Materials for Energy Production, Transformation and Storage 2017

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IOLITEC – The Company

IOLITEC, founded in May 2003, is an award-winning, dynamic, innovative and goal-oriented company whose activities go far beyond the production and sale of ionic liquids and nanomaterials. With more than **2'800 customers** and **6'500 frequently readers** of our **email bulletin "Ionic Liquids Today"**, we are one of the **global leading specialized companies in the field of ionic liquids** and **leading experts in the field of nano-dispersion technology**.

IOLITEC's HQ @ Heilbronn, Germany.

Batch production on the ton's scale.

IOLITEC @ Tuscaloosa, USA (Sales).

Quality control for best quality.

Continuous-flow-production.

High-quality ionic liquids.

With **solid experience in project management** and a **skilled team** of currently nine PhD-level chemists and engineers IOLITEC is in the strong position to give **reliable answers** and to deal with customer requests from many different sectors in a professional, efficient and goal-oriented way. Our **services include consulting and feasibility studies** as well as the development of marketable products and applications based on ionic liquids. For these purposes we can utilize a **compound library** of more than **1'500 ionic liquids** and an **extensive database of physical and chemical properties** compiled from data published in scientific journals and checked as well as supplemented with our own numerous measurements.

Our Philosophy

IOLITEC is with all consequences a customer-oriented company: The customer is in the center of all our activities.

IOLITEC enjoys working hand in hand with customers and partners in a friendly and open, but also focused way. Requests are handled always confidential and they are processed fast. We like to give reliable scientific answers on the highest possible level.

IOLITEC collects, measures, interprets and refines physico-chemical data of ionic liquids, following our philosophy to present our customers necessary information to design or to construct methods, processes or devices using ionic liquid technology.

IOLITEC is driven by technology and innovation. Based on reliable data, we identify by our own research or by co-operations with partners new applications and technologies. In co-operations, we share our knowledge with partners openly and combine it in interdisciplinary research. We define ourselves as specialists in translating selected properties into the molecular structure of ionic liquids.

IOLITEC wants to combine the best available quality with reasonable prices. Our customers shall have as soon as possible a monetary benefit, if we identified more efficient synthetic methods or if we scaled up our capacities.

IOLITEC is an independent producer, supplier and distributor of ionic liquids. We like to present our customers the broadest variety of materials, covering the most common classes of ionic liquids. These facts enable our customers to choose the most suitable products for their specific needs from our comprehensive portfolio. We offer those materials, which are not part of our actual portfolio, as custom synthesis, as long as IP of others is not infringed.

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Contents

Electrolytes and Materials for Batteries (IOLI*Lyte* LBE-series)

Based on our cumulated experience from numerous R&D-projects in the field of batteries, we are in the position to offer you novel electrolytes for three different categories of batteries:

a) Lithium Battery Electrolytes and Solvents

Since Lithium is the alkali metal with the lowest weight, it has a very good charge-weight-ratio. As a consequence it is no surprise that a lot of research activities about lithium-ion, lithium-air, or lithium metal batteries are going on worldwide today. In this context, we would like to offer you

- Electrolytes based on our Ionic Liquid Technology
- Conducting (Lithium-)salts
- High-Purity Solvents
- Ready-to-use electrolytes (Lithium salts dissolved in typical solvents)

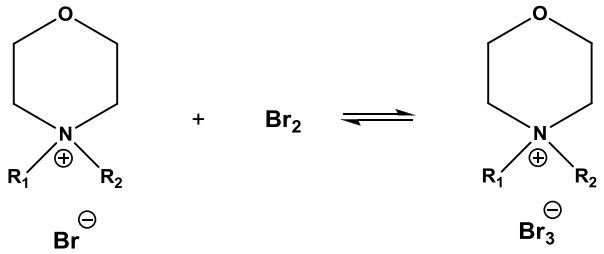
in best qualities for your research.

b) Redox-Flow Batteries

A redox-flow-battery is a type of rechargeable battery where the rechargability is provided by two chemical components dissolved in liquids. The liquids are part of the system and are typically separated by a membrane. A special type is the zinc-bromine battery where the net reaction is described by

$$Zn^{2+} + 2\ e^- \rightleftharpoons Zn$$
$$2\ Br^- \rightleftharpoons Br_2 + 2\ e^-$$
$$\overline{ZnBr_2 \rightleftharpoons Zn + Br_2}$$

One of the major challenges is to store the elementary Bromine within the electrolyte. This is typically realized by the reversible reaction with an ionic liquid, e.g.



For this technology IOLITEC offers a couple of interesting ionic liquids based on Bromide as anion. In addition to that, we are in the position to offer you other materials as custom-synthesis.

c) Zinc-Air Batteries

While Lithium-resources are comparable limited, there are worldwide activities to search for other metals being available in more or less unlimited amounts. Thus, for the next generation of batteries, Zinc might be an interesting option and thus also a potential alternative. Today the Zinc-air-concept is already realized for primary batteries, being e.g. applied to acousting hearing apparatus. In the next step, the design of secondary batteries is of great interest.
In this context, we'd like to offer you

- ionic liquids and interesting
- Zinc salts

that may be the key to success for innovative developments.

