EL-CELL®

Instrumentation for battery research

Product Overview

SUMMER 2021


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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

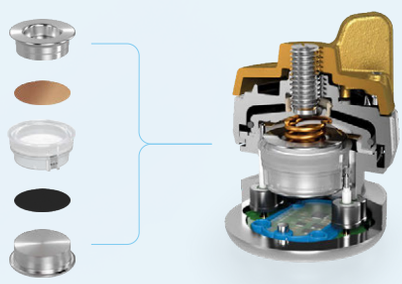
The PAT Series

Our modular system for testing of battery materials

With the PAT series, we are the first supplier worldwide to offer you a complete system consisting of test cells, tools, potentiostats, and control software that are perfectly matched to each other. This makes the testing of battery materials more efficient, more reproducible and easier than ever before.

PAT-Core

The PAT-Core is the core component of each PAT-Cell, which contains the actual cell stack with electrodes, current collectors, separator and electrolyte. The individual components of the PAT-Core are available in different variants that can be freely combined with each other. This means that the test cell can be quickly and easily adapted to a wide variety of test purposes.



PAT series test cells

The complete PAT-Cell consists of the respective PAT-Core and a cell housing, which hermetically protects the cell chemistry from the ambient atmosphere. There are different cell housings for different test purposes, e.g. for pressure measurement or for gas supply or for measurements at higher temperatures.
Unlike other products, PAT test cells are cableless. They are simply inserted into a docking station which can remain permanently connected to the battery tester used. This way the wiring does not have to be renewed before every test, which saves time and prevents mistakes.

PAT docking stations

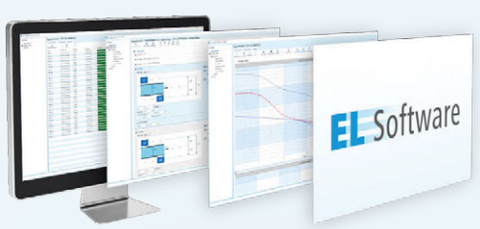
In order to connect and operate a PAT-Cell with a 3rd party potentiostat, the cell is simply inserted into the socket of a PAT docking station. Only the docking station itself needs to be permanently wired to the potentiostat, the PAT-Cells themselves are cableless. PAT docking stations can be connected and operated with all currently available potentiostats or battery cyclers.

PAT battery testers

Our PAT battery testers are specifically designed to meet the requirements of battery materials research. Our focus is on convenient handling and minimising laboratory space as much as possible through high integration of core components and a 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 like the connection matrix.
In an unprecedented way, this allows alternating between full-cell and half-cell control at runtime without having to change even a single cable.

EL-Software

EL-Software is the newly developed software solution from EL-CELL to plan, perform and evaluate experiments with the PAT battery testers. The software enables networked, location-independent operation with a scalable number of test channels and devices, while taking full advantage of the diverse capabilities of PAT series test cells and potentiostats.



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 lithium, 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.

