EL-CELL®

Instrumentation for battery research

Product Overview

Fall 2020


0V
1V
2V

We Advance Battery Research.

EL-Cell GmbH was founded 10 years ago in Hamburg, Germany. Since then, we have been developing laboratory equipment for research of energy storage systems, with particular focus on lithium-ion technology. We are distinguished by our expertise in electrochemistry and mechanical engineering as well as our eager ambition to develop innovative products.

We strongly believe that reliable and simple 3-electrode measurements are the most efficient way to develop new battery materials. This approach proves to be particularly useful in our PAT (**PA**rallel **T**esting) series, a modular test cell system with the highest standards of efficiency and ease of use. In addition, we offer a variety of in-situ test cells as well as tools for manufacturing battery components in the laboratory.

Our complete range of services is rounded out with our own potentiostats, which are precisely tailored to the special requirements of battery research.

This allows us to provide you with the complete set-up from a single source to carry out electrochemical experiments.

We also offer hands-on seminars so you can familiarise yourself with our instruments and benefit directly from our expertise. The training takes place in our own fully equipped battery lab, where we will also gladly perform a variety of measurement services for you. We are also readily available to find specific solutions for your individual tasks.

This brochure provides an overview of our current products and services.

Content

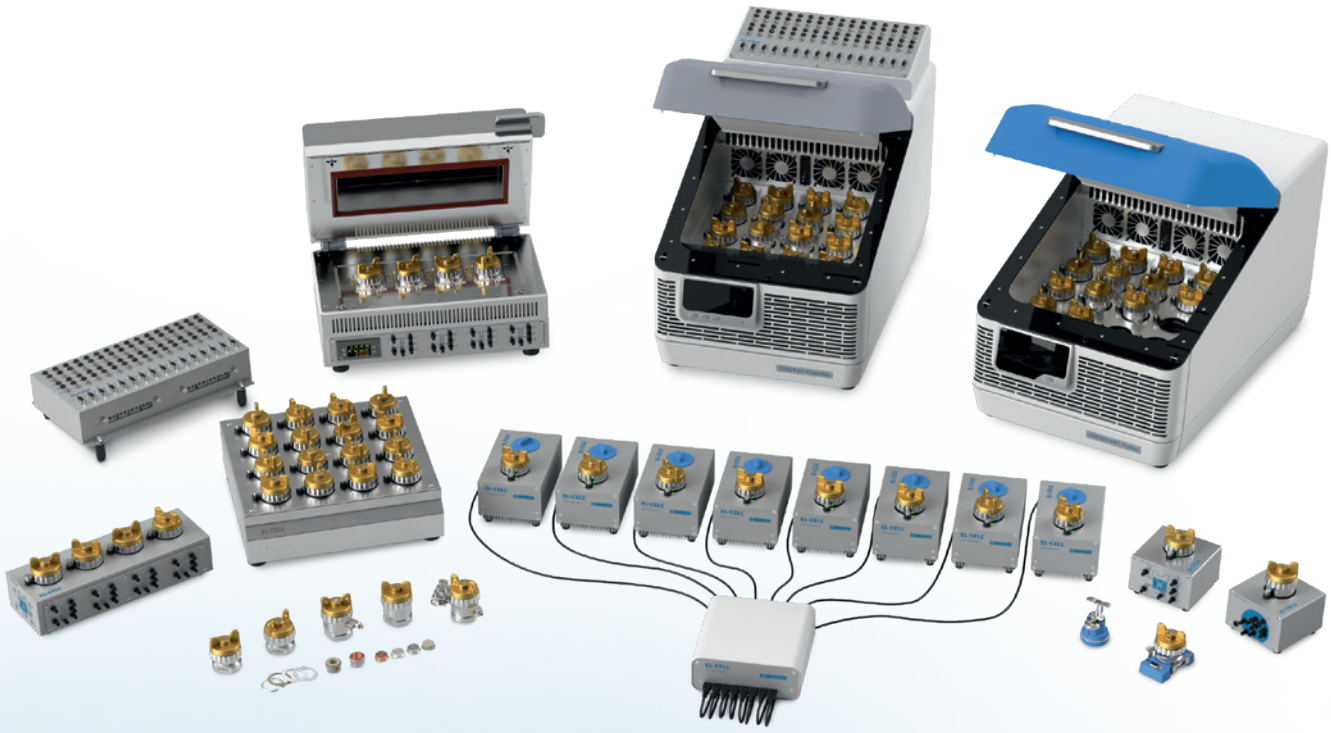
The PAT Series

Our modular system for testing of battery materials

Our PAT series is explicitly designed for efficient research of battery materials. The equipment is easy to use and still flexible enough to easily adapt it to unique test requirements. The main purpose of the PAT system is to improve the workflow from experiment design to results analysis. Recurring work, such as converting test set-ups, rewiring test cells, and programming test procedures, is kept to a bare minimum, which significantly reduces the risk of user errors. This in turn frees up more time for the user to fully focus on the experiment.

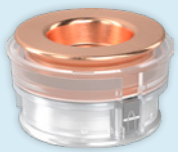
All PAT-Cells are designed for long-term measurements with three electrodes. You can record the electrical properties of the full cell and both half cells simultaneously with just one test run. These features significantly reduce the time and effort involved in testing compared to 2-electrode cells, such as commercially available coin cells.

The PAT system offers prefabricated single-use components for high-throughput testing as well as reusable components for smaller tests and tests involving special requirements. Other workflow enhancements, including the cableless design as well as digital cell recognition through the new PAT button, attest to our commitment to providing battery researchers with reliable and easy-to-use tools.



Speed up your battery testing

Step 1: Configure the PAT-Core



The PAT-Core is a customizable container for your battery / supercapacitor material

- Modular concept to fit almost all testing purposes
- Built-in ring reference for 3-electrode measurements
- Built-in separator
- Assembly highly reproducible
- Single-use and reusable components available
- Non-destructive disassembly enables for post-mortem analysis

Step 2: Setup the PAT test cell

PAT-Cells are available in multiple cell designs

- Long term testing (>1000 hrs) with two or three electrodes
- Cableless design saves space and time
- Test cells are helium leak tested for high tightness
- Automated identification available (PAT-Button)
- Test cells ready for robotic assembly in high-throughput setups

Step 3: Run your test either in a PAT battery tester or PAT docking station

PAT battery tester

Fully featured battery tester with integrated docking station and optional climate chamber

- Each channel with fully featured potentiostat / galvanostat / impedance analyser
- Integrated temperature chamber available
- EL-Software for experiment design, monitoring and analysis

PAT docking stations

For use with third party battery tester

- No cell cabling required. The docking station can remain permanently connected to an external battery tester or multi-channel potentiostat.
- Charge / discharge / EIS with any PAT cell
- Low space requirements, fits inside a climate chamber
- Integrated temperature control available

PAT-Core

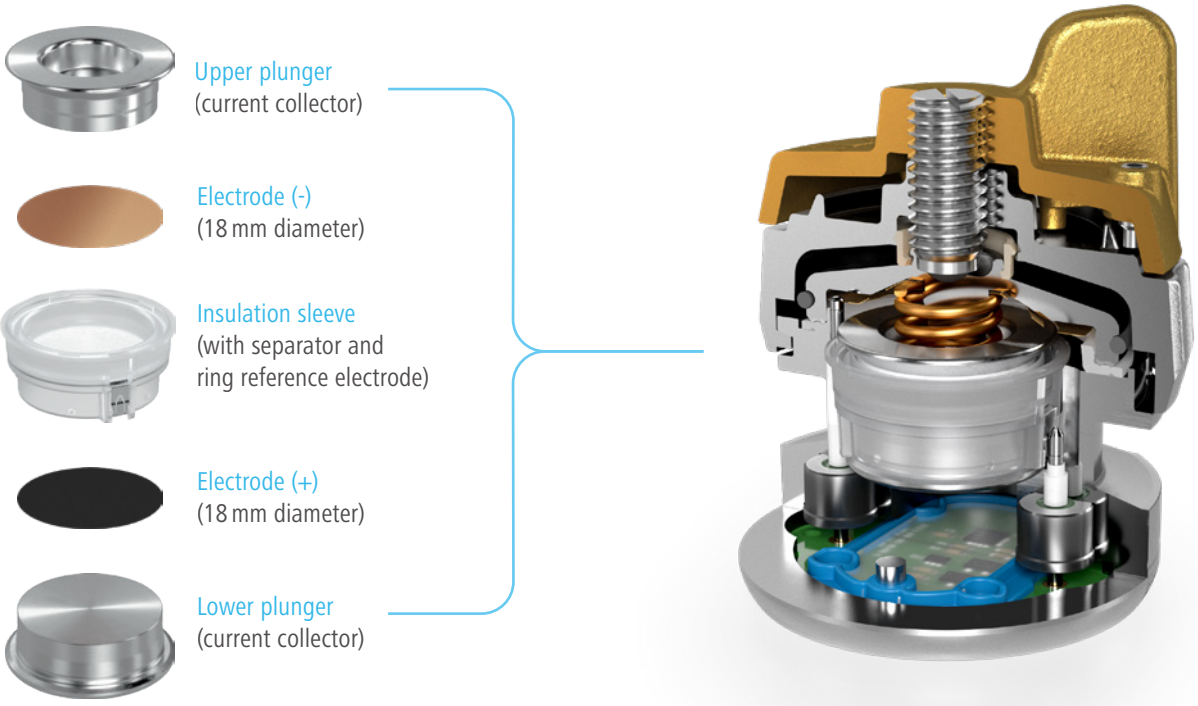
Enabling battery studies of unmatched quality

The PAT-Core is the world-wide patented, essential part of the PAT-Cell. It holds the electrodes undergoing testing in place and allows for precise alignment of the cell stack. The well-defined geometry of the PAT-Core enables high-quality two- and three-electrode tests of Li-ion and other battery materials as well as supercapacitors. The easy assembly of the PAT-Core minimizes the human factor in experiment preparation and even qualifies for robotic assembly. The standard PAT-Core comprises three components. The first part is a highly customizable insulation sleeve with a built-in separator and ring-shaped reference electrode. Different reference materials like sodium or magnesium and various separator materials such as glass fibre or microporous polyolefin are available. The single-use concept lowers lead times in the lab and minimizes the risk of cross-contamination.

The insulation sleeve is preassembled under a protective argon atmosphere at the EL-CELL® factory to ensure consistent quality for reproducible battery tests. PEEK is now made available as alternative material for the insulation sleeve; this way we are also able to offer the insulation sleeve as a reusable version for self-assembly.
The upper and lower plungers complete the PAT-Core and serve as current collectors. Battery researchers can choose from a broad range of different materials: battery-grade aluminum and copper, reusable stainless steel or precious metals, such as gold or platinum for special demands.
This way the PAT-Core is ready for both aprotic and aqueous electrolytes as well as special purposes such as high temperature environments.

Highlights of the PAT-Core

- High-precision concentric geometry of cell stack without manual alignment
- Modular concept adaptable for various configurations
- Long-term (>1000 hrs) half-cell measurements with three electrodes
- Easy, reproducible and automatable assembly - with and without reference electrode
- All battery-grade materials available: Al, Cu, polypropylene
- Optionally reusable insulation sleeve and current collectors



PAT-Core Configurations

The PAT-Core components: Perfectly adjustable for your experiment

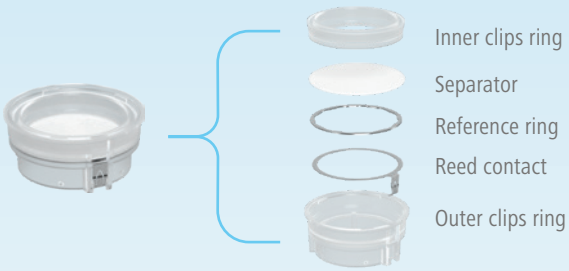
Different test cases require flexible cell configurations. PAT-Core components are available in a variety of materials to perfectly match the needs of your experiment. The examples shown below provide an overview of only the most common applications. We continuously expand the PAT system to include new chemistries.

Configuration examples	Aprotic $LiPF_6$ based electrolytes 	Aqueous supercap electrolytes 	Aprotic high-temperature electrolytes 
Lower electrode (+)	LCO / NCM / LFP..	Activated carbon	LCO / NCM / LFP..
Upper electrode (-)	Li metal	Activated carbon	Graphite / LTO
Lower plunger	Stainless steel or aluminum	PEEK with gold current collector	Stainless steel or aluminum
Upper plunger	Stainless steel or copper	PEEK with gold current collector	Stainless steel or copper
Insulation sleeve	Insulation sleeve (PP) with built-in reference ring (lithium), reed contact (nickel) and separator (FS-5P)	Insulation sleeve (PEEK), for self-assembly	Insulation sleeve (PEEK), for self-assembly
Reference	Contained in insulation sleeve	Activated carbon	Li metal
Separator		Whatman GF / A	Whatman GF / A
Reed contact		Gold plated stainless steel	Nickel plated stainless steel

Insulation sleeves for the precise concentric alignment of your cell stack.

There are two types of insulation sleeves for the PAT-Core. The variant made of polypropylene is a single-use item with built-in separator, ring reference and reed contact. The single-use concept lowers lead times in the lab and is the perfect choice for high-throughput testing. The PEEK variant on the other hand is reusable and optimal for higher temperatures (up to 200 °C). It is assembled before each testing so you can modify its components easily. It is the right choice for small scale testing and the more unusual ideas.