Ionic Liquid-based Electrolytes

IOLILYTE LBE 1000

Ionic Liquid-based Electrolyte 1-Propyl-1-methylpyrrolidinium bis(trifluoromethyl-sulfonyl)imide Purity: 99.5%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 2000

Ionic Liquid-based Electrolyte 1-Butyl-1-methylpyrrolidinium bis(trifluoromethyl-sulfonyl)imide Purity: 99.5%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 3000

Ionic Liquid-based Electrolyte 1-Propyl-1-methylpiperidinium bis(trifluoromethyl-sulfonyl)imide Purity: 99.5%	25 g 50 g 100 g 250 g 500 g 1 kg

Lithium-Salts

IOLILYTE LBE 0100

Lithium Salt Lithium bis(trifluoromethyl-sulfonyl)imide Purity: battery grade	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 0300

Lithium Salt Lithium bis(pentafluoroethyl-sulfonyl)imide Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 0200

Lithium Salt Lithium hexafluorophosphate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Electrolytes with Li BTA

IOLILYTE LBE 0110-100

Electroylte: 1M Li BTA in Propylene carbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(35)0-50

Electrolyte 1M Li BTA in Ethylenecarbonate/ Diethylcarbonate (50:50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(35)0-75

Electrolyte 1M Li BTA in Ethylenecarbonate/ Diethylcarbonate (25:75 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(45)0-50

Electrolyte 1M Li BTA in Ethylenecarbonate/ Dimethylcarbonate (50:50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(45)0-75

Electrolyte 1M Li BTA in Ethylenecarbonate/ Dimethylcarbonate (25:75 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(56)0-50

Electrolyte 1M Li BTA in Ethylenecarbonate/ Ethylmethylcarbonate (50:50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(56)0-75

Electrolyte 1M Li BTA in Ethylenecarbonate/ Ethylmethylcarbonate (25:75 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(354)0-33	
Electrolyte 1M Li BTA in Ethylenecarbonate/ Diethylcarbonate/ Dimethylcarbonate (33:33:33 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(457)0-33	
Electrolyte 1M Li BTA in Ethylenecarbonate/ Dimethylcarbonate Ethylacetate (33:33:33 m%) Purity: 99%%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 01(456)0-33	
Electrolyte 1M Li BTA in Ethylenecarbonate/ Ethylmethylcarbonate Dimethylcarbonate (33:33:33 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Electrolytes with $LiPF_6$

IOLILYTE LBE 02(35)0-50

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Diethylcarbonate (50:50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(35)0-75

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Diethylcarbonate (25:75 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(45)0-50

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Dimethylcarbonate (50:50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(45)0-75

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Dimethylcarbonate (25:75 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(56)0-50

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Ethylmethylcarbonate (50:50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(56)0-75

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Ethylmethylcarbonate (25:75 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(345)0-33

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Diethylcarbonate/ Dimethylcarbonate (33:33:33 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 02(457)0-33

Electrolyte 1M Li PF_6 in Ethylenecarbonate/ Dimethylcarbonate Ethylacetate (33:33:33 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Solvents for Li-Batteries

IOLILYTE LBE 0010

Solvent
Propylenecarbonate
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 0020

Solvent
PEG-200
Purity: Ph. Eur.

250 g
500 g
1 kg
5 kg

IOLILYTE LBE 0030

Solvent
Diethylcarbonate
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 0040

Solvent
Dimethylcarbonate
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 0050

Solvent
Ethylenecarbonate
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 0060

Solvent
Ethylmethylcarbonate
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 0070

Solvent
Ethylacetate
Purity: >99.8%

100 g
250 g
500 g
1 kg

Mixtures of Ionic Liquids

IOLILYTE LBE 14.000-90

Electrolyte with high stability
Viscosity: 48 cP (25 °C)
Conductivity: 9.37 mS/cm (30 °C)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 57.000-90

Electrolyte with low viscosity
Viscosity: 31 cP (25 °C)
Conductivity: 10.54 mS/cm (30 °C)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 65.000-90

Electrolyte with enhanced conductivity
Viscosity: 35 cP (25 °C)
Conductivity: 10.04 mS/cm (30 °C)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 54.002-80

Electrolyte with improved lithium ion conductivity and stability
Viscosity: 31 cP (25 °C)
Conductivity: 10.11 mS/cm (30 °C)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 467.000-80

Electrolyte with a high conductivity
Viscosity: 37 cP (25 °C)
Conductivity: 11.01 mS/cm (30 °C)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 67.000-90

Electrolyte
1-Allyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide/ 1,3-Dimethylimidazolium bis(trifluoromethylsulfonyl)imide (10:90 mol%)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLILYTE LBE 67.002-80

Electrolyte with improved lithium ion conductivity
Viscosity: 35 cP (25 °C)
Conductivity: 8.44 mS/cm (30 °C)
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

Ionic Liquids mixed with Organic solvents

IOLILYTE LBE 12.000-70

Electrolyte 1-Methyl-1-propylpyrrolidinium bis(trifluoromethylsulfonyl)imide in Propylenecarbonate (70: 30 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 12.000-50

Electrolyte 1-Methyl-1-propylpyrrolidinium bis(trifluoromethylsulfonyl)imide in Propylenecarbonate (50: 50 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 21.000-70

Electrolyte 1-Methyl-1-propylpyrrolidinium bis(trifluoromethylsulfonyl)imide in Propylenecarbonate (30: 70 m%) Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Additives for Li-Batteries

IOLILYTE LBE 0080

Additive Vinylenecarbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Bromine Complexing Agents

IOLILYTE FBE 1000	
Bromine Complexing Agent 1-Butyl-3-methylpyridinium bromide Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FBE 2000	
Bromine Complexing Agent *N*-Butyl-*N*-methyl-morpholinium bromide Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FBE 3000	
Bromine Complexing Agent 1-Butyl-1-methylpiperidinium bromide Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Materials for Zn-Air Batteries

IOLILYTE ZBE 0100	
Material Zinc trifluoromethansulfonate Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE ZBE 0200	
Material Zinc methansulfonate Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

Electrolytes for Zn-Air Batteries

IOLILYTE ZBE 1000	
Ionic Liquid-based Electrolyte 1-Ethyl-3-methylimidazolium dicyanamide Purity: >98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE ZBE 2000	
Ionic Liquid-based Electrolyte 1-Ethyl-3-methylimidazolium trifluoromethansulfonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Electrolytes and Materials for Supercapacitors (IOLI*Lyte* SCE-series)

Among capacitors so called **electrochemical double layer capacitors (EDLCs)** are having the highest power densities. EDLCs store the energy within the **Helmholtz double layer** at the electrodes. In some cases the electric is not only stored in an electrostatic way, but also by a redox reaction at the electrodes, leading to a higher specific capacity.

