge into the oxide that is transported to an electrode. An electrolyte redox reaction replenishes the dye with electrons and the electrolyte solution carries positive charges to the counter-electrode. The high power conversion of such devices can be attributed to the enormous surface area of the nanoporous electrode.

In conclusion, novel dye materials have the potential to greatly enhance the performance of all kinds of organic photovoltaic devices: small molecule, polymer, and dye-sensitized cells or other types of organic–inorganic hybrids, providing a broadened spectral response and/or improved transport properties.

References

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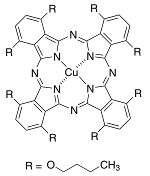
Copper(II) 1,4,8,11,15,18,22,25-octabutoxy-29*H*,31*H*-phthalocyanine, Dye content 95%

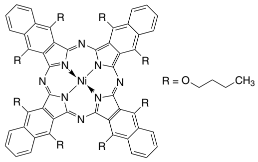
$C_{64}H_{80}CuN_8O_8$
FW: 1152.91
[*107227-88-3*]
$\lambda_{(abs)}^{max}$: 740 nm



386618-50MG	50 mg
386618-250MG	250 mg

Nickel(II) 5,9,14,18,23,27,32,36-octabutoxy-2,3-naphthalocyanine, Dye content 98%

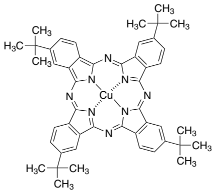
$C_{80}H_{88}N_8NiO_8$
FW: 1348.30
[*155773-70-9*]
$\lambda_{(abs)}^{max}$: 848 nm



418854-25MG	25 mg
418854-100MG	100 mg

Copper(II) 2,9,16,23-tetra-*tert*-butyl-29*H*,31*H*-phthalocyanine, Dye content 97%

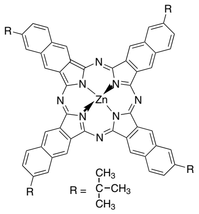
$C_{48}H_{48}CuN_8$
FW: 800.49
[*39001-64-4*]
$\lambda_{(abs)}^{max}$: 672 nm



423165-250MG	250 mg
423165-1G	1 g

Zinc 2,11,20,29-tetra-*tert*-butyl-2,3-naphthalocyanine, Dye content 90%

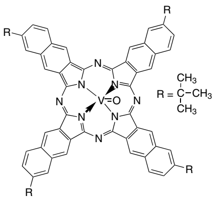
$C_{64}H_{56}N_8Zn$
FW: 1002.57
[*39049-43-9*]
$\lambda_{(abs)}^{max}$: 769 nm



432210-50MG	50 mg
432210-250MG	250 mg

Vanadyl 2,11,20,29-tetra-*tert*-butyl-2,3-naphthalocyanine, Dye content 95%

$C_{64}H_{56}N_8OV$
FW: 1004.12
[*105011-00-5*]
$\lambda_{(abs)}^{max}$: 808 nm

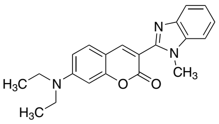


432962-100MG	100 mg
432962-500MG	500 mg

Organic Photovoltaic Materials

Coumarin 30, dye content 99%

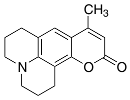
$C_{21}H_{21}N_3O_2$
FW: 347.41
[*41044-12-6*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 413 nm



546127-100MG	100 mg

Coumarin 102, dye content 99%

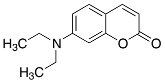
$C_{16}H_{17}NO_2$
FW: 255.31
[*41267-76-9*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 390 nm



546151-100MG	100 mg

Coumarin 110, dye content 99%

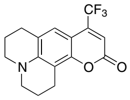
$C_{13}H_{14}NO_2$
FW: 216.26
[*20571-42-0*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 377 nm



546178-100MG	100 mg

Coumarin 153, dye content 98%

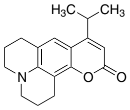
$C_{16}H_{14}F_3NO_2$
FW: 309.28
[*53518-18-6*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 422 nm



546186-100MG	100 mg

Coumarin 480 D, dye content 99%

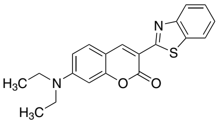
$C_{18}H_{21}NO_2$
FW: 283.36
[*171615-15-9*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 392 nm