Insulation sleeve (PP) for single-use



- No cross-contamination
- No cleaning or drying required
- Preassembled for lower lead time
- Operation temperature up to 70°C

Insulation sleeve (PEEK), reusable

- Reusable PEEK component(*)
- Easily adaptable before each test
- Operation temperature up to 200°C

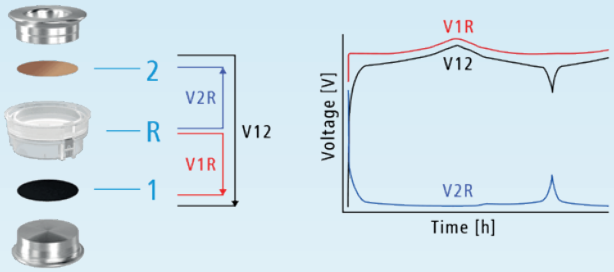
PAT-Core Configurations

Different separator materials for your test case

The following table shows our most common separator materials. Preassembled insulation sleeves using your own separator materials are available upon request.

Separator types	**FS-5P** (Freudenberg Viledon FS 2226E + Lydall Solupor 5P09B)	**Freudenberg Viledon FS 3005-25**	**Whatman GF/A**
Thickness	220 µm	25 µm	260 µm
Material	PP fibre / PE membrane	PET fibre, Al_2O_3	Borosilicate glass fibre
Porosity	FS: 67 % / 5P: 86 %	55 %	91 %
Wettability	Good	Good	Excellent
Resistance to dendrites	Good	Poor	Modest
Ability for full cell cycle tests	Excellent	Good	Good
Ability for half cell cycle tests (vs. Li)	Excellent	Poor	Modest
Ability for full cell EIS	Excellent	Excellent	Excellent
Ability for half cell EIS	Good	Poor	Good

The power of testing with a reference electrode



By monitoring the cell voltage and cell current of the battery, you can learn a lot about the performance and ageing of the battery as a whole.

However, a battery comprises two electrodes connected in series: cathode and anode. Which of the two is the bottleneck for charge transfer? Which electrode is dying off first? Using a reference electrode is the most convenient way to answer these questions.

The insulation sleeve of the PAT-Core is available with different built-in reference rings and separators. For Li-ion based systems we consider Li metal together with the polyolefin based separator FS-5P as a favorable solution. Many variants of the insulation sleeve are available for other battery chemistries including Mg, Na-ion and supercapacitors.

When used with a powerful battery tester such as the PAT-Tester-i-16, the reference electrode enables you to measure the electrochemical properties of both electrodes at the same time.

Advanced Use Cases with the PAT-Core

Testing with a finger-shaped reference electrode

Sometimes a finger-shaped reference electrode can be better than our standard ring-shaped reference electrode. The finger reference measures the electrical potential in the middle of the stack instead of at the outer edge of the cell stack. This can help to minimize artifacts caused by inhomogeneities of the electric field. The finger is made of stainless steel and coated with polyimide, except for the measurement area at the end of the finger. Different geometries of the finger are available.

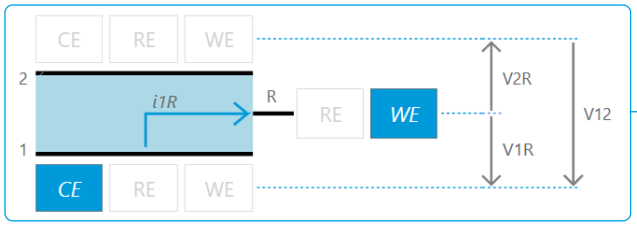
The finger-shaped reference electrode is considered useful for several scenarios:

- It can be employed as a stainless steel pseudo-reference electrode.
- It can be coated by the user with a reference material (e.g. LTO).
- It can be lithiated or delithiated by the user in-situ after cell assembly.

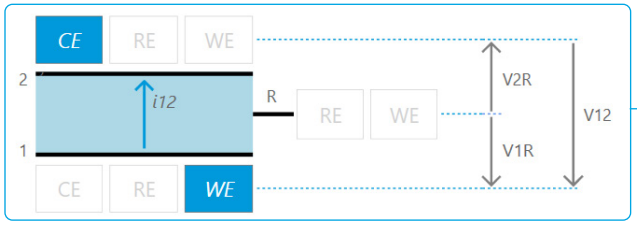
All these scenarios are perfectly supported by our PAT battery testers, like the PAT Tester-x-8 and EL-Software. This is shown here using the example of a cell consisting of NCM and graphite. After building the cell, the stainless steel finger is first electroplated with lithium utilizing the NCM electrode as the lithium source. In the second step, the lithiated finger is used as a stable reference electrode when cycling the NCM / graphite cell. Switching between the two modes is easy to do in the test script. No cable connections need to be changed, as would be necessary with a conventional battery tester.

PAT-Core with finger-shaped reed contact

EL-Software makes pre-lithiating a simple task.



Step 1: Pre-lithiation of the finger-shaped stainless steel electrode (R) from the NCM electrode (1)



Step 2: Once lithiated, the R electrode serves as a true reference when cycling the NCM / graphite cell.

PAT-Tester-x-8 running the EL-Software test script with a PAT-Cell.

PAT-Core Components

The PAT-Core is a modular system that meets the requirements of almost any test scenario. It is compatible with all PAT-Cells. Custom materials are available upon request.

Separators

Freudenberg FS 3005-25
25 µm
PET fibre, Al_2O_3

Whatman GF/A
260 µm
Borosilicate glass fibre

FS-5P
220 µm
Double layered separator:
PP fibre + PE membrane

Customized
?
Provided by customer

Reference rings

Lithium

Aluminum

Activated Carbon

Magnesium

Sodium

Reed contacts

Nickel

Gold

Stainless steel

with finger-shaped reference electrode
(partly coated with polyimide)

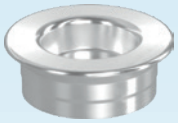
Insulation sleeves

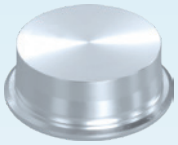
PP
- Single-use
- Preassembled

PEEK
- Reusable
- Heat resistant (up to 200 °C)
- For self-assembly

Current collectors: Plungers and discs

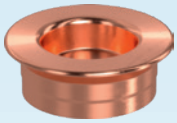
Aluminum

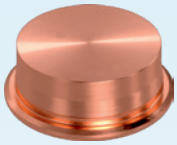




- Single-use
- Battery grade material
(Al 99.5, EN-AW-1050)

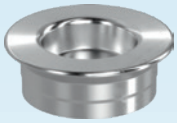
Copper

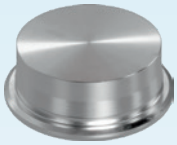




- Single-use
- Battery grade material
(Cu 99.9, E-CU 58)

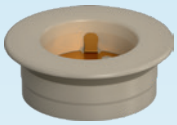
Stainless steel

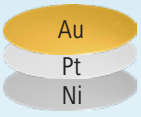




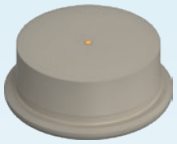
- Reusable
- Stainless steel
(316L, 1.4404)

PEEK





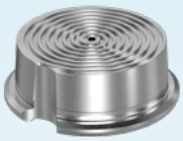
Current collector discs



- Reusable
- Corrosion resistant

Stainless steel / Nickel

- With perforated plate for gas analysis



- With flow field for time resolved gas analysis

PAT-Cell

Our electrochemical test cell for two- and three-electrode testing

The PAT-Cell is a test cell for 2- and 3-electrode measurements on battery materials. It uses the modular PAT-Core concept and can therefore be used for a variety of test purposes. The cell has no wiring but is inserted directly into a PAT battery tester or connected to any commercially available battery tester / potentiostat via a PAT docking station.

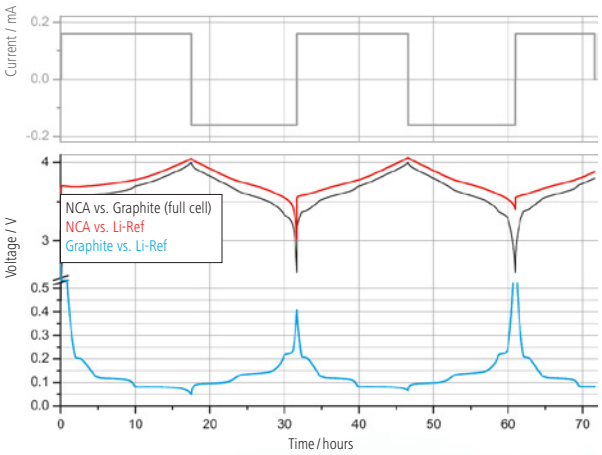
The easy handling is further improved by features such as the integrated PAT-Button. This electronic memory in the cell bottom enables automatic cell recognition when the cell is inserted into a PAT battery tester.

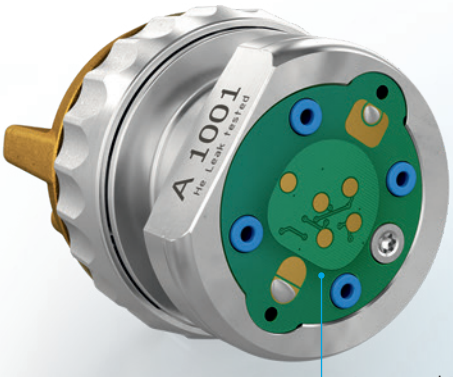
The PAT-Cell is equally suitable for automated high-thoughput scenarios and small-scale test series.

Features

- Cableless test cell with all the advantages of the PAT-Core
- For use with or without ring-shaped reference electrode
- Glass-to-metal seals for improved temperature resistance
- Leak-proof sealing with PE, PTFE, PEEK or aluminum seals
- Electronic cell ID (PAT-Button) for automatic cell identification
- Cell base made of stainless steel 1.4404 (316L) for compatibility with highly corrosive electrolytes.
- Guaranteed tightness: All PAT-Cells are helium leak tested at the EL-Cell factory.

Monitoring half-cell voltages during the initial cycles of NCA vs. Graphite





Integrated PAT-Button

PAT-Cell-Gas

PAT-Cell for in-situ gas analysis in a flow-through set-up

The PAT-Cell-Gas is a test cell dedicated for in-situ gas analysis of battery materials in a flow-through set-up. It combines all capabilities of the ECC-Air, ECC-DEMS and PAT-Cell-Press test cells. For that purpose, the test cell features a gas inlet and outlet and optionally a built-in pressure sensor and a valve port for gas sample removal with a syringe. The cell stack is placed on top of a perforated or grooved current collector (flow field), which is to be purged with a gentle stream of gas.

The lower electrode must be gas permeable, so as to allow for gas exchange with the feed gas. Typically, the cell is used with gas diffusion electrodes (such as for Li-air) or with Li-ion battery electrodes with a meshed current collector. The special design minimizes backmixing of the gas from the flowfield back into the headspace, and is thus very suitable for time-resolved gas analysis with a mass spectrometer, for example.

Features

- PAT series test cell with gas inlet and outlet (1/16 inch Swagelok Tube Fitting)
- PAT-Core design with or without ring-shaped reference electrode
- Lower plungers with perforated plate and with spiral-shaped flow field for optimized plug-flow available.
- Optional laser-welded pressure sensor, 0 to 3 bar abs.
- Optional gas sample port
- Electrode feedthroughs with glass-to-metal seals
- Optimized lid for use with metal seal
- Helium leak tested for high tightness

Special lower plunger with perforated plate

Lower plunger with spiral-shaped flow field

PAT-Cell-Gas Working Modes

Mode 1: Air mode

Upper plunger (current collector), stainless steel

Counter electrode e.g. LFP

Insulation sleeve (PP) with separator and reference electrode

Working electrode e.g. gas diffusion electrode

Lower plunger (current collector) with perforated plate, stainless steel

Gas flow inside the lower plunger

The lower plunger with perforated plate allows for electrochemical characterization of gas diffusion electrodes used for instance in Li-air batteries. The lower electrode is contacted by and "breathes" through the perforated stainless steel current collector supporting it. During operation, the pressure gradient building up between cell headroom and the gas volume below the perforated plate effectively prevents back-mixing. The relatively large volume below the perforated is at the expense of time resolution, but makes this solution robust against clogging of the gas path.

Mode 2: OEMS mode

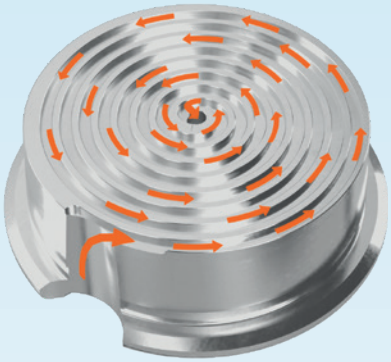
Upper plunger (current collector), stainless steel

Counter electrode e.g. LFP

Insulation sleeve (PP) with separator and reference electrode

Working electrode e.g. gas diffusion electrode

Lower plunger (current collector) with flow field, stainless steel



Gas flow along the surface of the lower plunger

The PAT-Core setup using a lower plunger with flow field provides almost perfect plug-flow of the purge gas being essential for quantitative time-resolved analysis. Gases evolved or consumed at the working electrode may be analysed through the composition change of the gas stream that is to be passed along the spiral-type flow field below the working electrode.

The composition of the outgoing gas can be analyzed by e.g. mass spectrometry. The pressure gradient between cell headroom and spiral-type flow field effectively prevents back-mixing. This and the tiny gas volume of the flow field ensure best possible time resolution.