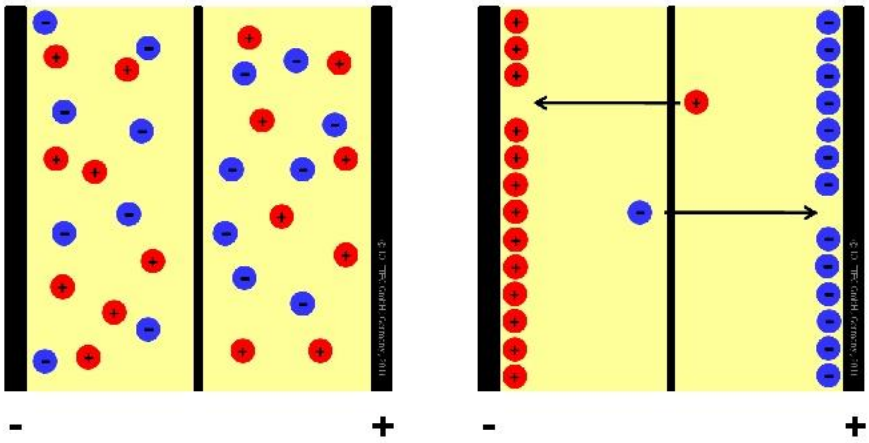


Fig. 1. Double Layer Capacitor discharged (left) and charged (right).

In EDLCs typically tetraalkylammonium-salts in acetonitrile as solvent are used, providing a good conductivity combined with a wide electrochemical window. A disadvantage for electrolytes of this type is the vapor pressure of the organic solvent: This fact can cause the risk of burning at elevated temperatures.

Ionic Liquids as novel electrolytes for EDLCs

The structure of ionic liquids is often similar to those of tetraalkylammonium salts, but the main difference is that suitable materials are liquid in a range from -35°C to 250°C without the need of an additional solvent such as acetonitrile, ethylene- or propylene carbonate. Furthermore, suitable ionic liquids do not have any tendency of vaporization.

In this context, the electrochemical properties are also interesting:

- Electric conductivity
- Electrochemical stability

A high value for the electric conductivity is beneficiary for the fast charging of the supercapacitor and a wide electrochemical window of the electrolyte represents stability against oxidation- and reduction-processes within the system. The higher the electrochemical window is, the higher the resulting capacity of the supercapacitor.

In several publications the use of ionic liquids was already successful demonstrated.[i] In particular the energy density and the safety aspects of supercapacitors may be enhanced in future by electrolytes based on ionic liquids.

In a joint-project funded by the European Union called "NEST - Nanowires for Energy STorage" IOLITEC develops novel ioni liquids for the use in Supercaps (http://www.project-nest.eu/).

Carbon Nanotubes as novel material for electrodes in EDLCs

Since their discovery by *Iijimi et al.* Carbon Nanotubes (CNTs) their interesting properties led to a broad variety of applications.[ii] The tubular structure of the two dimensional graphite provides a huge electrode surface area having small pores with nano-scale diameters. As a consequence, they are ideal conductive and at the time porous materials which can be applied to electrochemical storage systems as electrode materials (e.g. Lithium-ion-batteries, fuel fells or capacitors).

Another interesting aspect is the combination of CNTs with ionic liquids, forming so called "Bucky Gels". Within the ionic liquids CNTs are forming small bundles, which have a crosslinked structure.[iii] *Watanabe et al.* demonstrated that these gels can be applied as electrodes in EDLCs: The specific surface of 654 m^2/g was higher than those of conventional carbon electrodes, leading to a reduced resistance of the electrodes and an enhanced capacity.[iv]

Text: Dr. Thomas J. S. Schubert, IOLITEC GmbH, 2016.

[i] A. Lewandowski, M. Galinski, *J. Phys. Chem. Solids* **2004**, *65*, 281; A. Lewandowski, A. Swiderska, *Appl. Phys.* **2006**, *A 82*, 579-584;

[ii] S. IIjima, T. Ichihashi, *Nature* **1993**, *363*, 603.

[iii] T. Fukushima, A. Kosaka, Y. Ishimura, T. Yamamoto, T. Takigawa, N. Ishii, T. Aida, *Science* **2003**, *300*, 2072.

[iv] T. Katakabe, T. Kaneko, M. Watanabe, T. Fukushima, T. Aida, *J. Electrochem. Soc.* **2005**, *152* (10), A1913

Ionic Liquid-based Electrolytes

IOLILYTE SCE 1000	
Ionic Liquid-based Electrolyte 1-Ethyl-3-methylimidazolium tetrafluoroborate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE SCE 2000	
Ionic Liquid-based Electrolyte 1-Methyl-1-propyl-pyrrolidinium bis(trifluoro-methyl-sulfonyl)imide Purity: 99.5%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE SCE 3000	
Ionic Liquid-based Electrolyte 1-Methyl-1-propyl-piperidinium bis(trifluoro-methylsulfonyl)imide Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Solvents for Supercapacitors

IOLILYTE LBE 0010

Solvent Propylenecarbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 0020

Solvent PEG-200 Purity: Ph. Eur.	250 g 500 g 1 kg 5 kg

IOLILYTE LBE 0030

Solvent Diethylcarbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 0040

Solvent Dimethylcarbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 0050

Solvent Ethylenecarbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE 0060

Solvent Ethylmethylcarbonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE LBE LBE 0070

Solvent Ethylacetate Purity: >99.8%	100 g 250 g 500 g 1 kg

Electrolytes and Membrane-Materials and Fuel Cell Applications (IOLI*Lyte* FCE- and FCM-series)

In a proton exchange membrane fuel cell (PEM-FC) the controlled reaction of Hydrogen and Oxygen into water is performed to convert the released energy directly into electricity. Typical membrane Polymers (ionomers) are based on a PTFE-backbone, having sulfonic-acid group incorporated in the sidechains. The necessary proton-conductivity can only be achieved if the material is moistened with a sufficient amount of water. As a consequence, because of the vapor pressure of water the upper operation temperature is limited to 80°C. Novel concepts are using thus e.g. polybenzimidazole (PBI) as membrane material, which is forming a necessary matrix for proton conductive phosphoric acid.