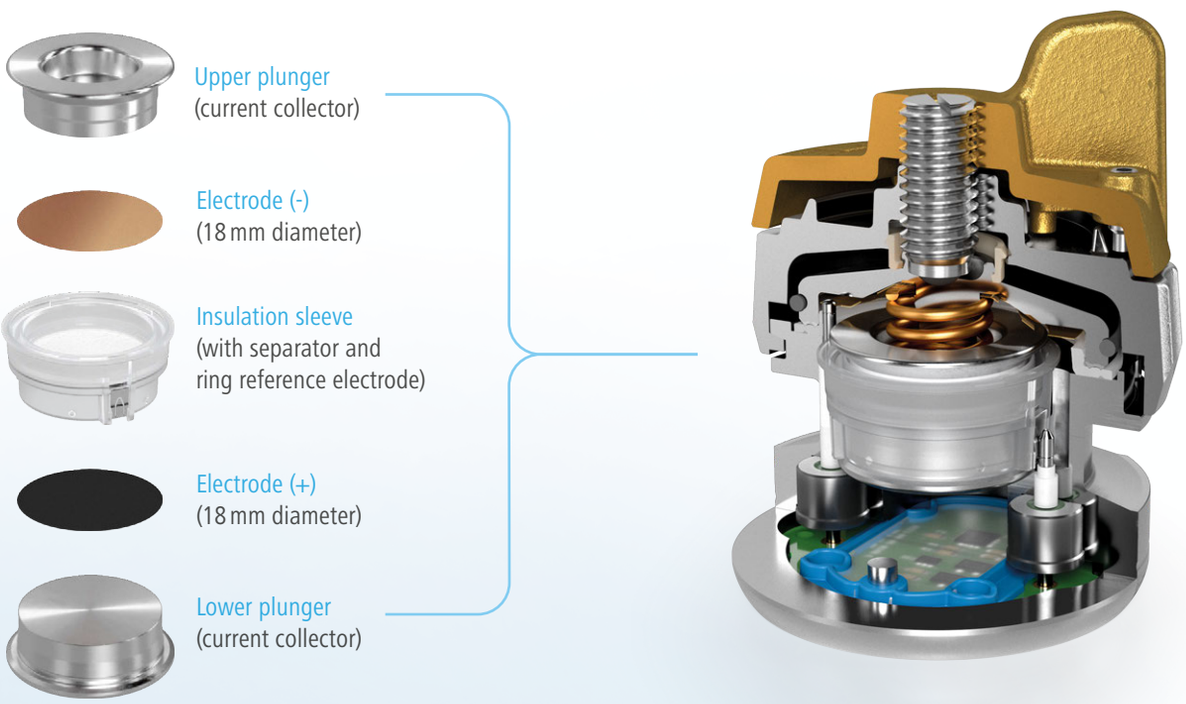
The insulation sleeve is preassembled under a protective argon atmosphere at the EL-CELL® factory to ensure consistent quality for reproducible battery tests. PEEK is now made available as alternative material for the insulation sleeve; this way we are also able to offer the insulation sleeve as a reusable version for self-assembly.

The upper and lower plungers complete the PAT-Core and serve as current collectors. Battery researchers can choose from 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) 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

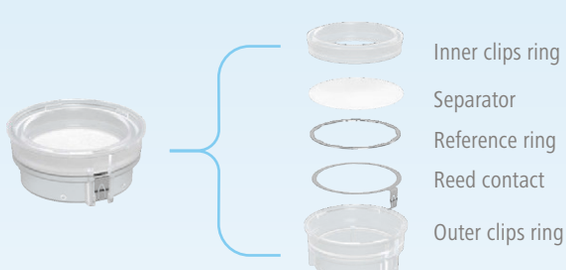
Different test cases require flexible cell configurations. PAT-Core components are available in a variety of materials to perfectly match the needs of your experiment. **The examples shown below provide an overview of only the most common applications.** We continuously expand the PAT system to include 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 / Graphite	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), ready-to-use	Insulation sleeve (PEEK), for self-assembly	Insulation sleeve (PEEK), for self-assembly
Reference	Li metal	Activated carbon	Li metal
Separator	Whatman GF / A	Whatman GF / A	Whatman GF / A
Reed contact	Nickel plated stainless steel	Gold plated stainless steel	Nickel plated stainless steel

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

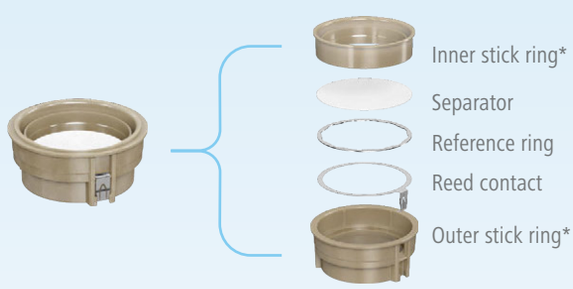
There are two types of insulation sleeves for the PAT-Core. The variant made of polypropylene is a single-use item with built-in separator, ring reference and reed contact. The single-use concept lowers lead times in the lab and is the perfect choice for high-throughput testing. The PEEK variant on the 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

