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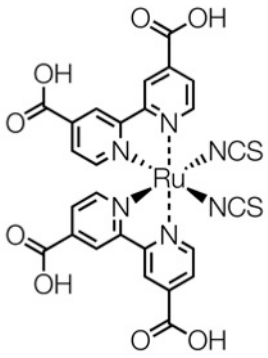
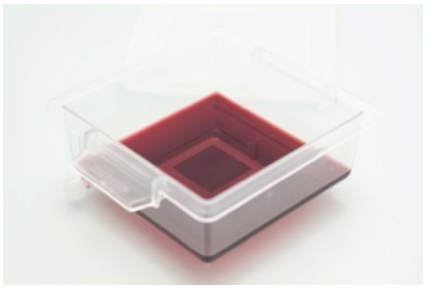
Ruthenizer 535

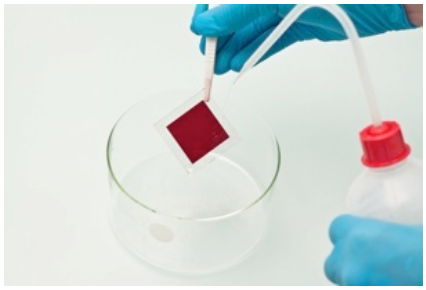
Standard Ruthenium Photo-Sensitizer for Dye Solar Cell Applications



Ruthenizer 535 is a high performance ruthenium sensitizer for Dye Solar Cell applications, suitable for both research and industry. It can be used as a standard for benchmarking, as well as manufacturing.

Ruthenizer 535 is a high quality dye tested in real solar cells at Solaronix. It is ready to use, doesn't require extra purification, and can be converted into the tetrabutyl ammonium salt, Ruthenizer 535-bisTBA.





Characteristics

Aspect	dark purple powder
Synonyms	N3
Chemical Name	*cis*-diisothiocyanato-bis(2,2'-bipyridyl-4,4'-dicarboxylic acid) ruthenium(II)
Molecular Formula	$C_{26}H_{16}O_8N_6S_2Ru$
Formula Weight	741.7 g/mol (incl. 2 cryst. H_2O)
CAS Number	141460-19-7
HS Code	7110.4900
Absorption λ(max)	538 (1.42); 398 (1.40); 314 (4.82) ($\varepsilon/10^4$ M^{-1} cm^{-1})
Emission λ(max)	830 (EtOH, rt.)
HOMO Level	-4.98 eV
LUMO Level	-2.88 eV
Solubility	EtOH, MeOH, AcCN, DMF, basic H_2O

Retail Quantities

100 mg	ref.	21512
200 mg	ref.	21522
500 mg	ref.	21552
1 g	ref.	21513
2 g	ref.	21523
5 g	ref.	21553
10 g	ref.	21514
20 g	ref.	21524
50 g	ref.	21554
100 g	ref.	21515

Pricing on product page:
solx.ch/ru535sx

How to Order

Please visit our webshop at shop.solaronix.com, or send us an e-mail or fax indicating your desired products.

Bulk Supply

In addition to the retail quantities listed above, Ruthenizer 535 is also available in bulk for industrial purpose. Please inquire.

USAGE

Ruthenizer 535 is known to very efficiently photo-sensitize titanium dioxide (titania) in the visible spectrum up to a wavelength of ~750 nm. This compound is commonly referred as N3 in the literature. It is so far one of the best pigments for Dye Solar Cells, and is considered an industry standard.

Ruthenizer 535 is used to prepare staining solutions in which metal-oxide semi-conductor electrodes will be immersed. The dye naturally adsorbs on the semi-conductor surface, resulting in a colored electrode bearing a sensitizing layer of dye molecules.

Staining Procedure For Titania Electrodes

Weigh the amount of dry powder necessary to make a 0.5 mM ethanol solution of the required volume. Make sure the volume is sufficient to completely immerse the electrode(s).

> *The addition of chenodeoxycholic acid (10 fold) in the staining solution yields a significant performance boost.*

Place the dye powder in a sealable container and add the required volume of ethanol. Absolute ethanol is good, but not strictly necessary. Alternatively, methanol can be used with this dye.

Stir the mixture in a sealed vessel at room temperature (e.g. a glass bottle with stir bar). The solution rapidly turns dark purple although most of the solid is yet to be dissolved. Coarse grains can take a while to dissolve so prolong stirring until no traces of solid are visible.