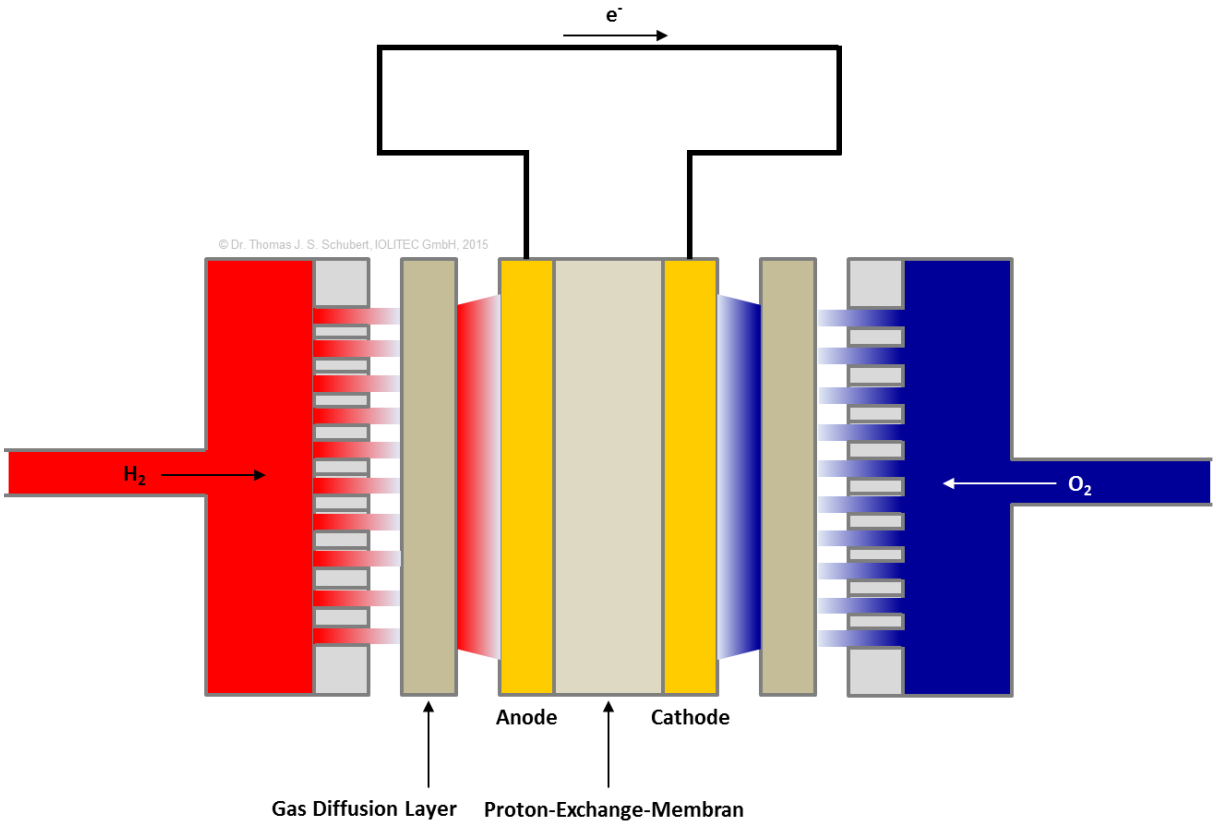
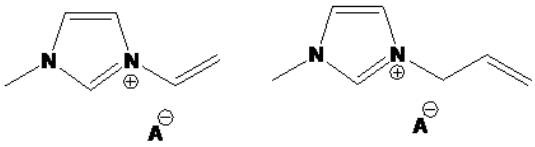


Fig. 1. Proton-Exchange-Mebrane Fuel Cell (PEM-FC).

Some ionic liquids are having a sufficient to good proton conductivity (IOLI*Lyte* FCE-series). In combination with their poor vapor pressure, they are interesting alternatives for phosphoric acid.

Another example of using ionic liquids in fuel cell technology is to polymerize suitable ionic liquids to generate novel types of ionomers. Those might be interesting alternatives for commly used

proton conductive membrane materials. In particular of interest are „Task Specific Ionic Liquids" (TSILs), bearing the necessary functionalities in ther sidechains (IOLI***Lyte*** FCE-series):



The design of the electrodes used in fuel cells is also an aspect of current R&D. Common material combinations are carbon black with metal- or noble metal catalysts.

In this context, the use of graphene or CNTs in combination with our metal-nanoparticles might also be of interest for actual applied research in this field (IOLI***Lyte*** FCM-series).

Ionic Liquids for Fuel Cells

IOLILYTE FCE 1000

Ionic Liquid-based Electrolyte Diethylmethylammonium trifluoromethanesulfonate Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 2000

Ionic Liquid-based Electrolyte Ethylmethylpropylammonium perfluorobutanesulfonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 3000

Ionic Liquid-based Electrolyte 1-Methylimidazolium bis(trifluoromethylsulfonyl)imide Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 4000

Ionic Liquid-based Electrolyte 1-Methylimidazolium trifluoromethanesulfonate Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 5000

Ionic Liquid-based Electrolyte 1-Ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 6000

Ionic Liquid-based Electrolyte Triethylammonium trifluoromethanesulfonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 7000

Ionic Liquid-based Electrolyte Triethylammonium methanesulfonate Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 8000

Ionic Liquid-based Electrolyte Choline dihydrogenphosphate Purity: 98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE FCE 9000	
Ionic Liquid-based Electrolyte 1-(4-sulfobutyl)-3-methyl-imidazolium trifluoromethanesulfonate Purity: 99%	25 g 50 g 100 g 250 g 500 g 1 kg

Thermal Fluids (IOLI*Therm* HTF-series)

Heat transfer media are of great importance for many industrial processes in which heat needs to be transported or transformed. The most important requirements for heat transfer media are:

- low vapor pressure
- high heat capacity
- low viscosity
- high thermal stability and
- low corrosivity

Besides these technical requirements eco- and human toxicity as well as bio degradability are of great importance for many applications.