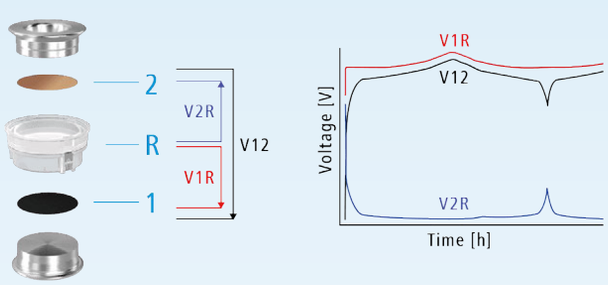
PAT-Core Configurations

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	Modest	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 insulation sleeves with Li metal reference together with glass fibre separator as the most robust and versatile 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 like 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

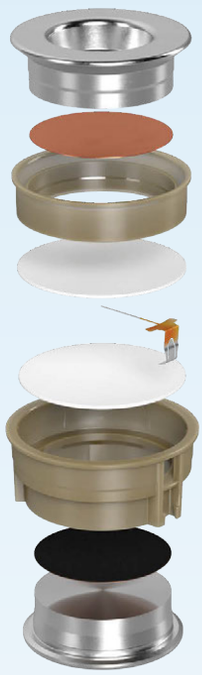
Sometimes a finger-shaped reference electrode can be better than our standard ring-shaped reference electrode. The finger reference measures the electrical potential in the middle of the stack instead of at the outer edge of the cell stack. This can help to minimize artifacts caused by inhomogeneities 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 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 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



Upper plunger, stainless steel

Upper electrode, graphite

Upper stick ring, PEEK

First layer of separator, glass fiber

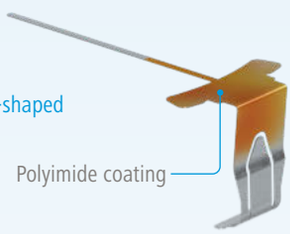
Reed contact with finger-shaped reference electrode

Second layer of separator, glass fiber

Lower stick ring, PEEK

Lower electrode, NCM

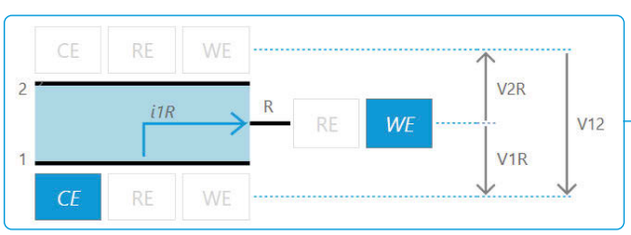
Lower plunger, stainless steel



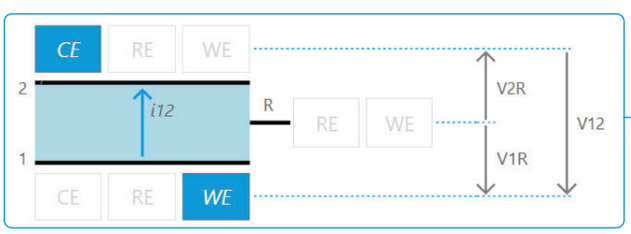
Reed contact with finger-shaped reference electrode

Polyimide coating

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.

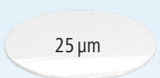
PAT-Tester-x-8 running the EL-Software test script with a PAT-Cell.