PAT-Cell-Press

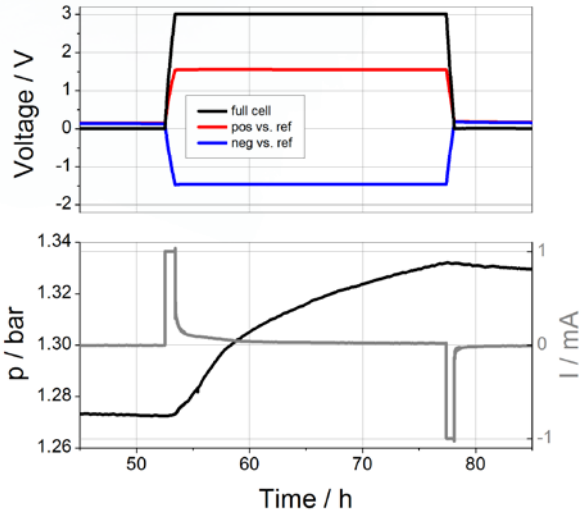
Pressure test cell for the PAT series

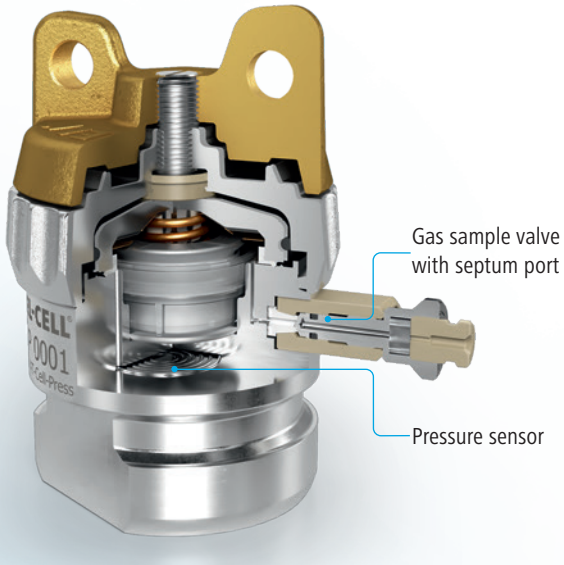
The PAT-Cell-Press is the PAT-Cell with an integrated pressure sensor and a sample port for drawing gas samples from the cell's headspace. The PAT-Cell-Press can be operated in three different ways: either as part of the PAT-Press package, plugged into the PAT-Chamber-16, or plugged into a PAT battery tester like the PAT-Tester-i-16. The advanced design of the PAT-Cell-Press includes a laser-welded pressure sensor and glass-to-metal seals for the electrode feedthroughs. The number of non-permanent seals is reduced to its minimum: a single PEEK or metal seal between cell lid and base, and a ferrule when the cell is ordered with the optional gas sample port. In order to ensure best testing results, every PAT-Cell-Press has been tested to be free of leaks before delivery.

Features

- Laser-welded pressure sensor, 0 to 3 bar abs.
- Optional gas sample port (PAT-Cell Press S)
- Optional plunger for gas diffusion electrodes
- Optional high volume lid for increased inside gas volume
- PAT-Core design with or without ring-shaped reference electrode
- Electrode feedthroughs with glass-to-metal seals
- Tested for helium leaks
- Optimized lid for use with metal seal

Pressure response during cc/cv cycling of a supercapacitor*





* Test setup: PAT-Cell-Press S, activated carbon electrodes, activated carbon reference, 1M $TEABF_4$ in acetonitrile, 25 µm polyolefine separator (2 x), CCCV cycles, 1 mA, 0/3 V, 35 °C

PAT-Cell-HT

Heat resistant PAT-Cell for up to 200 °C

The PAT-Cell-HT is a special version of the PAT-Cell equipped for temperatures up to 200 °C. For this purpose, the PAT-Cell-HT must be operated with specialized PAT-Core components and the PAT-Heater-4 as the high-temperature docking station.

Specialized PAT-Core for the PAT-Cell-HT

Inner stick ring, PEEK

Separator, e.g. glass fibre, or solid state electrolyte membrane

Reference ring, e.g. lithium metal

Reed contact

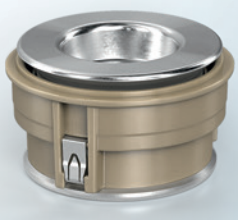
Outer stick ring, PEEK

Specialized PAT-Core components

To meet the challenges of battery tests at elevated temperatures up to 200 °C, we offer a specialized version of the insulation sleeve. This reusable sleeve is made of PEEK (rather then PP) and is especially useful for the investigation of solid state electrolyte membranes. Just like the standard sleeve, the PEEK insulation sleeve can be equipped with different reference materials. The standard current collectors (plungers) complete the PAT-Core. Available plunger materials are aluminum and copper (for single use), or stainless steel 316L (for reuse).

Features

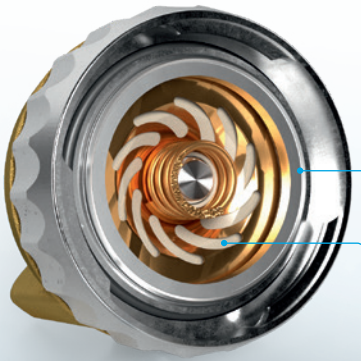
- PAT series test cell for 2-or 3-electrode testing at elevated temperatures
- Continuous operating temperature: up to 200 °C
- Glass-to-metal seals for improved temperature resistance
- Superior corrosion resistance for next-generation battery chemistries
- Compatible with liquid aprotic electrolytes and solid state electrolyte membranes



Optional Accessories for PAT Test Cells

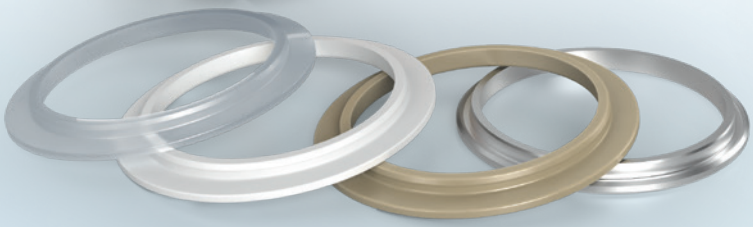
High volume screw cap
Adjust the dead volume from 4.4 ml up to 17.9 ml

Volume adjustment inlets



Screw cap for metal seal
Aluminum sealing ring for high tightness demands

Insulation lid inset

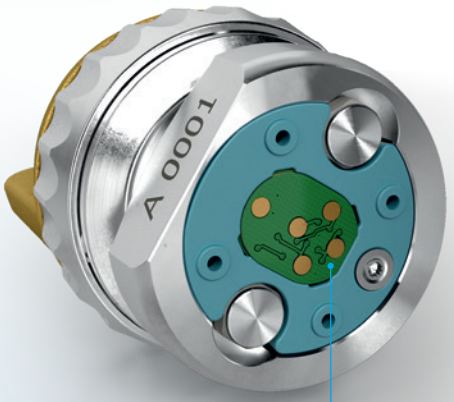


Sealing ring PE

Sealing ring PTFE

Sealing ring PEEK

Sealing ring Al



PAT-Button Upgrade Kit
Upgrade your PAT-Cells with an integrated EEPROM chip. It offers automated cell identification inside a PAT battery tester.

PAT-Clamp-1

Docking station with minimized dimensions

The PAT-Clamp-1 is our smallest docking station for a single PAT test cell. It was developed for tight space constraints. The socket can be left connected permanently to a common potentiostat or battery tester using 2 mm banana sockets or Sub-D connector. Therefore, there is no need to renew the connection between cell and potentiostat for every battery test. It also fits perfectly into any climate chamber with a cable feed-through and can be placed inside a glovebox. The cell is inserted and removed by bending up the clamp.

The PAT-Clamp-1 allows immediate functional testing of all PAT series test cells with smallest possible footprint. The PAT-Clamp-1 is often used in addition to a high-throughput solution. For instance, 16 PAT-Cells can be cycled in parallel in a PAT-Chamber-16 connected by a third-party battery tester without impedance capability. In that case, the impedance of each test cell can be measured before and after the cycle test in the PAT-Clamp-1 connected to the PAT-Tester-x or another impedance analyser.

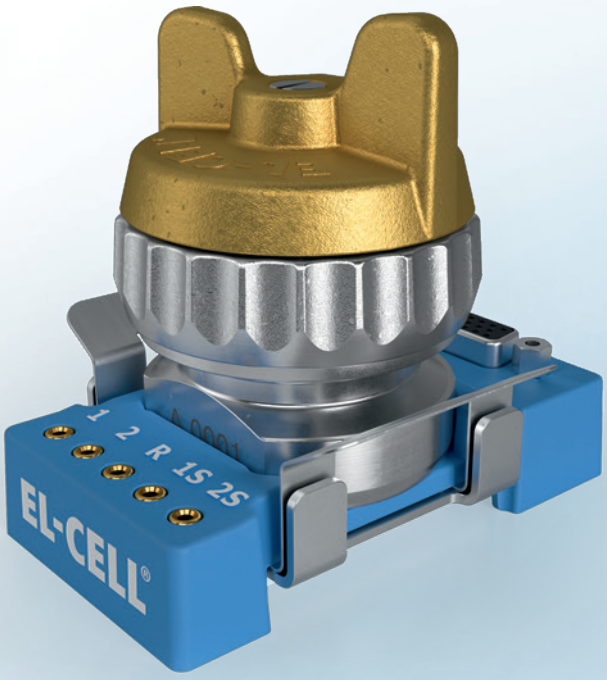
Features

- Socket for one PAT series test cell (charge / discharge / EIS compatible, please refer to the PAT-Compatibility table)
- Compatible with any potentiostat and battery tester
- Can be used inside a glove box environment
- Fits into tight spaces
- Flexible wiring via 2 mm banana sockets
- Saves wiring effort and space in the lab

Size comparison PAT-Clamp-1 and PAT-Stand-1

Technical Specifications

- Width x depth: 80 mm x 62 mm
- Height: 21 / 83 mm (without / with PAT-Cell-Press)
- Weight: 0.12 kg (without PAT-Cell)



PAT-Stand-1

PAT-Cell docking station for individual battery testing

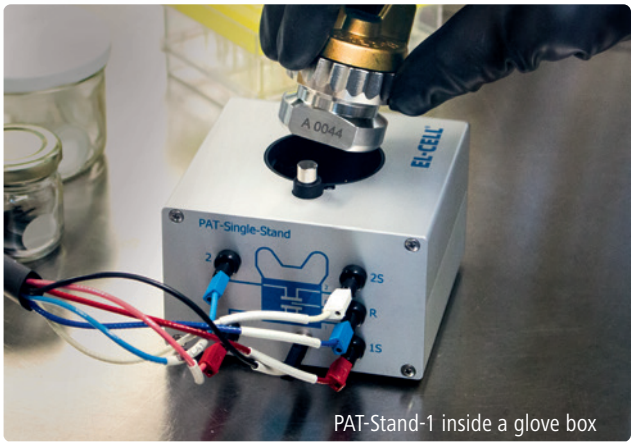
The PAT-Stand-1 is our standard docking station for a single PAT series test cell. The stand can be left connected permanently to a common potentiostat or battery tester using 4 mm banana sockets. No need to renew the connection between cell and potentiostat for every battery test. It also fits nicely into any climate chamber with a cable feed-through and can be placed inside a glovebox.

Thanks to the docking socket and push-button release, the PAT-Stand-1 is most comfortable to use by one hand. It allows immediate functional testing of all PAT-series test cells. Typically, it is used in combination with a high-throughput solution.

The PAT-Stand-1 is the most comfortable single docking station.

Features

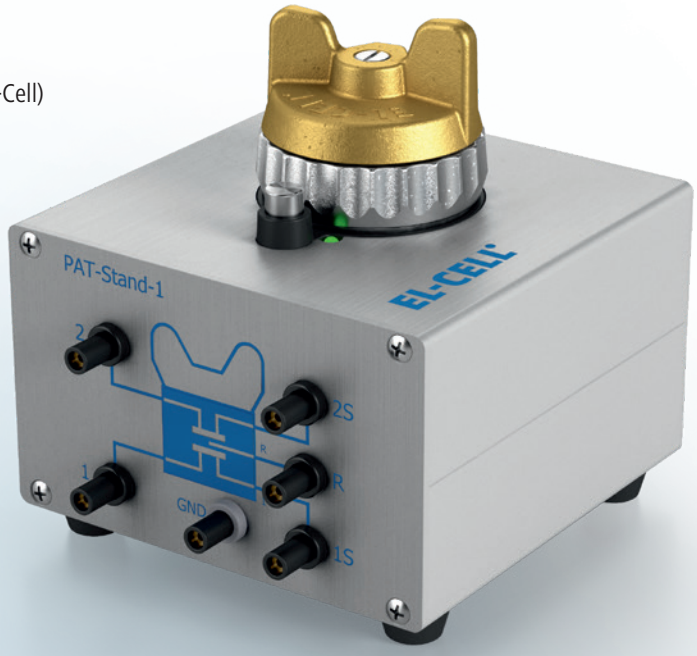
- Socket for one PAT series test cell
- Charge / discharge / EIS compatible with any PAT series test cell (please refer to the PAT-Compatibility table for further details)
- Compatible with PAT-Tester-x and any other potentiostat and battery tester
- Can be used inside a glove box environment
- Flexible wiring due to easy to access 4 mm banana sockets or Sub-D connector
- Saves wiring effort and space in the lab



PAT-Stand-1 inside a glove box

Technical Specifications

- Width x depth: 105 mm x 113 mm
- Height: 80 / 110 mm (without / with PAT-Cell)
- Weight: approx. 0.5 / 1 kg (without / with PAT-Cell)



PAT-Stand-4

Scale up of individual battery testing

The PAT-Stand-4 is a docking station connecting up to four PAT-Cells to any potentiostat or battery tester. The PAT-Stand-4 saves wiring effort, because it is not necessary to renew the connection between cell and potentiostat for every battery test.