Due to their very low vapor pressure ionic liquids have been investigated as heat transfer media in the early 21st century. In a feasibility study on the application of ionic liquids as heat transfer media for solar thermal devices which was initiated by IOLITEC and financed by the DBU e.V. it was shown that ionic liquids can be applied to this application.

Currently the ability of ionic liquids as reaction media for the conversion of carbon dioxide and hydrogen to methane is under investigation in the project "Storage of Electric Energy from Regenerative Sources from the Natural Gas Grid – H_2O Electrolysis and Synthesis of Gas Components", which is financed by the German Ministry of Education, Research and Science (BMBF).

$$CO_2\ (g) + 4\ H_2\ (g) \rightarrow CH_4\ (g) + 2\ H_2O\ (g) \qquad \Delta_R H^0 = -165\ kJ/mol$$

Heat Transfer Media for special Applications

Ionic liquids possess a couple of unique features that allow the development of new highly specialized applications. The combination of

- very low vapor pressure
- good heat capacity and
- high thermal stability

allows the use of ionic liquids as heat transfer media at very low pressures or under vacuum. In addition thermal energy can be stored in an open system since the very low vapor pressure prevents the ionic liquid from cooling by means of evaporation as it is known for water.

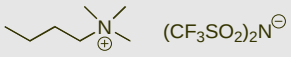
Another interesting aspect is the existence of complete water soluble ("hydrophilic") and water insoluble ("hydrophobic") ionic liquids. This allows combining the properties of other heat transfer media with those of the ionic liquids.

You will find our heat transfer media here. IOLITEC is very much interested in further developing our spectrum of applications for our heat transfer technology and we are looking for partners in this field.

Thermal Fluids

Butyltrimethylammonium bis(trifluoromethylsulfonyl)imide, 99%

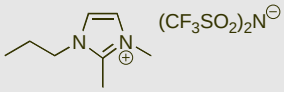
IL-0032-HP [258273-75-5] $C_9H_{18}F_6N_2O_4S_2$ MW 396.37



25 g
50 g
100 g
250 g
500 g
1 kg
5 kg

1,2-Dimethyl-3-propylimidazolium bis(trifluoromethylsulfonyl)imide, 99%

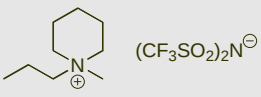
IL-0134-HP [169051-76-7] $C_{10}H_{15}F_6N_3O_4S_2$ MW 419.36



25 g
50 g
100 g
250 g
500 g
1 kg
5 kg

1-Methyl-1-propylpiperidinium bis(trifluoromethylsulfonyl)imide, 99%

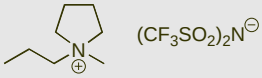
IL-0045-HP [608140-12-1] $C_{11}H_{20}F_6N_2O_4S_2$ MW 422.41



25 g
50 g
100 g
250 g
500 g
1 kg
5 kg

1-Methyl-1-propylpyrrolidinium bis(trifluoromethylsulfonyl)imide, 99%

IL-0044-HP [223437-05-6] $C_{10}H_{18}F_6N_2O_4S_2$ MW 408.38



25 g
50 g
100 g
250 g
500 g
1 kg
5 kg

Products for Dye Sensitized Solar Cells (DSSCs)

Dye-sensitised solar cells (DSSC) or Graetzel cells are considered a real alternative to the well-established silicon-based solar cells. Utilising a synthetic dye as the key component they convert sunlight into electricity via a complex electrochemical process. Their working principle is closely related to photosynthesis. Compared to silicon-based colar cells they offer the major advantage of staying functional even under diffuse light. They are transparent and can therefore be used as transluscent, power-generating building blocks.

To enable charge transfer within the solar cells, electrolytes are needed which have to fulfill a number of strict technical requirements, such us good electrochemical and thermal stability. From a very early stage, the development of the dye-sensitised solar cell was linked closely to the use of ionic liquids as the electrolyte, as their favourable properties made them the obvious materials of choice for this purpose. Over the last 15 years a huge number of systems composed of different dyes, electrolytes and addditives have been published in the scientific literature, some of them reaching efficiencies of more than 10% in the laboratory. The efficiency of dye-sensitised solar cells is strongly dependent on the interaction of the many different components and materials used and even with functional systems there is still room and need for further optimisation (More information). (In this video http://www.youtube.com/watch?v=NYhOb9ZB9qY Professor J.-E. Moser (EPFL) explains a new mechanism of electrical conductivity in ionic liquid electrolytes.)

IoLiTec is Europe's leading supplier of ionic liquids for the use in dye-sensitised solar cells. The high purity and reliable quality standard of IoLiTec's products (IoLiLyte® quality) have earned the company its strong reputation and prime position as the preferred partner of many companies and research institutions working in the field. A high level of flexibility enables IoLiTec to react promptly and efficiently to its customers' needs. Functional prototypes of dye-sensitized solar cells incorporating IoLiTec materials have already been built.

In collaboration with a number of top-class partners the commercialisation of the dye-sensitized solar cell in Germany is currently being driven forward by the ColorSol project which is funded by the Bundesministerium für Bildung, Forschung und Wissenschaft (BMBF). IoLiTec is entitled to use the registered trademark ColorSol® and the corresponding logo to promote and market its products and services. It is envisaged to develop the dye-sensitised solar cell into a marketable product within the next two year.