546232-100MG	100 mg

Coumarin 6, ≥99%

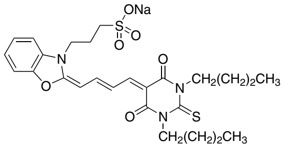
$C_{20}H_{18}N_2O_2S$
FW: 350.43
[*38215-36-0*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 457 nm



546283-100MG	100 mg

Merocyanine 540, dye content 90%

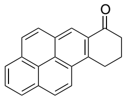
$C_{26}H_{32}N_3NaO_6S_2$
FW: 569.67
[*62796-23-0*]
$\lambda^{\text{max}}_{\text{(abs)}}$: 555 nm



323756-100MG	100 mg
323756-250MG	250 mg

9,10-Dihydrobenzo[*a*]pyrene-7(8*H*)-one, 97%

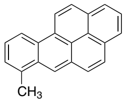
$C_{20}H_{14}O$
FW: 270.32
[*3331-46-2*]



180610-500MG	500 mg
180610-1G	1 g

7-Methylbenzo[*a*]pyrene, 98%

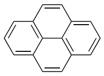
$C_{21}H_{14}$
FW: 266.34
[*63041-77-0*]



380903-100MG	100 mg
380903-500MG	500 mg

Pyrene, sublimed, 99%

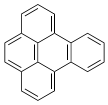
$C_{16}H_{10}$
FW: 202.25
[*129-00-0*]



571245-500MG	500 mg
571245-1G	1 g

Benzo[e]pyrene, 99%

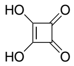
$C_{20}H_{12}$
FW: 252.31
[*192-97-2*]



B10102-25MG	25 mg
B10102-100MG	100 mg

3,4-Dihydroxy-3-cyclobutene-1,2-dione, 99%

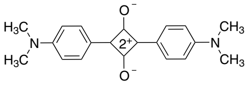
$C_4H_2O_4$
FW: 114.06
[*2892-51-5*]



123447-5G	5 g
123447-25G	25 g
123447-100G	100 g

1,3-Bis[4-(dimethylamino)phenyl]-2,4-dihydroxycyclobutenediylium dihydroxide, bis(inner salt), dye content 90%

$C_{20}H_{20}N_2O_2$
FW: 320.39
[*43134-09-4*]



149063-1G	1 g

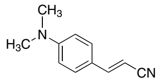
IR Dyes

Name	Dye Content	Formula Wt. (g/mol)	CAS Number	$\lambda^{max}_{(abs)}$ nm	Cat. No.
IR-140	95%	779.19	*53655-17-7*	823	260932-100MG 260932-500MG
IR-1061	80%	749.13	*155614-01-0*	1061	405124-50MG 405124-250MG
IR-1040	95%	790.78	*155614-04-3*	1040	405132-50MG 405132-250MG
IR-1100	95%	838.78	*155614-03-2*		405140-50MG 405140-250MG
IR-1050	97%	753.93	*155614-00-9*	1048	405183-100MG 405183-500MG
IR-27	99%	677.57	*83592-28-3*	988	406104-25MG 406104-100MG
IR-676 iodide	97%	610.57	*56289-64-6*	676	477508-1G
IR-775 chloride	~90%	519.55	*199444-11-6*	775	544914-250MG
IR-797 chloride	80%	505.52	*110992-55-7*	797	642339-250MG
IR-813 perchlorate	80%	683.66	—	813	642347-250MG

Non-Linear Optical Chromophores

4-(Dimethylamino)cinnamonitrile, mixture of *cis* and *trans*, 98%

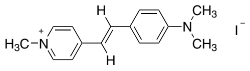
$C_{11}H_{12}N_2$
FW: 172.23
[*32444-63-6*]



145556-5G	5 g
145556-25G	25 g

trans-4-[4-(Dimethylamino)styryl]-1-methylpyridinium iodide, dye content 98%

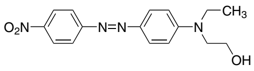
$C_{16}H_{19}IN_2$
FW: 366.24
[*68971-03-9*]
$\lambda^{max}_{(abs)}$: 475 nm