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



PET fibre, Al_2O_3

Whatman GF/A

Borosilicate glass fibre

FS-5P

Double layered separator:
PP fibre + PE membrane

Customized

Provided by customer

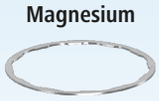
Reference rings

Lithium

Aluminum

Activated Carbon

Magnesium



Sodium

Other materials available on request

Reed contacts

Nickel

Gold

Stainless steel

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

Insulation sleeves

PP

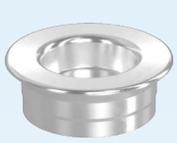
- Single-use
- Preassembled

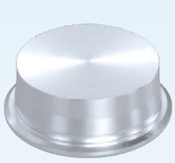
PEEK

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

Current collectors: Plungers and discs

Aluminum



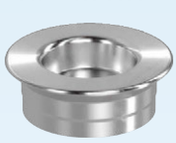


- Single-use
- Battery grade material
(Al 99.5, EN-AW-1050)

Copper

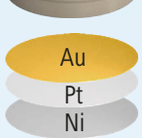
- Single-use
- Battery grade material
(Cu 99.9, E-CU 58)

Stainless steel



- Reusable
- Stainless steel
(316L, 1.4404)

PEEK with gold pin



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

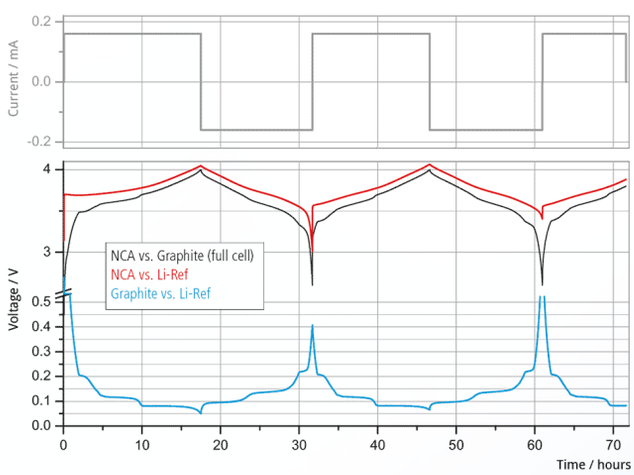
The ideal test cell for 3-electrode and high-throughput battery testing.

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 patented, 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 advantages of the PAT-Core
- For long term testing (> 1000 hrs) with two or three electrodes
- Proven cell design for easy handling and fast assembly
- Compatible with aprotic as well as aqueous electrochemistry
- PAT-Button for automatic cell identification in EL-Software

Sample test results



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

Height / Width / Length	61 / 49.5 / 49.5 mm
Weight	0.4 kg
Separator diameter	21.6 mm
Electrode diameter	18 mm
Operational temperature	-20 to 80 °C

Product website:

Speed up your workflow with the PAT-Button!

The PAT-Button is a workflow improvement feature found in PAT series test cells. It is basically an EEPROM chip installed on the bottom of the cell that stores the cell ID. When the cell is built, its specific ingredients and properties are assigned to this cell ID in EL-Software. In this way, the software recognizes a PAT-Cell once it has been built, even if the cell is disconnected from the PAT tester in between. **This speeds up the workflow and prevents operating errors.**

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
- 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 pressure sensor, 0 to 3 bar abs. (0.5 to 4.5 V output signal)
- Optional gas sample port
- Electrode feedthroughs with glass-to-metal seals
- **PAT-Button for automatic cell identification in EL-Software**

Variants

	Gas in- and outlet	Pressure sensor	Gas sample port
PAT-Cell-Gas	✓		
PAT-Cell-Gas P	✓	✓	
PAT-Cell-Gas S	✓		✓
PAT-Cell-Gas SP	✓	✓	✓

Height / Width / Length	116 / 56 / 100 mm
Width with sample port	70 mm
Weight	0.6 kg
Electrode diameter	18 mm
Gas connection	1/16 inch Swagelok tube fitting
Dead volume (with PAT-Core)	3.9 - 4.6 ml*
Range of pressure sensor	0 to 3 bar abs. (0.5 to 4.5 V signal output)
Accuracy of pressure sensor	< 5 mbar
Resolution of pressure sensor	< 0.2 mbar
Operational temperature	-20 to 80 °C