IoLiTec has developed a number of ready-to-use electrolytes for the use in dye-senstitised solar cells which will become commercially available in 2007 under the brand name IoLiLyte®. As part of the research project NEMESIS, which is funded by the Bundesministerium für Bildung, Forschung und Wissenschaft (BMBF) and coordinated by IoLiTec, the industrial production of high-purity ionic liquids is currently being organized. In a second follow-up project the resulting processes and methods will be tuned to be suitable for the large-scale production of solar cell electrolytes. Even today IoLiTec is in the position to provide multikilogram quantities of any selected electrolye for tests in pilot installations.

New concepts for sustainable buildings plan to use energy out of DSSCs, which are integrated into a steel roof. This video (http://www.youtube.com/watch?v=BJvmPxFE0tQ) will provide more details on this concept.

If you have any questions regarding our activities, applications or products in this field please feel free to contact us.

Ionic Liquids for DSSCs

IOLILYTE PVE 1000	
Ionic Liquid-based Electrolyte 1-Methyl-3-propylimidazolium iodide Purity: >98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE PVE 2000	
Ionic Liquid-based Electrolyte 1,2-Dimethyl-3-propylimidazolium iodide Purity: >98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE PVE 3000	
Ionic Liquid-based Electrolyte 1-Butyl-3-methylimidazolium iodide Purity: >98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE PVE 4000	
Ionic Liquid-based Electrolyte 1-Hexyl-3-methylimidazolium iodide Purity: >98%	25 g 50 g 100 g 250 g 500 g 1 kg

IOLILYTE PVE 5000	
Ionic Liquid-based Electrolyte 1,3-Dimethylimidazolium iodide Purity: >98%	25 g 50 g 100 g 250 g 500 g 1 kg

Additives for DSSCs

IOLITIVE PVE 0001

Additive:
Guanidinium iodide
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLITIVE PVE 0002

Additive:
Guanidinium thiocyanate
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLITIVE PVE 0003

Additive:
4-*tert*-Butylpyridine
Purity: 96%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLITIVE PVE 0004

Additive:
N-Methylbenzimidazole
Purity: >98%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLITIVE PVE 0005

Additive:
N-Butylbenzimidazole
Purity: >98%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLITIVE PVE 0006

Additive:
N-Octylbenzimidazole
Purity: >98%

25 g
50 g
100 g
250 g
500 g
1 kg

IOLITIVE PVE 0007

Additive:
Lithium iodide
Purity: 99%

25 g
50 g
100 g
250 g
500 g
1 kg

Electrolytes for DSSCs

IoLi*Lyte*® SP-361
0,1M I_3^- Imidazolium-based Electrolyte

ES-0001-HP

1-Methyl-3-propylimidazolium iodide Iodine N-Methylbenzimidazole 3-Methoxyvaleronitril	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

IoLi*Lyte*® SP-237
0,2M I_3^- PMIM/EMIM-based Electrolyte

ES-0005-HP

1-Methyl-3-propylimidazolium iodide 1-Ethyl-3-methylimidazolium thiocyanate Iodine N-Methylbenzimidazole Guanidinthiocyanate	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

IoLi*Lyte*® SP-382
0,15M I_3^- Imidazolium-based Electrolyte

ES-0002-HP

1-Methyl-3-propylimidazolium iodide Iodine Guanidine thiocyanate N-Methylbenzimidazole 3-Methoxyvaleronitril	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

IoLi*Lyte*® SP-196
0,2M I_3^- DiMIM/EMIM-based Electrolyte

ES-0007-HP

1,3-Dimethylimidazolium iodide 1-Ethyl-3-methylimidazolium iodide 1-Ethyl-3-methylimidazolium thiocyanate Iodine N-Methylbenzimidazole Guanidinthiocyanate	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

IoLi*Lyte*® SP-355
0,1M I_3^- Imidazolium-based Electrolyte

ES-0003-HP

1,2-Dimethyl-3-propylimidazolium iodide Iodine N-Methylbenzimidazole 3-Methoxyvaleronitril	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

IoLi*Lyte*® SP-196
0,2M I_3^- DiMIM/EMIM-based Electrolyte

ES-0007-HP

1,3-Dimethylimidazolium iodide 1-Ethyl-3-methylimidazolium iodide 1-Ethyl-3-methylimidazolium thiocyanate Iodine N-Methylbenzimidazole Guanidinthiocyanate	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

IoLi*Lyte*® SP-163
0,03M I_3^- BMIM-based Electrolyte

ES-0004-HP

1-Butyl-3-methylimidazolium iodide Iodine tert.-Butylpyridine Guanidin Thiocyanate Acetonitril/Varelonitril	25 g 50 g 100 g 250 g 500 g 1 kg 5 kg

General Terms and Conditions

I. General
These General Conditions of Sale and Delivery shall be an integral part of the contract of purchase. Conflicting or deviating conditions of purchase or other reservations made by the Buyer shall not be effective unless the Seller has expressly accepted them in writing for a particular order.

II. Offers, Orders
1. The Seller's offers shall not be binding with respect to price, quantity, delivery time and availability. 2. The Buyer's orders shall become binding on the Seller upon receipt by the Buyer of the Seller's written order acknowledgment (or invoice or delivery note).

III. Invoicing
1. The prices invoiced shall be the Seller's prices effective at the time of delivery plus statutory sales tax.
2. Should the Seller, in the interval between conclusion of the contract and delivery, effect a general price increase, the Buyer shall have the right to withdraw from the contract within two weeks of having been informed thereof, unless the price increase is exclusively due to an increase in freight rates. The right of withdrawal shall not apply to long-term supply contracts (contracts for the performance of a continuing obligation).
3. The weight of the goods on which the invoiced amount is to be calculated shall be ascertained in the dispatch department of the Seller's plant from which the goods are supplied unless the Buyer wishes them to be weighted, at his expense, by the railway authorities at the station of dispatch.