336408-1G	1 g
336408-5G	5 g

Disperse Red 1, dye content 95%

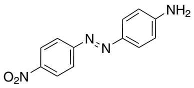
$C_{16}H_{18}N_4O_3$
FW: 314.34
[*2872-52-8*]
$\lambda^{max}_{(abs)}$: 502 nm



344206-5G	5 g
344206-25G	25 g

Disperse Orange 3, dye content 90%

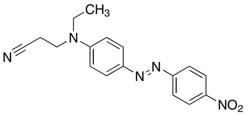
$C_{12}H_{10}N_4O_2$
FW: 242.23
[*730-40-5*]
$\lambda^{max}_{(abs)}$: 443 nm



364797-5G	5 g
364797-25G	25 g

Disperse Orange 25, dye content 95%

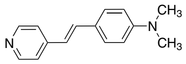
$C_{17}H_{17}N_5O_2$
FW: 323.35
[*31482-56-1*]
$\lambda^{max}_{(abs)}$: 457 nm



364819-1G	1 g
364819-5G	5 g

4-[4-(Dimethylamino)styryl]pyridine, 95%

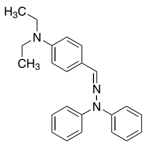
$C_{15}H_{16}N_2$
FW: 224.30
[*889-36-1*]
$\lambda^{max}_{(abs)}$: 377 nm



394211-250MG	250 mg
394211-1G	1 g

4-(Diethylamino)benzaldehyde diphenylhydrazone, 97%

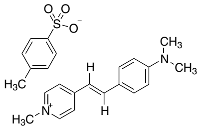
$C_{23}H_{25}N_3$
FW: 343.46
[*68189-23-1*]



462438-1G	1 g
462438-25G	25 g

trans-4-[4-(Dimethylamino)styryl]-1-methylpyridinium *p*-toluenesulfonate, 98%

$C_{23}H_{26}N_2O_3S$
FW: 410.53
[*80969-52-4*]
$\lambda^{max}_{(abs)}$: 475 nm



514160-5G	5 g

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Two-Photon Absorbing Chromophores

Seth R. Marder and Joseph W. Perry
Department of Chemistry and BioChemistry
Georgia Institute of Technology, Atlanta, Georgia
and Focal Point Microsystems, Atlanta, Georgia

Under normal conditions, the probability of a dye molecule absorbing one photon of light is linearly proportional to the intensity of the input beam. However, with sufficiently intense light, such as that of a laser beam, it is possible for a dye molecule to absorb two photons, each approximately half the energy normally required to reach an excited state. This two-photon absorption (TPA) process is intrinsically weak under normal light intensities relative to one-photon excitation. The probability of a molecule absorbing two photons simultaneously is proportional to the square of the intensity of the input beam.

Two-photon absorption allows for the excitation of molecules with precise three-dimensional (3D) spatial confinement. This 3D control of excitation arises from the fact that the intensity of a focused laser beam decreases quadratically with distance from the focal plane. Since the probability of TPA is proportional to the square of the intensity, TPA falls off as the fourth power of the distance from the focus, so TPA is negligible at distances appreciably above and below the focal plane. TPA allows for the excitation of dye molecules imbedded in a normally absorbing medium since the target molecules can be selectively excited with photon energies below the single-photon absorption energies of the medium.

Attempts to utilize TPA in various applications have been somewhat limited because the chromophores used were developed for one-photon excitations and exhibit rather low efficiencies for absorbing two photons, called the TPA cross section (δ). The development of molecules with large δ[1] would decrease the need for very high power lasers, making TPA applications more reliable and more economically feasible. Dyes with large δ are currently in demand for a variety of applications including two-photon excited fluorescence microscopy[2] and three-dimensional microfabrication.[3–5] The key to the design of molecules with high sensitivity to TPA is an understanding of how δ depends on molecular structure. In 1998, we reported that π-conjugated molecules, which undergo large changes of quadrupole moment upon excitation, often exhibit large δ.[1] Dye molecules with donor-π-donor (**Figure 1**), donor-acceptor-donor (D-A-D), and acceptor-donor-acceptor (A-D-A) structural motifs exhibit exceptionally large values.[5]