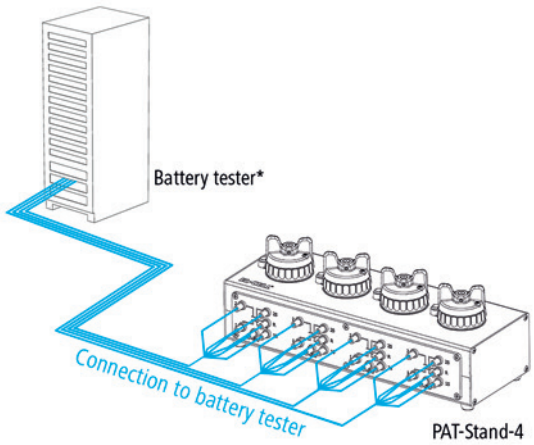
The easy-to-access banana sockets at the side of the docking station allow for flexible switching between operation modes (full cell, cathode half cell, anode half cell).

The PAT-Stand-4 enables you to perform simultaneous battery tests on a small scale.

Features

- 4 x 1 docking station for up to 4 PAT series test cells
- Compatible with all of today´s multi-channel potentiostats and battery testers
- Charge / discharge / EIS compatible with any PAT series test cell (please refer to the PAT-Compatibility table for further details)
- Can be placed on the bench, inside the temperature chamber, or inside a glove box
- Flexible wiring due to easy-to-access banana sockets
- Saves wiring effort and space in the lab

Schematic view of a connected PAT-Stand-4



* Any third-party battery tester can be used with the PAT-Stand-4

Technical Specifications

- Width x depth: 301 mm x 119 mm
- Height: 84 / 114 mm (without / with PAT-Cells)
- Weight: approx. 1.5 kg (without PAT-Cells)

PAT-Stand-16

High-throughput docking station

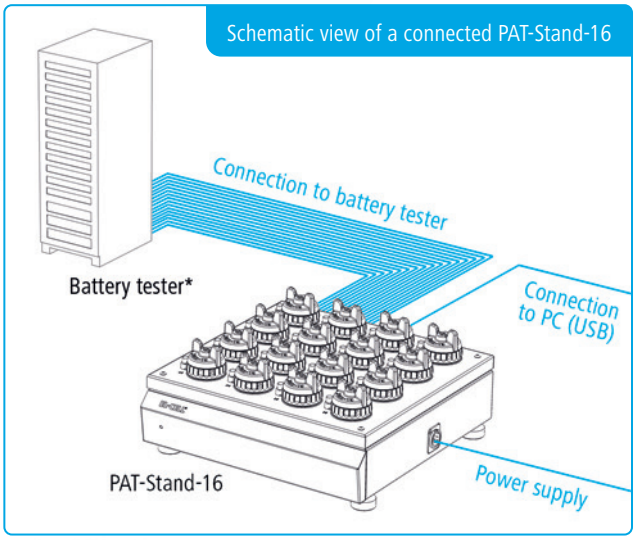
The PAT-Stand-16 is the docking station for up to 16 PAT-Cells in a 4 x 4 array. It has a built-in data logger recording full- and half-cell voltages, cell current, tray temperature and time. The PAT-Stand-16 can be operated with a standard multi-channel potentiostat (like the Biologic MPG-2 or VMP300) or battery tester (like the Maccor 4000). The PAT-Stand-16 saves wiring effort, because it is not necessary to renew the connection between cell and potentiostat for every battery test.

Furthermore, it fits nicely into a normal climate chamber (such as Binder KB53), which saves space in the lab.
A typical setup comprises the PAT-Stand-16 placed inside a temperature chamber and an external 16-channel battery tester.

The PAT-Stand-16 is the entry-level solution for high-throughput testing with the PAT system.

Features

- 4 x 4 docking station for up to 16 PAT-Cells
- Integrated data logger for recording of cell data (current, full- and half-cell voltages) and tray temperature
- Compatible with all of today's multi-channel potentiostats and battery testers
- Charge / discharge / EIS compatible with any PAT-series test cell (please refer to the PAT-Compatibility table for further details)
- Can be placed on the bench or inside temperature chamber
- Saves wiring effort and space in the lab
- Flexible wiring possible with optional PAT-Connect-16



* All available battery testers can be used with the PAT series

Technical Specifications

- Width x depth: 315 mm x 315 mm
- Height: 120 / 148 mm (without / with cells)
- Weight: approx. 7 kg (without cells)

PAT-Heater-4

Heated chamber for four PAT-Cell-HT

The PAT-Heater-4 is a heated docking station connecting up to four PAT-Cell-HT to any potentiostat or battery tester. The working temperature is adjustable from ambient temperature up to 200°C.

The PAT-Heater-4 saves wiring effort, because it is not necessary to renew the connection between cell and potentiostat for every battery test. The easy-to-access banana sockets at the side of the docking station still allow for flexible wiring.

The PAT-Heater-4 is the temperature-controlled docking station for parallel electrochemical tests at high temperatures up to 200 °C.

Features

- Heated chamber up to 200 °C
- 4 x 1 docking station for up to four PAT-Cell-HT
- Compatible with all of today´s multi-channel potentiostats and battery testers
- Flexible wiring due to easy-to-access banana sockets
- Saves wiring effort and space in the lab

Technical Specifications

- Width x depth: 400 mm x 265 mm
- Height: 230 mm
- Weight: 14 kg (without PAT-Cells)

PAT-Chamber-16

Temperature-controlled PAT series docking station

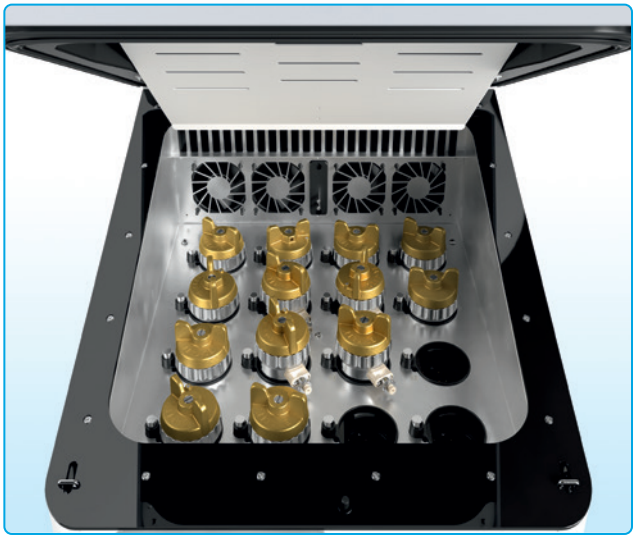
The PAT-Chamber-16 combines the high-throughput testing abilities of the PAT-Stand-16 with a temperature-controlled cell chamber. The integrated Peltier device enables you to test at the exact temperature you need, between +10 °C and +80 °C. The PAT-Chamber-16 is our first high-throughput docking station that is capable of utilizing both the PAT-Cell and the PAT-Cell-Press for in-situ pressure monitoring of up to 16 test cells at the same time.

Just like the PAT-Stand-16, the PAT-Chamber-16 comes with a built-in data logger recording full- and half-cell voltages, cell current, time, global temperature and individual cell pressure.
A typical setup comprises the PAT-Chamber-16 with PAT-Connect and an external 16-channel battery tester.

The PAT-Chamber-16 is the high-throughput testing solution with integrated temperature control.

Features

- Temperature-controlled docking station for up to 16 PAT series test cells
- Integrated Peltier device for temperature control between +10 and +80°C
- Ready for PAT-Cell-Press for pressure monitoring
- Charge / discharge / EIS compatible with any PAT-series test cell (please refer to the PAT-Compatibility table for further details)
- With data acquisition of cell current, cell voltage, half-cell voltages, global temperature, individual cell pressure
- Compatible with all of today's potentiostats and battery testers
- Flexible wiring possible with optional PAT-Connect-16



Technical Specifications

- Width x depth: 380 mm x 640 mm
- Height: 375 mm
- Weight: approx. 24 kg (without PAT-Cells)

Image shows PAT-Chamber-16 with top-mounted PAT-Connect-16.

PAT Battery Tester

EL-CELL® operates its own fully equipped electrochemical laboratory, where we perform a wide variety of test measurements for our customers and for our in-house product development. Our long-standing practical experience with electrochemical testing made us eager to develop test equipment that is specifically tailored to the needs of battery research, allowing us to exploit the full potential of our PAT-Cells.

We have incorporated our discoveries into the development of a new generation of battery testers, the EL-CELL® PAT tester series. Our focus is on convenient handling and minimising laboratory space as much as possible through high integration of core components and modern system architecture. Each test channel of a PAT battery tester contains a fully equipped potentiostat/galvanostat and impedance analyser as well as new, unique features. A connection matrix facilitates alternating between full-cell and half-cell control at runtime without having to change even a single cable. In an unprecedented way, impedance measurements may be combined with cyclic voltammetry and constant current cycles.

The brand new EL-Software enables networked, location-independent operation with a scalable number of test channels and devices.

From experiment design and test monitoring to test result analysis, the EL-Software supports the researcher through all important process steps. An easy-to-navigate database stores all information such as measurement results or applied battery components and thus provides optimal oversight. The open export interfaces allow seamless integration of EL-Software into existing software pipelines.

Two different product lines, based on the same system architecture, offer a variety of application options:

The PAT-Tester-i-16, a highly integrated device, combines a temperature controlled chamber, a docking station for up to 16 PAT-Cells and the battery tester with 16 fully equipped test channels. Minimal space requirement makes the PAT-Tester-i-16 the perfect solution for high-throughput test scenarios.

The PAT-Tester-x-8 is the perfect solution whenever maximum flexibility is required. Up to 8 test cells can be tested simultaneously in very different environments with this device: on the laboratory bench, in the glovebox, in a climatic chamber, or wherever else you want. The electronics of the single channel are identical to the one in the PAT-Tester-i-16. This guarantees the highest performance, not only for PAT-Cells, but also for all other EL-CELL® test cells as well as for coin cells and a variety of other cell formats.

PAT-Tester-i-16

PAT-Tester-x-8

Highlights

- Multi-channel battery cycler / potentiostat / galvanostat / impedance analyser with fully independent test channels
- Latest 24-bit hardware for highest accuracy
- Modern multi-user, multi-device architecture for maximum reliability and usability
- Perfectly tailored for PAT-Cells, and still open for other small cell formats
- Two product lines available:
  - PAT-Tester-i-16 with 16 channels and temperature control for high-throughput
  - PAT-Tester-x-8 with 1 to 8 channels for special purpose and maximum flexibility
- High operation reliability due to built-in solid-state disc serving as internal data buffer

PAT-Tester-i-16

The high-throughput test solution

Until now, battery research solutions for higher throughput were modular systems built around wired test cells or test cells docked into a docking station. The cells and docking stations needed to be placed into a temperature-controlled chamber and connected via many cables to a potentiostat / galvanostat outside.
Such modular and distributed set-ups are flexible, but have severe drawbacks such as a large foot print, an extensive cable harness, and susceptibility to experimental mistakes.
With the new PAT-Tester-i-16 we integrate all functions of a 16-channels battery tester, a PAT docking station, and a temperature-controlled test chamber into one single instrument.

The world-wide patented cableless connection between test cell and potentiostat saves space in your lab and eliminates wiring effort. Plug the PAT-Tester into the main power supply, connect it to your LAN and get full remote access from any host PC on the network!
The internal impedance analyser is capable of simultaneously recording both half-cell impedances while running constant current cycles or voltammetric experiments. Aquire the DC and AC characteristics of your test cells at the same time!
All test channels feature a connection matrix for software-controlled switching between half- and full-cell measurements without reconnecting any cables.

The PAT-Tester-i-16 enables intuitive PAT series testing with the smallest possible footprint.

Technical Specifications

- Width x depth: 380 mm x 640 mm
- Height: 375 mm
- Weight: approx. 26 kg (without PAT-Cells)

Sample Test Case

Learn about DC and AC characteristics of both half cells at the same time.

First cycle of a Li-ion battery – Combining constant current cycling with GEIS

Test setup:

- Battery tester: PAT-Tester-i-16
- Test cell: PAT-Cell with PAT-Core:
- WE: NCM 111 (CCI, approx. 2 mAh / cm²)
- CE: Graphite (CCI, approx. 2 mAh / cm²)
- RE: Li metal
- Separator: FS-5P (PP fibre + PE membrane)
- Electrolyte: 1M $LiPF_6$ in EC:DMC (1:1) with 2% VC (100 µl)

Test procedure:

CC charge / discharge with concurrent GEIS analysis

Test results:

The diagrams show the initial charge-discharge cycle of a PAT-Cell tested in the PAT-Tester-i-16. During the galvanostatic cycles, the impedance was measured every half hour between 10 kHz and 100 mHz.