IV. Payment
1. The handing in of bills of exchange shall be subject to the Seller"s prior consent and shall not constitute payment. The maturity of bills shall not exceed 90 days from the invoice date. Discount expenses, bill charges, bill tax and similar expenses incurred in the period beginning 30 days after the invoice data shall be for the Buyer's account.
2. Where the Seller has reason to doubt the Buyer's solvency or credit worthiness and the Buyer is not prepared to effect advance cash payment or provide the Seller with security as requested, the Seller shall have the right to cancel that portion of the contract which he has not yet performed.
3. Deposits and advance payments shall be made inclusive of sales tax.
4. Payment shall not be deemed to have been effected until the amount has been cleared into one of the Seller's accounts.
5. The Seller reserves the right to use payments for the settlement of the invoices which have been outstanding longest, plus any interest on arrears and costs accrued thereon, in the following order: costs, interest, principal claim.
6. The Buyer shall not have the right to withhold payments. Counterclaims may only be offset if they are uncontested or have become res judicata.

V. Delivery
1. The Seller shall make every effort to effect delivery as early as possible. There shall be no fixed periods for delivery.
2. Should, notwithstanding the preceding paragraph, a fixed period for delivery have been agreed, and should the Seller default with the supply, the Buyer shall grant the Seller a reasonable respite, normally of four weeks.
3. Delivery shall be subject to punctual delivery of the appropriate goods by the Seller's own suppliers.
4. The day of delivery shall be the day on which the goods leave the Seller's plant or warehouse or, if that day cannot be ascertained, the day on which the goods are put at the Buyer's disposal.
5. The provision of packaging including tankers and tank containers by the Seller shall be subject to special conditions.

VI. Force Majeure, Impediments to Performance
Force majeure of any kind, unforeseeable production, traffic or shipping disturbances, fire, floods, unforeseeable shortages of labor, utilities or raw materials and supplies, strikes, lockouts, acts of government, and any other hindrances beyond the control of the party obliged to perform which diminish, delay or prevent production, shipment, acceptance or use of the goods, or make it an unreasonable proposition, s hall relieve the party from its obligation to supply or take delivery, as the case may be, as long as and to the extent that the hindrance prevails. If, as a result of the hindrance, supply and/or acceptance is delayed by more than eight weeks, either party shall have the right to cancel the contract. Should the Seller's suppliers fail to supply him in whole or in part, the Seller shall not be under obligation to purchase from other sources. In such cases, the Seller shall have the right to distribute the available quantities among his customers while at the same time taking into account his captive requirements.

VII. Shipment
1. The Seller reserves the right to choose the route and the mode of transport. Any additional costs resulting from special shipping requests made by the Buyer shall be borne by the Buyer. Unless prepaid freight has been agreed, the Buyer shall also bear any increases in freight rates which become effective after the contract has been concluded, any additional costs resulting from re-routing a consignment, storage expenses, etc.
2. The risk of destruction, loss or damage shall pass to the Buyer upon dispatch of the goods or, if they are collected by the Buyer, at the time they are placed at the Buyer's disposal.

VIII. Retention of Title
1. Title to the goods shall not pass to the Buyer until he has fulfilled all liabilities arising from his business connection with the Seller, which shall include settling accessory claims and claims for damages and honoring cheques and bills. Title to the goods shall also remain with the Seller if the Seller's claims have been included in a current account and the balance of this account has been struck and acknowledged.
2. If the Buyer defaults in his obligations to the Seller, the Seller shall have the right, without granting a respite and without cancelling the contract, to demand the return of the goods to which he retains title. Acceptance of the returned goods shall not constitute cancellation of the contract unless the Seller has expressly declared this in. If the Seller cancels the Contract, he shall have the right to demand appropriate compensation for having permitted the Customer to use the item for a certain period.
3. If goods to which the Seller retains title are processed into new products, the Buyer shall be deemed to be effecting such processing on behalf of the Seller without thereby acquiring any claims on the Seller. The Seller's title shall thus extend to the products resulting from the processing. If goods to which title is retained by the Seller are processed together with, mixed with or attached to goods to which title is retained by third parties, the Seller shall acquire co-ownership of the resulting products in the ratio of the invoice value of the goods owned by him to the invoice value of the goods owned by those third parties. If the goods, as a result of such mixing or attaching become part of a principal matter of the Buyer, the Buyer, by accepting these Conditions, assigns in advance his title to the new item to the Seller.
4. The Buyer shall be under obligation to provide, on behalf of the Seller, adequate storage of the goods to which the Seller retains title, to service and repair them at his expense and to insure them at his expense against loss and damage up to an extend which may reasonably be expected of a prudent businessman. By accepting these Conditions the Buyer assigns in advance to the Seller any claims which may accrue to him under the insurance policies.
5. As long as the Buyer duly meets his liabilities to the Seller, he shall have the right, in the normal course of business, to do as he wishes with the goods to which the Seller retains title. This shall not apply, however, if he and his customers have concluded an agreement according to which the Buyer must not assign his claims on them to third parties. The Buyer shall not have the right to pledge, chattel mortgage or otherwise encumber the goods to which the Seller retains title. When reselling the goods, the Buyer shall make the passing of the title subject to full payment of the goods by his customers.
6. By accepting these Conditions, the Buyer assigns in advance to the Seller any claims which may arise from a resale of the goods to which the Seller retains title, together with any incidental rights and security interests including bills of exchange and cheques, so as to provide the Seller with security for all claims he has on the Buyer as a result of the business connection. If goods to which the Seller retains title are sold together with other goods at a single price, the assignment shall be limited to the portion of the invoice value which covers the goods to which the Seller retains title. If the Buyer sells goods of which the Seller has co-ownership pursuant to clause VIII. 3., the assignment shall be limited to the portion of the invoice value which corresponds to the Seller's co-ownership. If the Buyer uses goods to which the Seller retains title for processing a third party's product on a contract basis, in accepting these Conditions he assigns in advance his contractual claim on the third party to the Seller in order to provide him with security for his claim. As long as the Buyer duly meets his liabilities to the Seller, he may collect claims from a resale or from contract processing himself. He shall not have the right to assign or pledge such claims as security.
7. If the Seller believes his claims to be at risk, the Buyer shall, at the Seller's request, inform his customers of the assignment of his claims to the Seller and supply the Seller with all necessary information and documents. Any acts of third parties aimed at seizing goods to which the Seller retains title or at appropriating claims assigned to him shall be brought to the Seller's attention by the Buyer immediately.
8. If the value of the security provided to the Seller exceeds the value of the claims to be safeguarded by more than 20 per cent, the Seller shall, at the Buyer's request, bring the excess coverage down to 20 per cent by releasing security of his own choice.