Two-Photon Initiated Chemistry

TPA provides a means of activating chemical or physical processes with high spatial resolution in three dimensions and has enabled the development of 3D optical data storage. TPA also enables 3D lithographic microfabrication using both negative-tone and positive-tone resists. Under tight-focusing conditions, the absorption is confined at the focus to a volume of order λ^3, where λ is the laser wavelength, resulting in a volume element that can be routinely 1 μm^3 or smaller. Under appropriate conditions, subsequent chemical reactions, such as photo-initiated polymerization can be localized in this small volume. Two-photon excitable resins incorporating high δ molecules as initiators have been used to demonstrate two-photon-induced polymerization (TPIP) with an order-of-magnitude increase in photosensitivity relative to commercial resins.

High-sensitivity TPIP resins can be employed for 3D lithographic microfabrication (3DLM).[5] In negative-tone implementation of 3DLM, photoexcitation initiates a cross-linking reaction in the photopolymer resin, reducing the solubility of the exposed material. In this process, an arbitrary 3D pattern is impressed into a photopolymer by scanning the focus of an intense laser beam within the material. The exposed 3D pattern is developed to give a freestanding 3D microstructure by dissolving away the unexposed material in a single exposure/development cycle. The 3DLM approach can be used to produce a variety of 3D microstructures such as integrated optical elements and micromechanical structures. The three-dimensionally periodic structures such as the "stack-of-logs" structure (**Figure 2**) are of interest as photonic bandgap materials. The 3DLM technique is robust and being developed commercially by Focal Point Microsystems, L.L.C. (fpmicro.com) of Atlanta, GA. Focal Point Microsystems develops instrumentation and materials for 3DLM and provides custom microfabrication services.

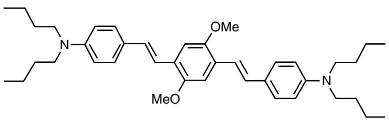


Figure 1. Example of a donor-π-donor two-photon absorbing chromophore with a large cross section.

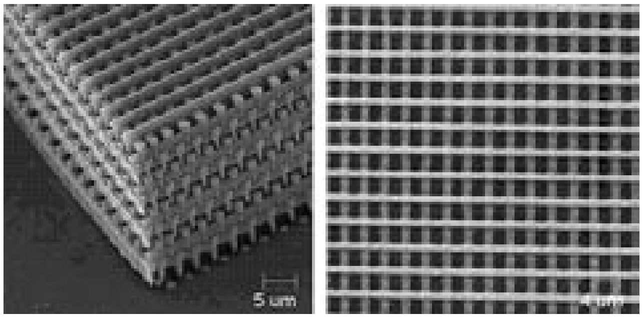


Figure 2. Two views of a photonic crystal lattice fabricated by two-photon microfabrication.

References

(1) Albota, M. et al. *Science* **1998**, *281*, 1653.

(2) Denk, W.; S *Science* **1990**, *248*, 73.

(3) Strickler, J. H.; Webb, W. W. *Proc. SPIE* **1990**, *1398*, 107.

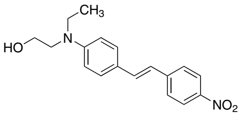
(4) Maruo, S.; Nakamura, O.; Kawata, S. *Opt. Lett.* **1997**, *22* 132.

(5) Cumpston, B. H. et al. *Nature* **1999**, *398*, 51.

Related Products

2-[Ethyl[4-[2-(4-nitrophenyl)ethenyl]phenyl]amino]ethanol, 98%

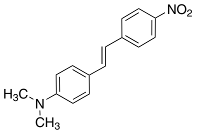
$C_{18}H_{20}N_2O_3$
FW: 312.36
[*122258-56-4*]



518565-250MG	250 mg

4-Dimethylamino-4′-nitrostilbene, 97%

$C_{16}H_{16}N_2O_2$
FW: 268.31
[*2844-15-7*]



538477-500MG	500 mg

Organic Field Effect Transistors

Professor Dan Frisbie
Crystalline Organic Semiconductors Interdisciplinary Research Group
University of Minnesota, Minneapolis, Minnesota

Progress toward realizing practical, low-cost plastic electronics hinges significantly on cutting-edge research to speed up the charge carriers in organic semiconductors. Although it is uncertain just how pervasive organic semiconductor technology will become, the potential for new products, such as electronic paper, smart labels, flexible flat-panel displays, solar cells, and solid-state lighting is clearly very exciting.