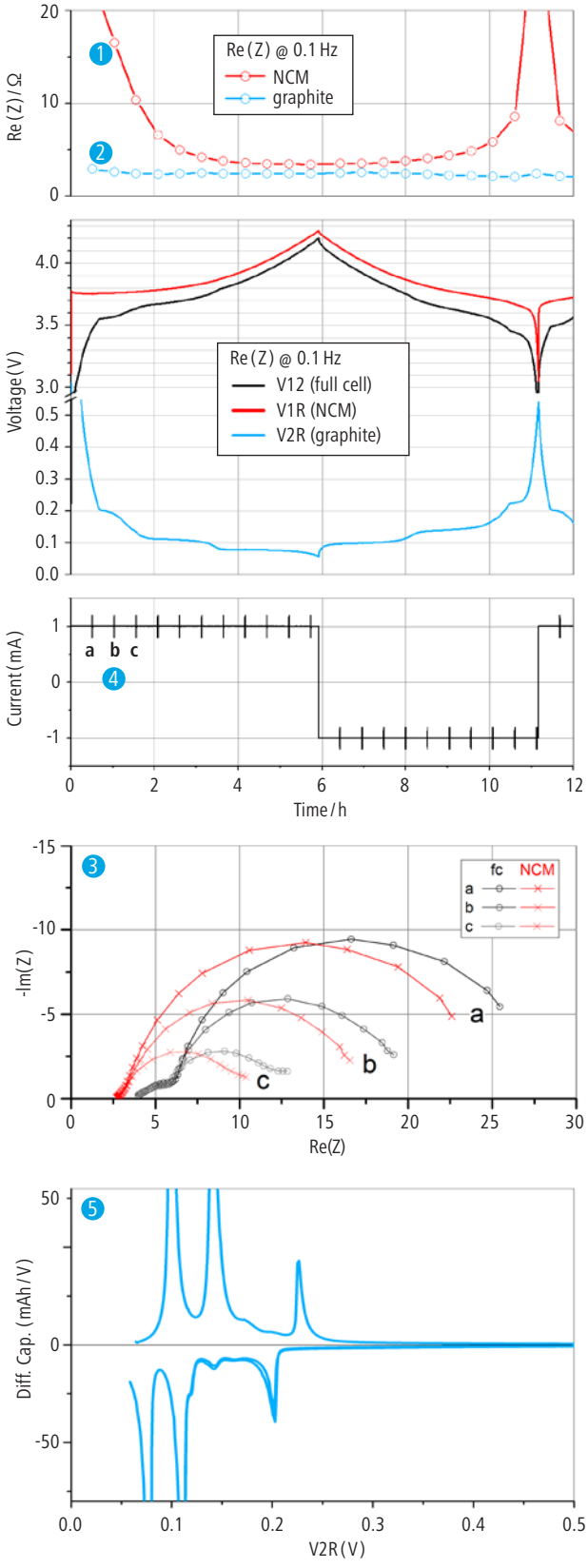
The first diagram shows the real part of the two half cell impedances (1 and 2) at 100 mHz extracted from the complete set of impedance data gathered during the experiment.

Another subset of EIS data is shown as Nyquist spectra (3) recorded at times a, b and c (4).

The last diagram shows the differential capacity of the graphite half cell, as already calculated during the test (5).

Conclusion:

Battery testing with the PAT-Tester-i-16 offers the unique possibility of measuring the DC and AC characteristics of both half cells at the same time.



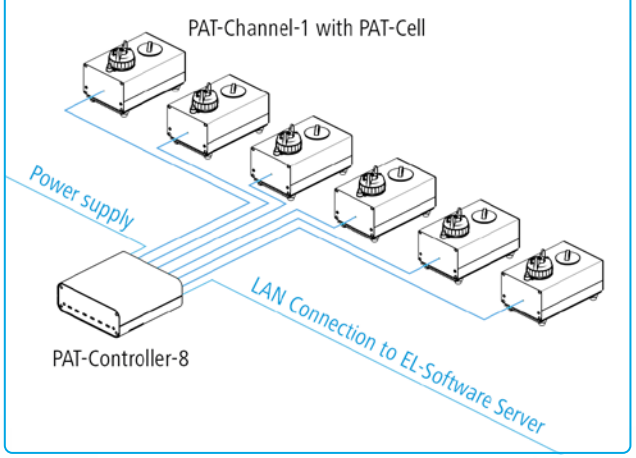
PAT-Tester-x-8

The individual test solution

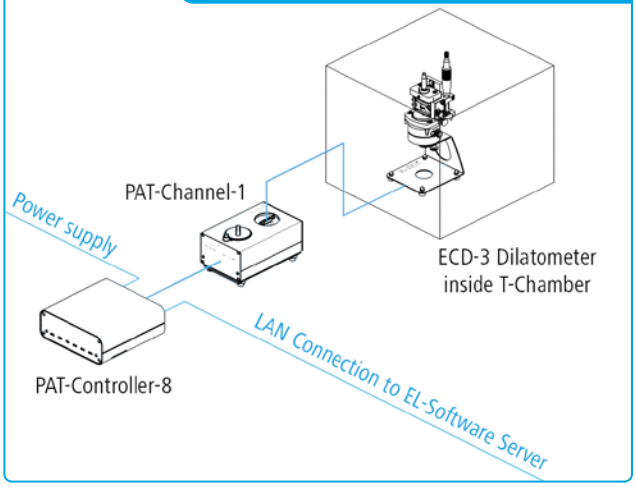
The PAT-Tester-x-8 is the perfect choice for small scale and special purpose testing. It brings the same battery tester hardware and software as the PAT-Tester-i-16. However the fully featured channels (galvanostat / potentiostat / impedance analyzer) are separated into individual devices. Up to 8 of these PAT-Channels may connect to one single PAT-Controller-8 which serves as the control unit for storing all measurement data and enabling communication with the EL-Software server.

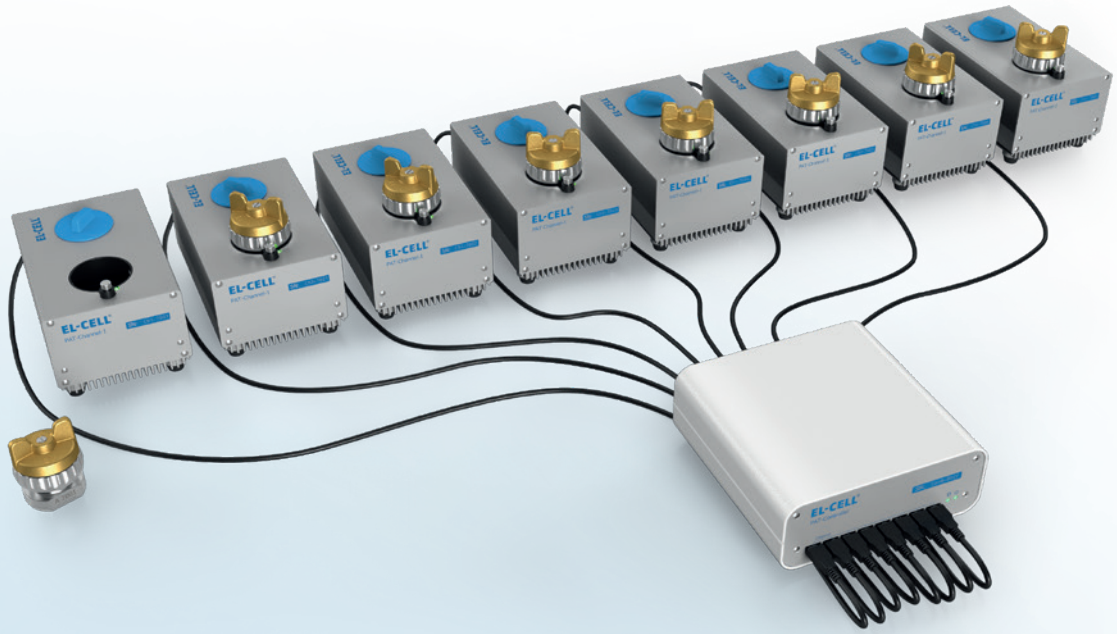
That way each channel of the PAT-Tester-x-8 can be controlled from any client PC in the same network via the EL-Software.
The individual PAT-Channels can be placed where they are needed: on the bench, in a climate chamber, or inside the glove box. While tailored for PAT-Cells, each PAT-Channel can also connect to almost any other test cell including the ECD dilatometer and optical in-situ cells.
The PAT-Tester-x-8 offers maximum flexibility with up to 8 channels for small scale and special purpose testing.

PAT-Tester-x-8 setup with 6 PAT-Channels



Single-channel setup with ECD-3 Dilatometer





PAT Battery Tester Specifications

General	
Channels per device	1 to 16 (PAT-Tester-i-16) 1 to 8 (PAT-Tester-x-8)
Voltage	-7 V to + 7 V
Current	± 100 mA
Cell connection / Electrode connection	3 electrodes plus sense wires, connection matrix
ADC	2 x 24 Bit
DAC	1 x 18 Bit
Bandwidth ranges (stability factor)	500 kHz (fast) 50 kHz (medium) 5 kHz (slow)
Acquisition time (time base)	1 ms
Internal sample buffer	100 GByte
Computer interface	1 GBit Ethernet Runs standalone Multiuser

Other	
Temperature Chamber (PAT-Tester-i-16 only)	+ 10 °C to + 80 °C, software controlled
Additional data input (each channel)	Digital (I^2C) sensor signal, e.g. for cell temperature Analog sensor signal, e.g. for gas pressure
Calibration	Fully automatic self-calibration with internal voltage reference and three internal calibration cells
Cell Identification	PAT-Button with unique serial number stored in EEPROM

Voltage	
Acquisition of ...	Full cell voltage Both half cell voltages Auxiliary voltage
Measurement accuracy	±0.02% of FSR
Control resolution	57 µV (18 Bit)
Measurement resolution	x µV (24 Bit)

Current	
Current ranges	± 100 mA ± 10 mA ± 1 mA ± 100 µA Autorange
Measurement noise floor	< 1 µA @ 100 mA < 100 nA @ 10 mA < 10 nA @ 1 mA < 1 nA @ 100 µA
Measurement accuracy	± 0.05 % of FSR
Control resolution	1 nA min. (18 Bit)

Impedance (each channel)	
Frequency range	100 µHz to 100 kHz
Impedance mode	PEIS and GEIS (simultaneous measurement of full- and half-cell impedances)
Impedance range	1 mΩ to 100 MΩ

EL-Software

EL-Software is the software platform to control all EL-CELL battery testers, be it single-channel or multi-channel systems. EL-Software is covering all test cases from strain measurements with the ECD dilatometer through simple cycle tests on a single button cell to high throughput material testing with the PAT system.

All relevant data, like cell components, test procedures or the resulting test data, are written into a central, conveniently searchable database. This growing data treasure is accessible for all users in the same network and helps to speed up the process of experiment planning and interchanging of test data significantly. With the powerful yet easy-to-use test composer you can set up virtually any test procedure, whether it's for a simple voltammetric experiment or a complex test that combines constant current cycles at different C-rates with intermittent impedance measurements. In batch mode, any number of test procedures can be performed sequentially, either for a single test cell or for a group of test cells – all this without writing a single line of code. Available control modes are constant current, constant voltage, open circuit, linear voltage sweep, galvanostatic and potentiostatic impedance.

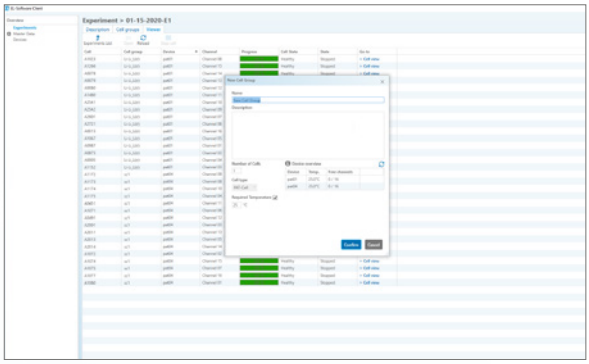
Finally, EL-Software provides you with state-of-the-art graphics capabilities for visualizing your test results, while the open export interfaces allow seamless integration into existing software pipelines.

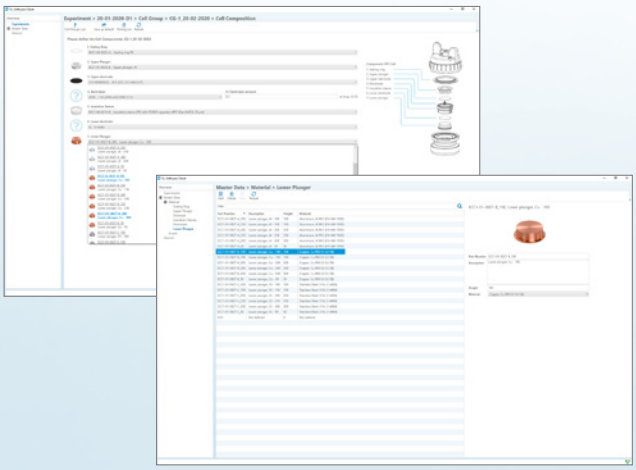
EL-Software guides you through the individual steps of testing with the PAT system and other test cells.