> *If necessary, briefly sonicate the solution to help dissolution. Beware that excessive sonication is potentially harmful to the dye molecules.*

Position the titania electrodes in a flat-bottomed, sealable container, side by side, with titania layers facing up. This is important in order to prevent scratching the fragile titania surface.

Pour a freshly prepared dye solution into the container and fully immerse the electrodes. Too little liquid won't allow the titania surface to adsorb enough dye and the electrodes may appear unevenly colored.

> *For best results fire the titania electrodes just before staining so they don't pick up ambient moisture. It is best to put them in the staining bath while still warm, 50-60°C. Such mesoporous titania electrodes are easily polluted by volatile substances.*

Seal the container with a lid and wait for the titania surface to get entirely stained. This takes several hours and can be conveniently left overnight. Make sure to avoid excessive light exposure during the staining process. Dye molecules are very light sensitive in solution, and even more so when adsorbed on titania and dry.

Remove the stained electrodes with plastic tweezers (to avoid metal traces pollution). Rinse thoroughly with ethanol to remove any excess dye which could otherwise cause a detrimental build up of dye molecules. Discard the rinsing waste.

> *Staining solutions can be reused several times, provided the concentration is sufficient. However, dye solutions are not suitable for long term storage. Dye oxidation and precipitation may occur over time. It is preferable to store the dried dye powder in its original container and prepare solutions when needed.*

Completely dry the electrodes with an inert gas flow or with a brief gust from a hair-drier held at a reasonable distance. Make sure to assemble the solar cells immediately. Stained electrodes are fragile, keep them in a sealed environment away from light until you are ready for assembly.

A properly stained titania electrode should look quite dark (especially if opaque) and purple. A brownish color indicates the dye has degraded and will result in poor cell performance.

Common Pitfalls

A white or faded coloration indicates poor staining, the entire surface of the electrode visibly didn't get colored. Try to increase the dye concentration or lengthen the staining time. If the problem persists, use recommend staining conditions for troubleshooting, change solvent, or check for moisture in the solution.

It could also indicate the structure of the titania electrode is not porous enough. Investigate possible titania issues such as firing process, poor porosity, or large particle size.

A brownish stained electrode indicates the dye has been oxidized, it's no longer purple. Discard the staining solution for a fresh one if it has changed color. Also, avoid exposing

freshly stained electrodes to ambient atmosphere or moisture for too long, dye molecules adsorbed on the titania can be easily oxidized, especially when exposed to light.

Staining the electrodes for too long can also lead to reduced solar cell performance because of dye molecule aggregation. Consider using a lower dye concentration, or shortening the staining time if possible.

Deprotonated Analogue: Ruthenizer 535–bisTBA

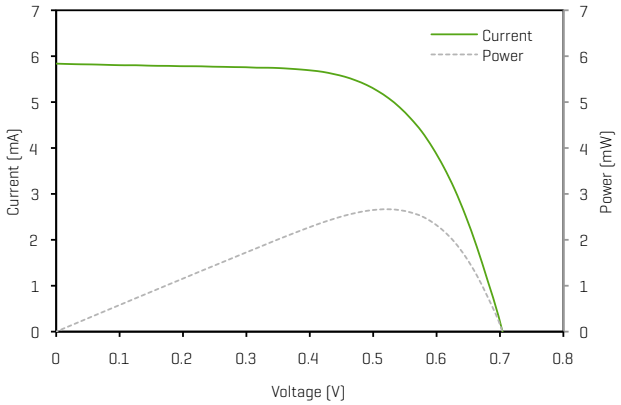
Ruthenizer 535 exists in a doubly deprotonated form, named Ruthenizer 535–bisTBA, which allows for higher photovoltaic performances (eg. higher V_{oc}). Ruthenizer 535–bisTBA is notably more soluble than Ruthenizer 535, making it easier to work with concentrated staining solutions. See solx.ch/ru535tba for more information.