Our research group focuses on understanding how the structure of organic semiconductors determines the charge carrier velocity. Broad ranging expertise of seven collaborating faculty members in molecular synthesis, electrical transport measurements, spectroscopy, and computation is brought to bear on the design and characterization of new organic semiconductor materials. Twin goals are to define structure–property relationships and to maximize electron and hole mobilities for applications in field effect transistors (FETs) that could some day be used in printed plastic circuitry.

Learning how to make charges move faster in organic materials is basic research with a potentially big payoff. Room temperature hole mobilities for thin films of pentacene (**P1802**) are now ~1 cm^2/Vs, comparable to the electron mobilities achieved in amorphous hydrogenated silicon, a commercially successful thin film semiconductor material. However, it is desirable to have even higher mobilities in organic semiconductors. It is also desirable to discover new *n*-channel, or electron conducting organic semiconductor materials, so that so-called complementary circuits can be made employing both *p*- and *n*-channel organic semiconductors. Other important figures of merit for organic semiconductors include the threshold voltage, the on-to-off current ratio, and operational and environmental stability.

At the core of organic electronics are many fundamental questions about how to design and assemble molecular solids, and about the connection between electronic delocalization and crystal structures. Answering these questions requires determination of structure–property relationships. While there are generally accepted notions about what is important for electrical conduction, e.g., electronic delocalization based on strength and symmetry of intermolecular interactions, the ramifications of these ideas in molecular materials are only just emerging, making organic electronics an exciting area for current research.

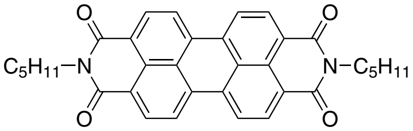


Figure 1. Molecular Structure of a dialkyl-substitituted perylene diimide, which functions as an *n*-channel organic semiconductor in OFETs.

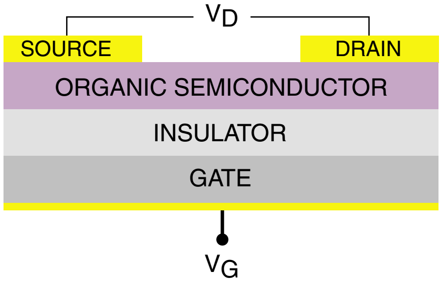


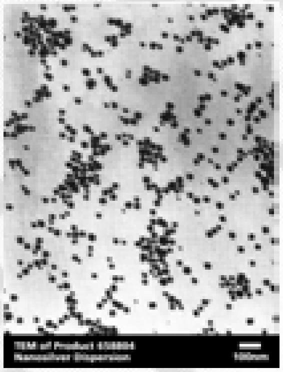
Figure 2. Geometry of an organic field effect transistor (OFET). The voltage on the gate, VG, controls the current that flows from source to drain electrode.

Nanoparticle Dispersions

Proprietary surfactants are used to maintain an evenly dispersed suspension ideal for forming thin films and homogeneous composites.

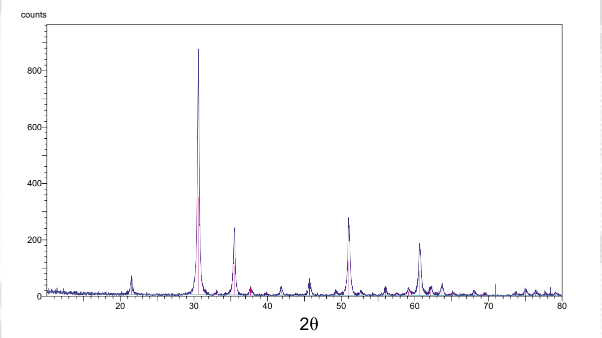
658804 Silver, nanoparticles,
10 wt. % dispersion in ethylene glycol

- Conductive coatings
- Conductive polymer matrixes[1]
- Fluorescent dispersions[2]
- Antimicrobial applications



657212 Indium tin oxide, nanoparticles,
25 wt. % dispersion in isopropanol

- Antistatic coatings
- Transparent, conductive coatings



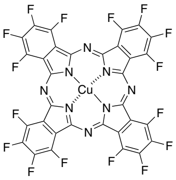
XRD of indium tin oxide (90:10)

(1) Lee, H.-H. et al. *Int. J. Adhesion Ahesives* **2005**, *25*, 437. (2) Treguer, M. et al. *Solid State Sci.* **2005**, *7*, 812.