Working with EL-Software

Highly scalable test setups

EL-Software focuses on the cell groups to be compared instead of individual test channels. This novel approach makes it easy to set up and perform experiments with a freely scalable number of test channels and devices. With EL-Software, you always have an overview of your experiment. The system is very flexible and allows both efficient tests with high throughput and small test setups with few test cells.





Convenient experiment design

With EL-Software you can easily plan complex experiments, from test procedures to the required components of each test cell.

The software's own database already contains all available cell components of the PAT series and can easily be extended by further components such as own separator materials or electrolytes, but also other cell types. Configure your test cells according to your application in our convenient modular system.

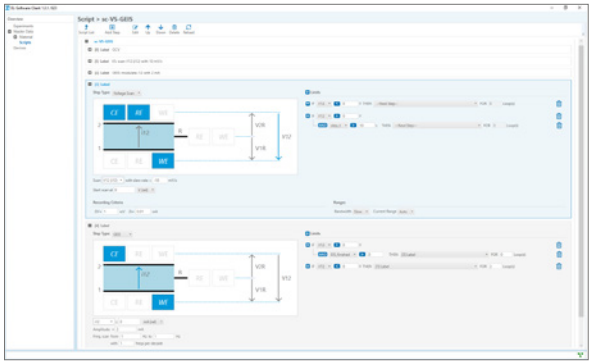
Compose test scripts

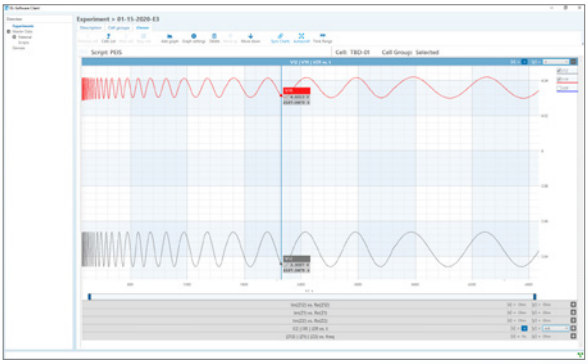
Create your test scripts comfortably and efficiently in the Composer, a powerful visual editor integrated into EL-Software. The Composer uses an easy-to-learn modular principle to create even complex test procedures in a very short time. As a unique feature, the connection between test cell and PGStat can be changed directly in the test script. The user can seamlessly switch between the different control modes for half and full cell with a few mouse clicks without interrupting the measurement or reconnecting any cables.

Test procedures can consist of several individual test scripts per experiment with any number of process steps. You can integrate predefined standard templates from the script library or create your own templates to simplify your work.

Simply switch between the different operating modes such as PEIS, GEIS or Voltage Scan and link the individual process steps using conditions and limits.

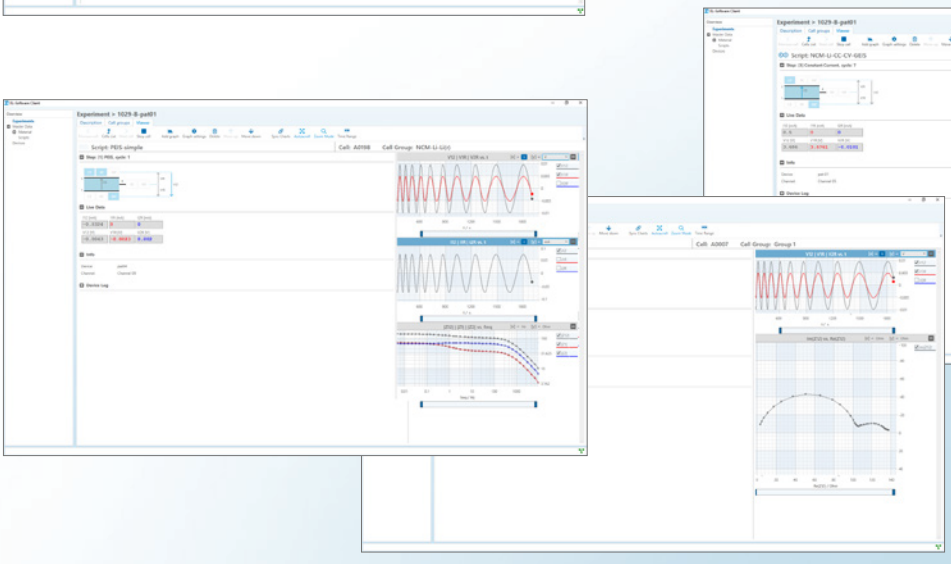
It is also possible to program your own scripts in Lua and import them directly into EL software. This allows you to implement even very special test procedures with ease. EL-software sets no limits to your creativity.

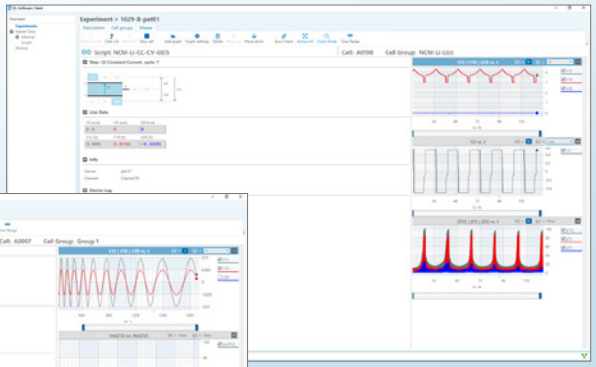




Experiment monitoring: Always keep the overview

The well-structured cell viewer gives you feedback on your ongoing measurements. Forget about the time when measurement results had to be processed before you could draw conclusions from them. Instead, plot your measurement data in real-time, compare and calculate the various parameters directly in the running measurement using freely configurable graphs.

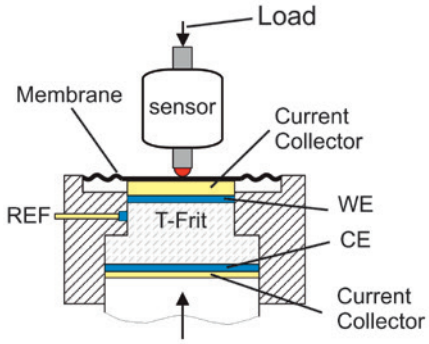




Electrochemical Dilatometer

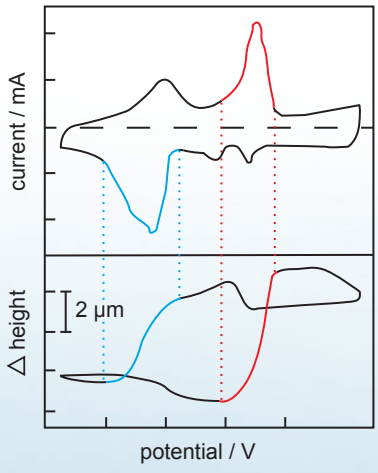
Watch your electrodes breathe

Our electrochemical dilatometer is available in two versions, the ECD-3 and the ECD-3-nano. The two instruments mainly differ in the resolution and drift stability of the displacement sensor system that is attached to the electrochemical cell. The electrochemical cell is identical for both versions.



Working principle

The ECD-3 and ECD-3-nano electrochemical dilatometers measure the thickness change of a working electrode during the electrochemical cycle. The heart of the dilatometer is an electrochemical cell hermetically sealed against ambient atmosphere.

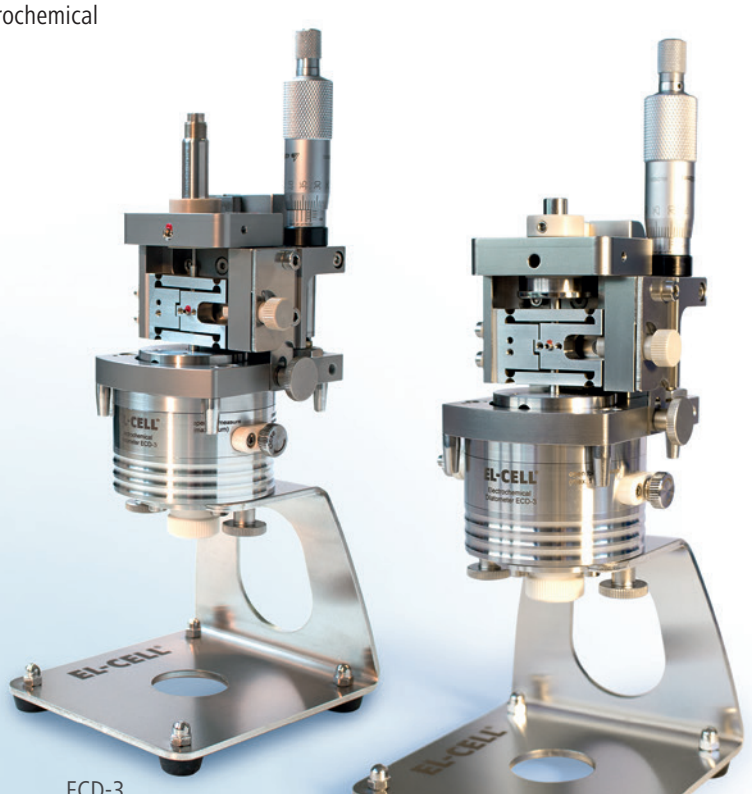


Current response and height change of layered ruthenium oxide in 2 M H_2SO_4 during slow scan voltammetry. Courtesy of Prof. Wataru Sugimoto, Shinshu University, Japan.

The working electrode (WE) and the counter electrode (CE) are separated by a stiff glass frit soaked with electrolyte. The upper WE is sealed by means of a flexible metal membrane, through which any charge-induced thickness change is transmitted towards the sensor/load unit attached on top. The fixation of the glass frit ensures that only the thickness change of the working electrode is being detected without interference from the CE. Optionally, a reference electrode REF can be placed at the edge of the frit close to the working electrode.

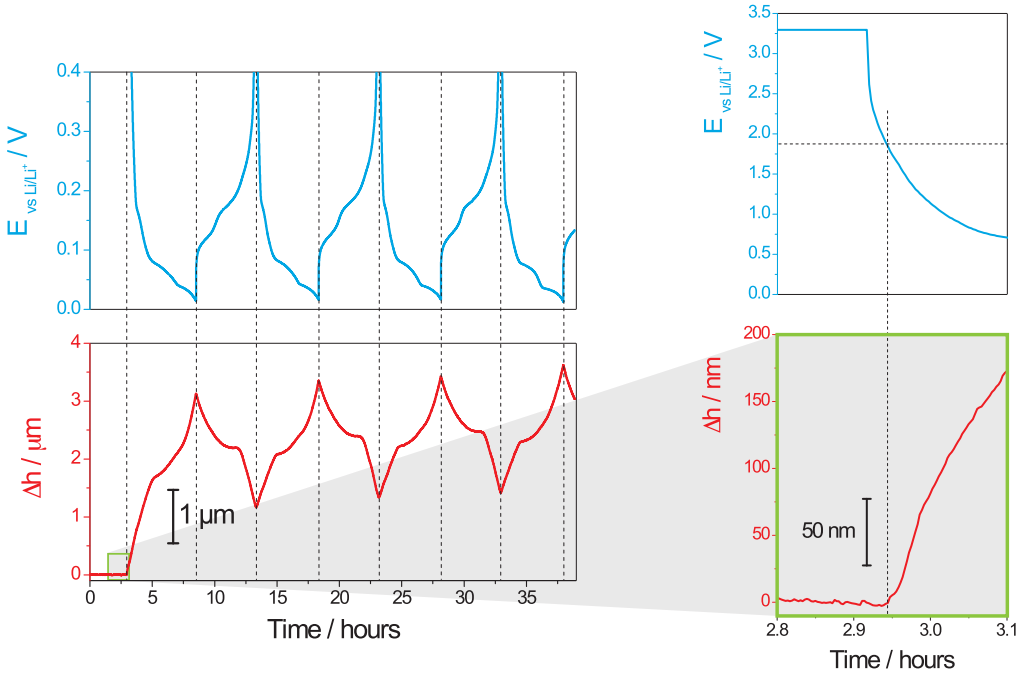
Options

Various add-ons are available for special testing requirements, such as for using aqueous electrolytes, for using single grains or crystals instead of bound electrode films and for measuring the thickness change of the whole battery stack instead of only the working electrode.



ECD-3

ECD-3-nano



Expanding and shrinking of a graphite electrode during lithium insertion and extraction (figure left).
The detailed view shows the onset of expansion at 1.9 V vs. Li / Li+ (figure right).

Technical Specifications

	ECD-3	ECD-3 nano
Displacement sensor system	LVDT	capacitive
Displacement range	500 µm	250 µm
Displacement resolution	**≤ 50 nm**	**≤ 5 nm**
Signal drift (sample-free)	≤ 100 nm / hour	≤ 20 nm / hour
Test specimen	Electrode films, optional single crystals / grains Diameter ≤ 10 mm, thickness ≤ 1 mm	
Load on test specimen	approx. 1 N	
Chemical compatibility	Aprotic organic electrolytes; optional aqueous electrolytes	
Cell electrolyte volume	approx. 0.5 ml	

ECC-Opto-Std

Processes on your working electrode will become directly visible

The ECC-Opto-Std test cell serves to monitor the optical properties of an electrode material in the course of electrochemical charging. It is dedicated to the inspection of electrodes using optical methods such as light microscopy or Raman spectroscopy in reflection mode. Basically, the respective instrument looks through a transparent window onto the working electrode.

The ECC-Opto-Std is easily adapted through optional special kits (e.g. for XRD) to the respective battery system and optical instrumentation.