IX. Damages
1. No claims for compensation may be lodged by the Buyer - including those of a non-contractual nature - for any minor negligent breach of duty by the Seller, his executive staff or other agents, unless such breach concerns a duty that is crucial for the object of the contract.
2. The Seller shall only be liable for indirect damage or damage which could not be foreseen at the time of conclusion of the contract if such damage is due to a gross fault on the part of the Seller or one of his managerial employees.
3. The above limitations shall not apply to damage resulting from death, injury or damage to health.However, this shall not affect the applicablility of compelling statutory liability regulations such as, for example, liability for the assumption of a guarantee or product liability law.

X. Notification of Defects
1. Notification of defects shall only be recognized if filed in writing within two weeks of receipt of the goods, together with supporting evidence, samples and packing slips, stating the invoice number and date, and the markings on the packaging.
2. Hidden defects must be notified to the Seller immediately upon discovery, but not later than five months after receipt of the goods. This shall not affect the periods of limitation. The burden of proving that a defect is a hidden defect shall rest with the Buyer.
3. Goods forming the subject of a complaint shall not be returned to the Seller except with the Seller's express consent.

XI. Buyer's Rights in the event of Defects
1. Warranty claims made by the Buyer shall only entitle the Buyer to be supplied with a replacement. If the replacement provided by the Seller is also defective, the Buyer may reduce the purchase price or opt to cancel the contract. Claims for damages as defined in Section IX shall remain unaffected by the above. Claims made by the Buyer due to expenses incurred as a result of reworking, in particular transport, travel, labor and material costs, shall be excluded where such expenses have been increased by the fact that the item was subsequently transported to a location other than the premises of the party placing the order, unless the goods were supplied to this location in line with their intended use.
2. In the event of recourse to the guarantee by the Buyer following a successful claim against the latter on the basis of the provisions governing the purchase of a consumer good, the claims under a right of recourse in accordance with the regulations on the purchase of consumer goods shall remain unaffected. Section IX shall apply to any claim for damages.
3. The Buyer must inform the Seller without delay of any case of recourse within the supply chain. Statutory claims under a right of recourse by the Buyer against the

Seller shall not apply with respect to arrangements entered into by the Buyer with its customer over and above statutory warranty claims.
4. Any guarantee agreement must be made in writing. A statement of guarantee shall only be effective if it describes the content of the guarantee and the duration and physical scope of guarantee protection in sufficient detail.

XII. Periods of Limitation

In cases that fall under § 438, paragraph 1, no. 3 of the Federal Civil Code (BGB), warranty claims shall expire with effect from one year from the beginning of the statutory period of limitation. In cases that fall under § 438, paragraph 1, no. 2 of the Federal Civil Code (BGB) warranty claims shall expire with effect from two years from the beginning of the statutory period of limitation. Compelling regulations governing the statutory period of limitation or the question of liability, such as, for example, liability for the assumption of a guarantee, liability for willful intent and gross negligence, for death, physical injury or damage to health, for the violation of essential contractual obligations, liability in accordance with the product liability law and the provisions relating to the sale of consumer goods shall remain unaffected.

XIII. Properties of Goods, Technical Support, Use and Processing

1. The properties of the goods shall as a general rule only include the properties as stated in the product descriptions, specifications and labeling of the Seller. Public statements, claims or advertising shall not be classed as information on the properties of the item for sale.
2. Technical advice provided by the Seller verbally, in writing or by way of trials is given in good faith but without warranty, and this shall also apply where proprietary rights of third parties are involved. The Seller's technical advice shall not release the Buyer from the obligation to test the products supplied by the Seller as to their suitability for the intended processes and uses The application, use and processing of the products are beyond the Seller's control and therefore entirely the Buyer's responsibility.

XIV. Trademarks

1. The Buyer shall not have the right to refer to the Seller's products when offering or supplying substitute products or, in price lists or similar business communications, to use the word "substitute" in conjunction with the Seller's - protected or unprotected product designations or list these designations together with any designations for substitute products.
2. When using the Seller's products for manufacturing purposes or when processing them into new products, the Buyer shall not have the right, without the Seller's prior consent, to use the Seller's product designations, especially his trademarks, on the resulting products or on the packaging therefore or in any relevant printed matter or advertising literature, particularly by mentioning the Seller's products as components of his own products. The supply of goods under a trademark shall not be deemed agreement to the use of this trademark for the products manufactured therefrom.

XV. Place of Performance and Jurisdiction, Invalidity of Individual Clauses

1. Place of performance for delivery shall be the Seller's dispatch department; place of performance for payment shall be "Freiburg im Breisgau".
2. Place of jurisdiction for both parties shall be Freiburg im Breisgau. The Seller shall furthermore have the right to sue the Buyer at the Buyer's general place of jurisdiction.
3. Should any clause in these General Conditions of Sale and Delivery be or become invalid, this shall not affect the validity of the remaining clauses or remaining parts of the clause concerned. T he parties shall replace any invalid arrangement by an effective one which conforms as far as possible to the economic purpose of the invalid clause.

Heilbronn, April 2017