Organic Field Effect Transistor Semiconductors

Copper(II) 1,2,3,4,8,9,10,11,15,16,17,18,22,23,24,25-hexadecafluoro-29*H*,31*H*-phthalocyanine, Dye content 80%

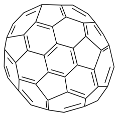
$C_{32}CuF_{16}N_8$
FW: 863.92
[*14916-87-1*]
$\lambda^{max}_{(abs)}$: 689 nm



446653-250MG	250 mg
446653-1G	1 g

[5,6]-Fullerene-C70, 99%

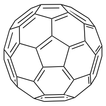
C_{70}
FW: 840.75
[*115383-22-7*]



482994-10MG	10 mg
482994-50MG	50 mg

Fullerene-C60, sublimed, 99.9%

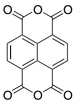
C_{60}
FW: 720.64
[*99685-96-8*]



572500-25MG	25 mg
572500-100MG	100 mg
572500-500MG	500 mg

1,4,5,8-Naphthalenetetracarboxylic dianhydride

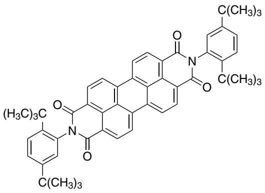
$C_{14}H_4O_6$
FW: 268.18
[*81-30-1*]



N818-5G	5 g
N818-25G	25 g
N818-100G	100 g

N,*N*′-Bis(2,5-di-*tert*-butylphenyl)-3,4,9,10-perylenedicarboximide, Dye content 97 %

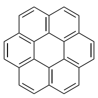
$C_{52}H_{50}N_2O_4$
FW: 766.96
[*83054-80-2*]
$\lambda^{max}_{(abs)}$: 528 nm



264229-100MG	100 mg

Coronene, purified by sublimation, 99%

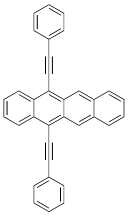
$C_{24}H_{12}$
FW: 300.35
[*191-07-1*]



335355-25MG	25 mg
335355-100MG	100 mg
335355-500MG	500 mg

5,12-Bis(phenylethynyl)naphthacene, technical grade, 85%

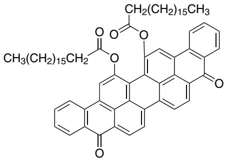
$C_{34}H_{2}0$
FW: 428.52
[*18826-29-4*]
$\lambda^{max}_{(abs)}$: 550 nm



471151-250MG	250 mg
471151-1G	1 g

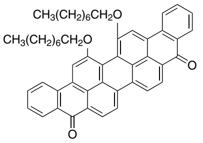
Pentaphene-78

$C_{70}H_{84}O_6$
FW: 1021.41
[*82145-74-2*]
$\lambda^{max}_{(abs)}$: ≤577 nm



641782-1G	1 g
641782-5G	5 g

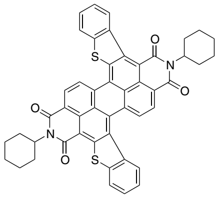
Violanthrone-79



641790-1G	1 g
641790-5G	5 g

Perylene-66, Dye content 90%

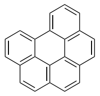
$C_{48}H_{34}N_2O_4S_2$
FW: 766.92
$\lambda^{max}_{(abs)}$: 549 nm



641804-1G	1 g
641804-5G	5 g

Benzo[ghi]perylene, 98%

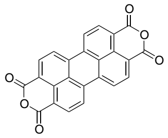
$C_{22}H_{12}$
FW: 276.33
[*191-24-2*]



B9009-5MG-A	5 mg
B9009-25MG-A	25 mg
B9009-100MG-A	100 mg

Perylene-3,4,9,10-tetracarboxylic dianhydride

$C_{24}H_8O_6$
FW: 392.32
[*128-69-8*]



P11255-25G	25 g
P11255-100G	100 g

For questions, product data, or new product suggestions, please contact the Materials Science Team at matsci@sial.com.