The ECC-Opto-Std comes standard with a borosilicate glass window. Depending on your testing purposes, different window materials are available.

Features

- 2- and 3-electrode cell with optical window for aprotic electrochemistry
- Full delivery scope for light microscopy
- Special kits for XRD and Raman available
- Materials in contact with electrolyte are stainless steel 1.4404, PEEK, PE and the window material.
- Adjustable, reproducible and homogeneous mechanical pressure on electrodes
- Reliable low-leakage sealing with PE seals
- Easy and reliable electrolyte filling
- Fast assembly and dismantling and easy cleaning of cell components
- Electrodes are easily accessible for post-mortem analysis

In this experiment, the ECC-Opto-Std test cell has been used to visualize the colour change of a graphite electrode during electrochemical lithiation. The microscope "looked" through the 1 mm diameter hole in the copper foil onto the backside of the graphite electrode.

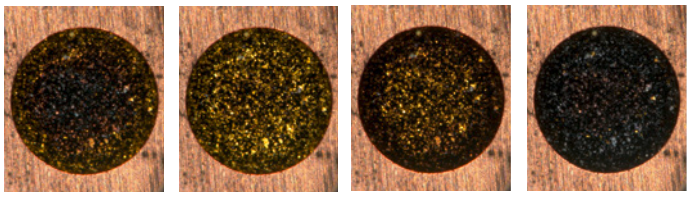
Sample Test Results

I. Electrochemical lithiation of a graphite electrode

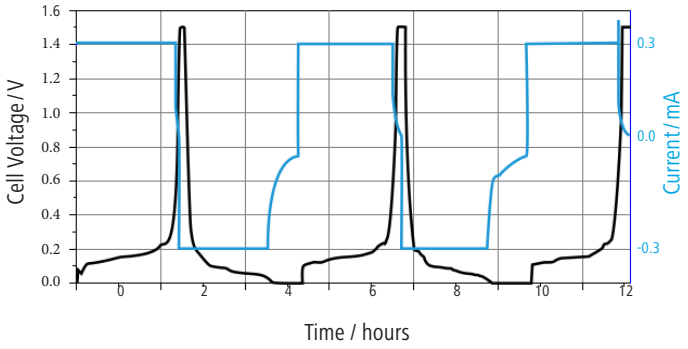
In this experiment, the ECC-Opto-Std test cell has been used to visualize the colour change of a graphite electrode during electrochemical lithiation.

Test setup:

- WE: Free-standing graphite electrode on a Cu foil current collector with a hole (1 mm diameter)
- CE: Lithium metal, 10 mm in diameter, 0.2 mm thick
- Separator: nonwoven glass fibre, 10 mm in diameter, 1 mm thick
- Electrolyte: 1 M $LiPF_6$ in EC / DMC (1/1) with 2% VC
- Microscope: Keyence VHX-700FD with VHX-1020 camera and 200x VH-Z20R zoom



After 4 hours | After 5 hours | After 6 hours | After 7 hours

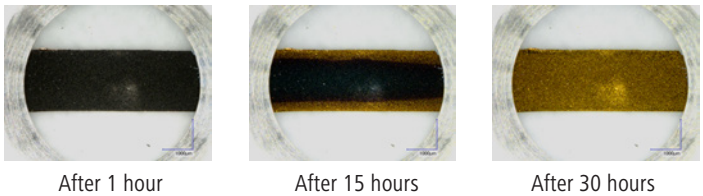


II. Visualizing the potential gradient

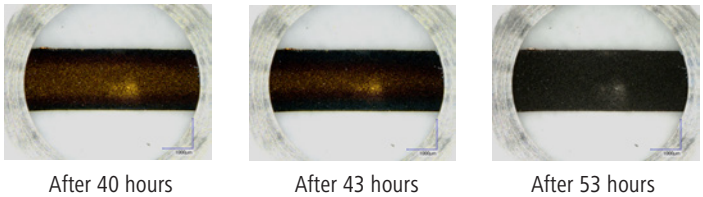
In this battery test, we show how the ECC-Opto-Std test cell can be used to visualize a potential gradient inside graphite just by using a standard graphite electrode with a continuous copper foil as the current collector (rather than a current collector with a hole).

Test setup:

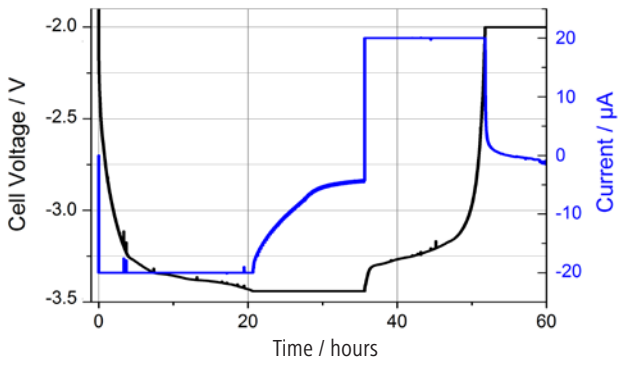
- WE: Strip of graphite electrode (CCI, 1.1 mAh / cm^2, 50 µm thick, 2 mm wide), with the Cu foil current collector pointing to the counter electrode
- CE: Lithium iron phosphate electrode (CCI, 3.6 mAh / cm^2, 9 mm in diameter)
- Separator: Nonwoven glass fibre, 10 mm in diameter, 0.5 mm thick
- Electrolyte: 1 M $LiPF_6$ in EC / DMC (1/1) with 2 % VC
- Microscope: Keyence VHX-700FD with VHX-1020 camera and 50 x VH-Z20R zoom



After 1 hour | After 15 hours | After 30 hours



After 40 hours | After 43 hours | After 53 hours



ECC-Opto-Std-Aqu

The ECC-Opto-Std-Aqu optical test cell is a variant of our popular ECC-Opto-Std, specialized for use with aqueous electrochemistry. Like the ECC-Opto-Std, it is a 2- and 3-electrode test cell for optical characterization in the reflective mode. Typical uses include optical and confocal Raman microscopy. Components in direct electrolyte contact are made of gold, PEEK, EPDM and the window material.

Technical Specifications

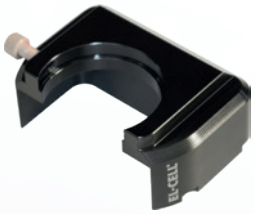
- Width: 75 mm
- Depth: 66 mm
- Height: 21 mm

Cell Holder

Various cell holders are available for mounting the ECC-Opto-Std and ECC-Opto-Std-Aqu to microscopes, spectrometers and XRDs.

Cell holder I for ECC-Opto-Std

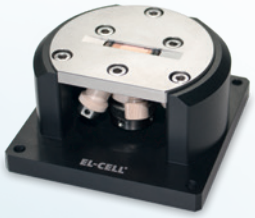
The Cell holder I is designed for the use of the ECC-Opto-Std in light microscopes utilizing standard microscope slides (75 x 26 mm, ISO 8037-1).



- Width: 32 mm
- Depth: 75 mm
- Height: 50 mm

Cell holder II for ECC-Opto-Std

The Cell holder II fits in XRD machines like the Bruker D8. It is intended to be used in combination with Lid ECC1-00-0127-M.



- Width: 41.3 mm
- Depth: 78 mm
- Height: 76 mm

Cell holder III for ECC-Opto-Std

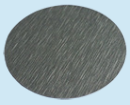
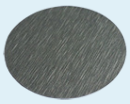
The Cell holder III is designed for use in a Bruker FTIR Hyperion 2000 microscope.

- Width: 75 mm
- Depth: 66 mm
- Height: 21 mm

Window Kits

The ECC-Opto-Std comes standard with a borosilicate glass window and a cell lid with a 2 mm diameter window opening. Depending on your testing purposes additional window kits are available.

Each kit includes one or more windows and a modified cell lid. Further window materials like magnesium oxide, silicon dioxide, silicon nitride or PET (Mylar®) are available upon request.

	Window	Lid	Details
ECC-Opto Beryllium window kit ECC1-00-0156-B	Beryllium window 	Lid ECC1-00-0127-C 	For X-Ray characterization Lid opening: 10 mm For Cell holder I and III
ECC-Opto Beryllium window kit II ECC1-00-0156-H	Beryllium window 	Lid ECC1-00-0127-M 	For X-Ray characterization Lid opening: 23.3 x 5 mm For Cell holder II
ECC-Opto Polyester window kit ECC1-00-0156-G	Polyester (PET) window 	Lid ECC1-00-0127-C 	For X-Ray characterization Lid opening: 10 mm For Cell holder I and III
ECC-Opto Polyimide window kit ECC1-00-0156-F	Polyimide (Cirlex) window 	Lid ECC1-00-0127-C 	For X-Ray characterization Lid opening: 10 mm For Cell holder I and III
ECC-Opto Zinc selenide window kit ECC1-00-0156-D	Zinc selenide window 	Lid ECC1-00-0127-E 	For IR characterization Lid opening: 10 mm For Cell holder I and III
ECC-Opto Calcium fluoride window kit ECC1-00-0156-E	Calcium fluoride window 	Lid ECC1-00-0127-E 	For IR characterization Lid opening: 10 mm For Cell holder I and III
ECC-Opto Sapphire window kit ECC1-00-0156-C	Sapphire window 	Lid ECC1-00-0127-B 	For Raman characterization and light microscopy Lid opening: 10 mm For Cell holder I and III

ECC-Opto-Gas

Test cell for optical characterization of gas diffusion electrodes in metal-air batteries.

The ECC-Opto-Gas is an in-situ test cell for the optical characterization of gas diffusion electrodes (GDE) in metal-air batteries. The cell features a sapphire window with a meander-shaped flow field, which can be purged with gas during charge / discharge.

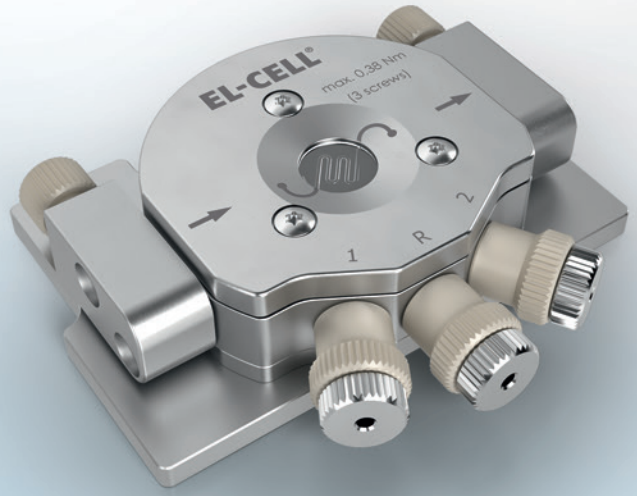
The ECC-Opto-Gas can be mounted on the stage of almost any light or Raman microscope in order to "look" through the transparent window onto the backside of the GDE. The cell is equipped for use with aprotic organic electrolytes.

Features

- In-situ test cell for the optical characterization of gas diffusion electrodes (GDE) in aprotic organic electrolytes.
- Minimized dimensions suitable for light and Raman microscopes working in the reflective mode
- The cell stack, with the GDE on top, is placed below a sapphire window with a meander-shaped flow field. This way, the microscope is "looking" through the window onto the backside of the GDE.
- During charge / discharge, a gentle stream of gas may be purged along the flow field. This way the electrochemical conversion taking place at the backside of the gas diffusion electrode can be observed.
- Materials in electrolyte contact are stainless steel 1.4404, PPS and PE.
- The disc-shaped GDE can have a diameter of up to 11 mm. The inspection area diameter is 10 mm.
- Cell assembly and electrolyte filling may be carried out inside a glove box. Once sealed, the cell may be operated outside the box at ambient atmosphere.
- Connection to potentiostat / battery tester via 2 mm banana sockets
- Electrodes are easily accessible for post-mortem analysis

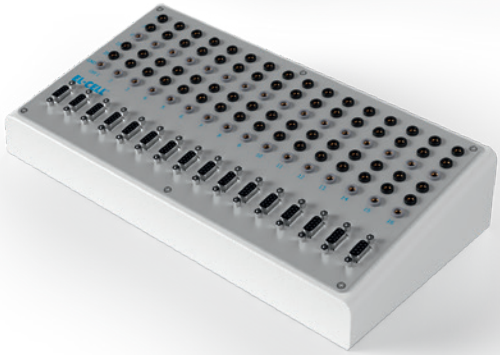
Technical Specifications

- Width: 75 mm
- Depth: 66 mm
- Height: 21 mm



Accessories & Tools

EL-CELL® offers useful tools and accessories for enhancing the work experience with our test cells and to ease your life as a battery researcher.