EXAMPLE

A Dye Solar Cell Sensitized with Ruthenizer 535

A 36 mm^2 titania photo-anode was prepared with 4 printed layers of Ti-Nanoxide T/SP and 1 printed layer of Ti-Nanoxide R/SP on a TCO22-7 glass substrate. The electrode was stained in a solution of Ruthenizer 535 using the procedure described above with chenodeoxycholic acid (1:10) as a co-adsorbent. A platinum coated cathode was prepared on another TCO22-7 substrate with a layer of Platisol T. The two electrodes were laminated together using Meltonix 1170-60, and the solar cell was filled with Iodolyte AN-50 through a hole in the cathode. The filling hole was then sealed with Meltonix 1170-60 and a thin glass circle of 6 mm diameter.

The resulting solar cell was placed under 1 sun illumination using a calibrated Solaronix Solixon Class-A solar simulator and equipped with an adequate mask to avoid over-illumination, yielding the following current-voltage curve and tabulated results.



V_{oc} 704 mV

J_{sc} 16.22 mA/cm^2

FF 0.65

Eff. 7.4 %

STORAGE AND SAFETY

Storage

Store the product in its original container, upright and tightly sealed. Keep in a dry place at room temperature, and away from light.

The product is not known to suffer from degradation when stored properly. Consider filling the container with inert gas for very long term storage.

While in use, avoid leaving the container open unnecessarily.

Safety

Ruthenizer 535 is for research and development use only and is intended to be manipulated by knowledgeable personnel. Ensure good ventilation of the workplace, and wear suitable protective equipment.

Signal word: Warning

For a complete description of safety measures, please refer to the Material Safety Datasheet (MSDS) of Ruthenizer 535.

solaronix.com/msds/

RELATED PRODUCTS

Cited in This Document

- Chenodeoxycholic Acid, staining additive.
- TCO22-7, FTO coated glass substrates.
- Ti-Nanoxide T/SP, screen-printable titania nanoparticles paste.
- Ti Nanoxide R/SP, screen-printable reflective titania paste.
- Platisol T, platinum precursor paint.
- Iodolyte AN-50, high efficiency electrolyte.
- Meltonix 1170-60, hot-melt sealing films.
- Solixon, continuous illumination solar simulators.

Consider Also

- Ruthenizer 535-bisTBA, higher performing analogue.
- Ruthenizer 620-1H3TBA, panchromatic ruthenium dye.
- Ruthenizer 520-DN, amphiphilic ruthenium dye.

REFERENCES

Articles About N3

For further reading, have a look at the following articles:

- J. Am. Chem. Soc. 1993, 115, 6382-6390 [doi:10.1021/ja00067a063]
- Adv. Mater. 1997, 9, 904-906 [doi:10.1002_adma.19970091111]
- Chem. Mater. 1998, 10, 2533-2541 [doi:10.1021_cm980303g]
- Inorg. Chem. 1999, 38, 3836-3846 [doi:10.1021_ic990344u]
- Inorg. Chem. 1999, 38, 6298-6305 [doi:10.1021_ic990916a]
- Acc. Chem. Res. 2000, 33, 269-277 [doi:10.1021_ar980112j]
- Thermochimica Acta 2000, 348, 105-114 [doi:10.1016_S0040-6031(99)00486-4]
- J. Phys. Chem. B 2001, 105 (29), 6867–6873 [doi:10.1021/jp004411d]
- J. Am. Chem. Soc. 2002, 124, 489-493 [doi:10.1021_ja016561n]
- J. Phys. Chem. B 2002, 106, 3926-3932 [doi:10.1021_jp014343a]
- J. Photochem. Photobiol. A. Chemistry 2004, 164, 3–14 [doi:10.1016_j.jphotochem.2004.02.023]
- Inorganica Chimica Acta 2009, 362, 5155-5162 [doi:10.1016_j.ica.2009.09.001]

People Using Ruthenizer 535

A selection of publications using Ruthenizer 535:

- Applied Physics Letters 2005, 87, 113113 [doi:10.1063/1.2048816]
- Solar Energy 2005, 79, 422–430 [doi:10.1016/j.solener.2005.02.017]
- J. Phys. Chem. C 2008, 112, 19151–19157 [doi:10.1021/jp806281r]
- Electrochimica Acta 2009, 54, 4123–4130 [doi:10.1016/j.electacta.2009.02.052]
- Energy Environ. Sci., 2010, 3, 838–845 [doi:10.1039/b921360k]
- J. Phys. Chem. C 2010, 114, 8398-8404 [doi:10.1021/jp100268r]
- RSC Adv. 2012, 2, 5123-5126 [doi:10.1039/C2RA00041E]

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