Guest–Host Liquid Crystals

Bahman Taheri, Ph.D.
AlphaMicron, Inc., Kent, Ohio

Guest–host liquid crystals combine a guest dichroic dye with a host liquid crystal. The orientation and hence the absorption cross-section of the dye is coupled to the orientation of the host liquid crystal, which itself can be controlled by an external electric field. The "operation window" of these systems depends on the concentration of the guest dye, making them suitable for applications where the contrast ratio can be compromised in favor of a higher clear state transmission. Variable transmittance eyewear and auto-dimming mirrors are examples of such applications.

Figure 1 shows a schematic of a chiral-based, liquid crystal system in the absence and presence of an external electric field. This system, known as a Gharadjedaghi type configuration, provides a high transmission in the "off" state and can be tuned for polarization control. The performance of a guest–host system depends on the orientational order parameter of the dye, as well as its absorption cross-section and dichroic ratio. AlphaMicron develops systems for eyewear applications and has achieved order parameters of 0.85 across the visible spectrum. These dyes permit a transmission swing of 50–60%, which is a parameter required by the U.S. Air Force for a variable transmittance visor.

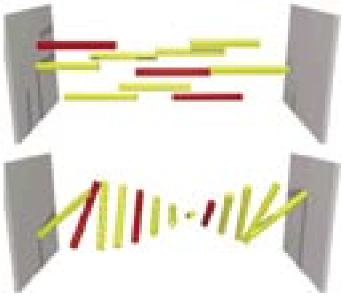


Figure 1. Gharadjedaghi guest–host configuration in the off (top) and on (bottom) state.

Since guest–host systems do not require external polarizers, they are well suited for fabrication on plastic substrates. AlphaMicron has pioneered the implementation of guest–host systems on double-curved flexible plastic substrates. This achievement has enabled the use of liquid crystals in eyewear applications ranging from Air Force visors to ski goggles and sunglasses. **Figure 2** shows an HU55-P visor incorporating AlphaMicron's Variable Attenuation Liquid Crystal Device (VALiD™) technology. Pilots can use this visor in conjunction with helmet-mounted displays (HMDs). HMDs use the visor as a combiner to project relevant information into the pilot's panoramic view. The VALiD™ based visor controls the ambient light to enhance the visibility of the projected information in a variety of lighting conditions. The system can also be used as a stand-alone visor during missions where the lighting conditions change.

Figure 2. Air Force HU55-P visor with VALiD™.

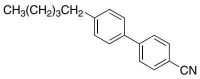
Most recently, AlphaMicron introduced a liquid crystal ski goggle for the consumer market under the UVEX brand (**Figure 3**). The goggle allows the user to switch the tint of the goggle instantaneously with a touch of a button or automatically via a light sensor. It addresses the problem of changing lighting conditions frequently encountered by skiers, especially during cloudy days. The system can be designed to be polarization sensitive and is compatible with contrast-enhancing lenses. This product marks the first implementation of a liquid crystal technology on curved plastic substrates and opens the door for other applications including sunglasses and prescription eyewear.

Figure 3. UVEX's F1 Magic Goggle with AlphaMicron's VALiD™ technology.

Liquid Crystals

4'-Pentyl-4-biphenylcarbonitrile, liquid crystal (nematic), 98%

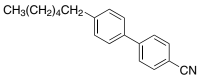
$C_{18}H_{19}N$
FW: 249.35
[*40817-08-1*]



328510-250MG	250 mg
328510-1G	1 g

4'-Hexyl-4-biphenylcarbonitrile, liquid crystal (nematic), 98%

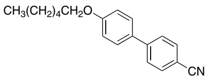
$C_{19}H_{21}N$
FW: 263.38
[*41122-70-7*]



338648-250MG	250 mg
338648-1G	1 g

4'-(Hexyloxy)-4-biphenylcarbonitrile, liquid crystal (nematic), 96%

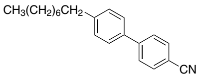
$C_{19}H_{21}NO$
FW: 279.38
[*41424-11-7*]