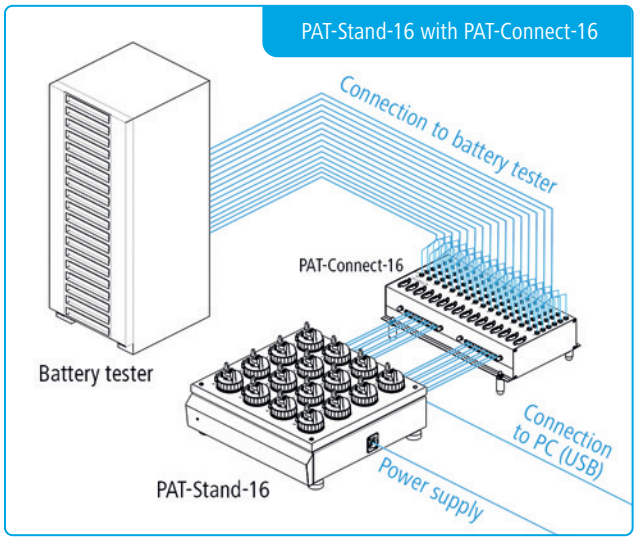
PAT-Connect-16

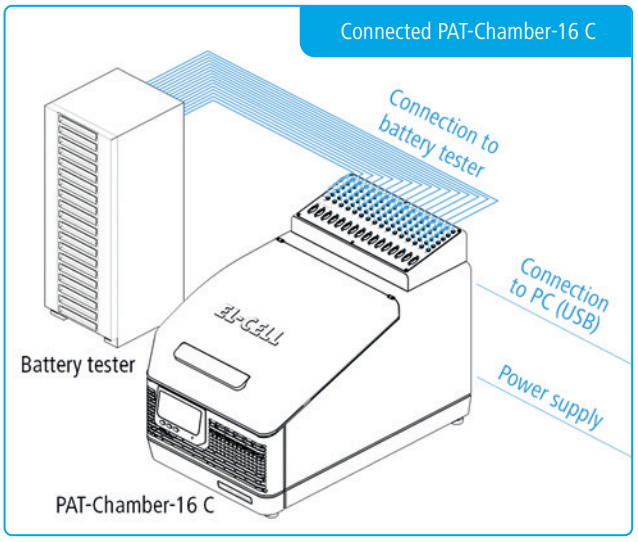
Adapter box for flexible wiring connections

The PAT-Connect-16 is an intermediate box between the PAT-Stand-16 / PAT-Chamber-16 and your potentiostat / battery tester. It enables flexible switching between operation modes (full cell, cathode half cell, anode half cell) without manipulating the permanent cable connection between the adapter box and the stand / chamber.

Features

- Easy-to-access banana sockets for flexible connection to the potentiostat / battery tester: WE, WE-Sense, CE, CE-Sense, RE
- Sub-D connector for optional auxiliary signals from the docking station: buffered half cell voltages, temperature, sensor signals
- Available as modular box (PAT-Connect-16) to be placed on the bench or fixed on the wall, or as an attachment on top of the PAT-Chamber-16 (PAT-Connect-16 C)

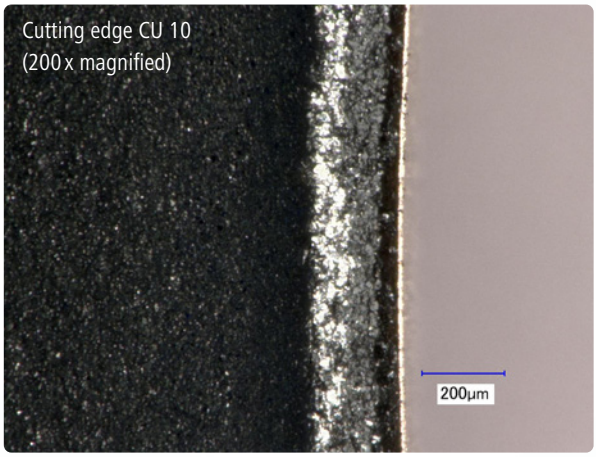




EL-Cut

High-precision cutting pliers eliminate torn and chipped electrode edges.

The proper cutting of the electrodes is often a neglected factor in battery testing. Torn and chipped electrode edges – although invisible to the bare eye – inevitably cause current inhomogeneity and are thus likely to affect experimental results. Life cycle and impedance results are especially vulnerable to such artifacts. Electrodes being cut (fine blanked) by the EL-Cut are produced in tools with a few microns of cutting clearance. The fine blanking process results in electrodes having clean cutting surfaces without torn or chipped edges and being almost perfectly flat.



Cutting edge CU 10
(200 x magnified)

Features

- Perfectly cut electrodes
- Electrode thickness: max. 300 µm for coatings on Al and Cu foil (may vary for other support materials)
- Any size (diameter) from 6 to 40 mm. Different shapes (e.g. squared) are available upon request.

ECC-LiPunch

Punching tool for lithium foil

The ECC-LiPunch is the perfect tool for smoothly punching lithium discs for PAT and ECC series test cells. The punching knife can easily be removed for cleaning.

Features

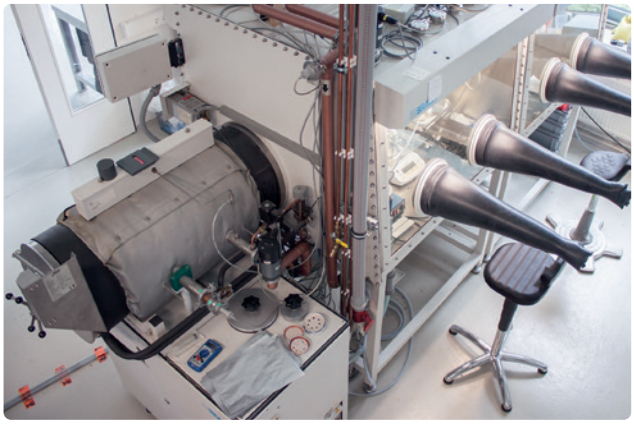
- For punching precise and flat lithium discs
- Standard size for EL-CELL® test cells: 18 mm diameter
- Other available sizes:
  6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 16.6, 17, 18, 19, 20 mm

Services

In addition to our hardware we also offer a wide scope of services like hands-on seminars or electrochemical service measurements in our own research laboratory.

Lithium Battery Application Lab

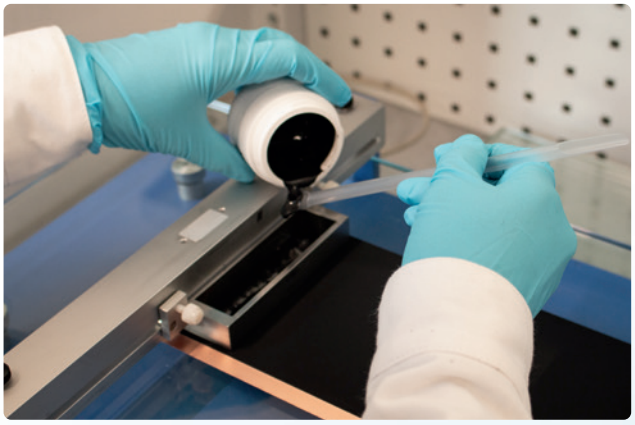
No time or equipment available to run battery tests yourself? We can help you to solve your testing problems in our own laboratory:



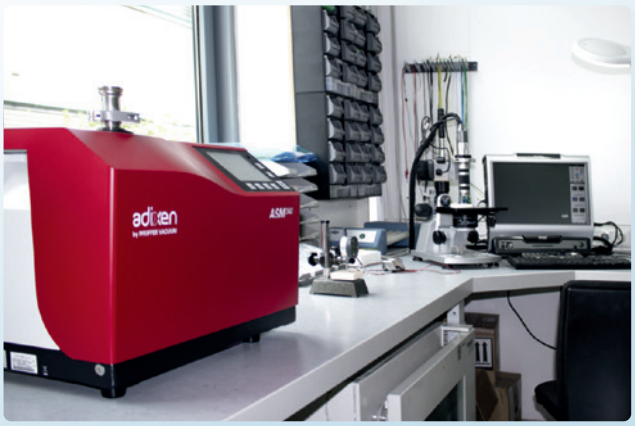
- Manufacturing (slurry preparation, casting, drying, punching) of electrodes from client's material; formulation and characterization of electrolytes
- Cycle life and impedance tests on half and full cells (to some extent materials can be provided by us)
- Round robin tests for validation and tuning up of client's test capabilities
- Testing of client's materials with EL-CELL® test equipment

Equipment

Our professional research laboratory provides the following equipment to run different electrochemical experiments. With this equipment we are able to operate at the highest standard of academia and industry:



- All kind of EL-CELL® battery test cells (PAT series test cells, dilatometer, optical and pressure test cells)
- Tools and handling equipment for electrochemical experiments (e.g. cutting and punching tools)
- Equipment for the preparation of electrode slurries and for casting/drying electrode films
- MBraun glove box system for test cell assembly
- Laboratory fume hood for the coating of electrode films
- Helium leak tester
- Temperature-controlled test cabinets



- **Different kinds of potentiostats and battery testers:**
  - PAT-Tester-i-16
  - Maccor 4000 series cycler
  - Biologic VSP multichannel impedance analyser
  - Gamry Interface 1000
- All standard consumables, such as lithium metal, $LiPF_6$ based electrolytes, anode and cathode materials

Hands-on Seminars

In our seminars, researchers can learn about the latest devices and applications while working efficiently with our products.

Covered topics:

- Li-ion battery introduction: Working principles, terminology, materials used, related technologies (Li-metal batteries, Li-ion capacitors, supercapacitors, dual intercalation batteries)
- Safety and corrosion issues in the Li-ion research laboratory
- Electrode generation from powder to sheet
- Pros and cons of different test cells (coin, pouch cells, Swagelok®,Hohsen, PAT-Cell)
- Building 2- and 3-electrode PAT-Cells
- Testing with PAT-Cells and PAT-Tester-i-16:
  - Lifetime and CC-CV cycle tests
  - Impedance measurements
  - Cyclic voltammetry
- Electrochemical in-situ / operando techniques with
  - ECC-Opto-Std: Visualizing the gradients of electrode potential and lithium concentration
  - PAT-Cell-Press: Quantifying the gassing during battery formation
  - ECD-3-nano: Measuring electrode dilation during charge and discharge

Facts:

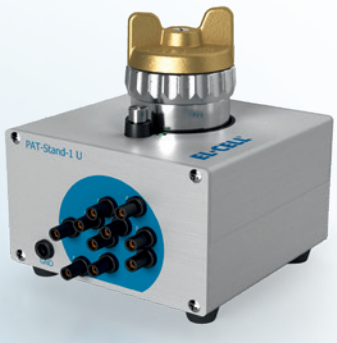
- Duration: two days (8 hours per day)
- Location: Tempowerkring 8 - 21079 Hamburg, Germany
- Pricing: regular registration: 1,300 Euro (1,200 Euro*)
  PhD-students**: 650 Euro (600 Euro*)

See website www.el-cell.com for next dates.
* Early bird (4 weeks before)
** confirmation required

Customizations

Our main focus is on lithium-ion batteries, but we also design test cells for other energy storage technologies. We can customize our devices and tools according to your individual purpose and even create new solutions for specific experiments. Just ask!

PAT-Cell-Twin-Ref:
Specialized PAT-Cell for simultaneous testing with two reference electrodes.



PAT-Stand-1 U:
Docking station for use with specialized PAT-Cells like the PAT-Cell-Twin-Ref with flexible signal outputs depending on the cell design

What is the right test cell for you?

Test cells

	Aprotic electrolytes $LiPF_6$ and R_4NBF_4 [2]	Aqueous electrolytes [5]	Available current collectors
PAT-Cell	**yes**	**yes**	Cu, Al, SS[3]
PAT-Cell-Gas	**yes**	**yes**	Cu, Al, SS[3]
PAT-Cell-Press	**yes**	**yes**	Cu, Al, SS[3]
PAT-Cell-HT	**yes**	**yes**	Cu, Al, SS[3]
ECC-Opto-Std	**yes**	no	Cu, Al, SS[3]
ECC-Opto-Std-Aqu	**yes**[4]	**yes**	Au, Pt, Ni
ECC-Opto-Gas	**yes**	no	Ni
ECD-3-nano	**yes**	**yes**[1]	SS[3], Al, Cu, Au[1]
ECD-3	**yes**	**yes**[1]	SS[3], Al, Cu, Au[1]

[1] with optional aqueous kit only [2] for organic supercapacitors [3] SS = stainless steel 1.4404 (316L) [4] depends on current collector

[5] The compatibility of the specific electrolyte used must be checked by the customer and is at the sole responsibility of the customer.

PAT Compatibility

Docking / Test station	PAT-Cell	PAT-Cell-Press	PAT-Cell-HT	PAT-Cell-Gas
PAT-Clamp-1 / PAT-Stand-1	C	C	C	C
PAT-Clamp-1+ PAT-Press Box + T-Chamber	C	C T P	C	C T P
PAT-Stand-1 + PAT-Press Box + T-Chamber	C	C T P	C	C T P
PAT-Stand-4	C	C	C	C
PAT-Stand-16	C	C	C	C
PAT-Chamber-16	C	C T P	C	C T P
PAT-Heater-4			C T	
PAT-Tester-x-8	C	C T P	C	C T P
PAT-Tester-i-16	C	C T P	C	C T P

Supported features: C: charge / discharge / impedance
T: temperature control
P: gas pressure

Colours: all test cell features supported
some test cell features not fully supported
test cell incompatible

What is the right tool for you?

Test cells	ECC-LiPunch (several sizes)	EL-Cut (several sizes)
All PAT series test cells	• diameter = 18 mm	• diameter = 18 mm
ECC-Opto-Std	• diameter = 10 mm	• diameter = 10 mm
ECC-Opto-Std-Aqu	-	• diameter = 10 mm
ECC-Opto-Gas	-	• diameter = 12 mm
ECD-3, ECD-3-nano	• diameter = 12 mm	• diameter = 10 mm

• recommended

EL-CELL® delivers worldwide directly and through its japanese distributor.

For further information please visit our website www.el-cell.com or contact us directly!

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EL-CELL®

electrochemical test equipment