338656-1G	1 g

4'-Octyl-4-biphenylcarbonitrile, liquid crystal (nematic), 98%

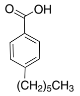
$C_{21}H_{25}N$
FW: 291.43
[*52709-84-9*]



338680-250MG	250 mg
338680-1G	1 g

4-Hexylbenzoic acid, liquid crystal, 99%

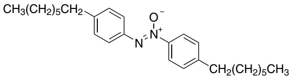
$C_{13}H_{18}O2$
FW: 206.28
[*21643-38-9*]



359319-250MG	250 mg
359319-1G	1 g

4,4′-Diheptylazoxybenzene, liquid crystal (nematic)

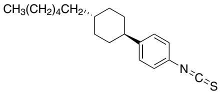
$C_{26}H_{38}N_2O$
FW: 394.59
[*37592-89-5*]



366781-1G	1 g
366781-5G	5 g

1-(*trans*-4-Hexylcyclohexyl)-4-isothiocyanatobenzene, liquid crystal (nematic), 99%

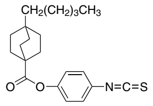
$C_{19}H_{27}NS$
FW: 301.49
[*92444-14-9*]



366854-1G	1 g

4-Isothiocyanatophenyl 4-pentylbicyclo[2.2.2]octane-1-carboxylate, liquid crystal (nematic), 99%

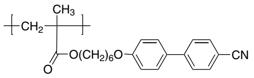
$C_{21}H_{27}NO_2S$
FW: 357.51
[*121235-90-3*]



370053-250MG	250 mg
370053-1G	1 g

Poly[6-[4-(4-cyanophenyl)phenoxy]hexyl methacrylate]

$C_{23}H_{25}NO_3$
FW: 363.40
mp: 101–106 °C
Average M_n: ~20,000
M_w/M_n: <1.2
side chain liquid crystal polymer

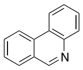


588482-250MG	250 mg

Other Electronic Dyes

Phenanthridine, ≥99%, purified by sublimation

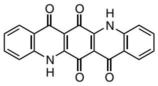
$C_{13}H_9N$
FW: 179.22
[*229-87-8*]



262692-1G	1 g
262692-5G	5 g

Quinacridonequinone

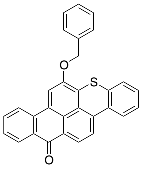
$C_{20}H_{10}N_2O_4$
FW: 342.30
[*1503-48-6*]



634484-1G	1 g
634484-5G	5 g
634484-10G	10 g

Thioxanthone-64, dye content 90%

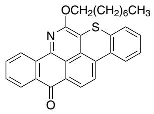
$C_{30}H_{18}O_2S$
FW: 442.53
$\lambda^{max}_{(abs)}$: 536 nm



641758-1G	1 g
641758-5G	5 g

Quinolin-65, dye content 80%

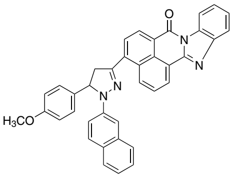
$C_{30}H_{29}NO_2S$
FW: 467.62
[*834884-59-2*]
$\lambda^{max}_{(abs)}$: 375 nm



641766-1G	1 g
641766-5G	5 g

Pyrazole-72, dye content 95%

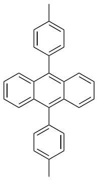
$C_{38}H_{26}N_4O_2$
FW: 570.64
[*85833-79-0*]
$\lambda^{max}_{(abs)}$: ≤519 nm



641774-1G	1 g
641774-5G	5 g

9,10-Di-*p*-tolyl-anthracene

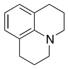
$C_{28}H_{22}$
FW: 358.47
[*43217-31-8*]
$\lambda^{max}_{(abs)}$: 376 nm



648973-2G	2 g

Julolidine, 97%

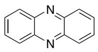
$C_{12}H_{15}N$
FW: 173.25
[*479-59-4*]



J1001-5G	5 g
J1001-25G	25 g

Phenazine, 98%

$C_{12}H_8N_2$
FW: 180.21
[*92-82-0*]



P13207-5G	5 g
P13207-10G	10 g

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