Product website:

*Depending on the lower plunger used

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

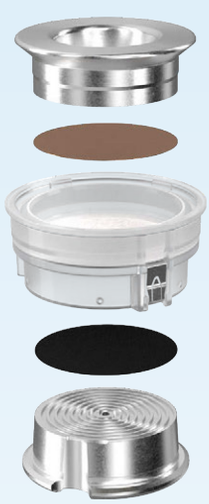
Working electrode e.g. gas diffusion electrode

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



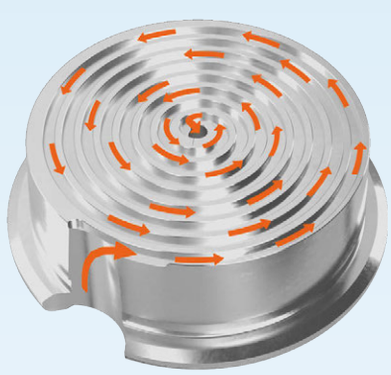
Upper plunger (current collector), stainless steel

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

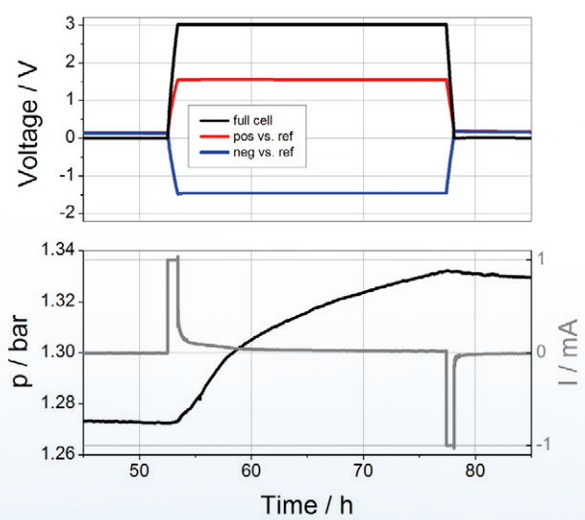
The PAT-Cell-Press is the PAT-Cell with an integrated pressure sensor and an optional sample port for drawing gas samples from the cell's headspace. The PAT-Cell-Press can be operated directly in a PAT-Chamber-16 or PAT battery tester such as the PAT-Tester-i-16. For use in other PAT docking stations, a separate PAT-Press-Box is available for recording the analog pressure signal. 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

- Cableless test cell with all advantages of the PAT-Core
- Laser welded pressure sensor, pressure range of 0 to 3 bar abs. (0.5 to 4.5 V output signal)
- Optional gas sample port (PAT-Cell-Press S)
- Compatible with aprotic as well as aqueous electrochemistry
- Analog outputs for pressure and temperature for seamless integration with other instruments
- PAT-Button for automatic cell identification in EL-Software

Sample test result

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

Height / Width / Length	61 / 49.5 / 49.5 mm
Width with sample port (PAT-Cell-Press-S)	70 mm
Weight	0.5 kg
Separator diameter	21.6 mm
Electrode diameter	18 mm
Dead volume (with PAT-Core / without PAT-Core)	3.6 / 8.1 ml
Range of pressure sensor	0 to 3 bar abs. (0.5 to 4.5 V output signal)
Accuracy of pressure sensor	< 5 mbar
Resolution of pressure sensor	< 0.2 mbar
Operational temperature	-20 to 80 °C

Product website:

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

Height / Diameter	61 / 49.5 mm
Weight	0.5 kg
Separator / membrane diameter	21.6 mm
Electrode diameter	18 mm
Operational temperature	-20 to 200 °C

Product website:

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).

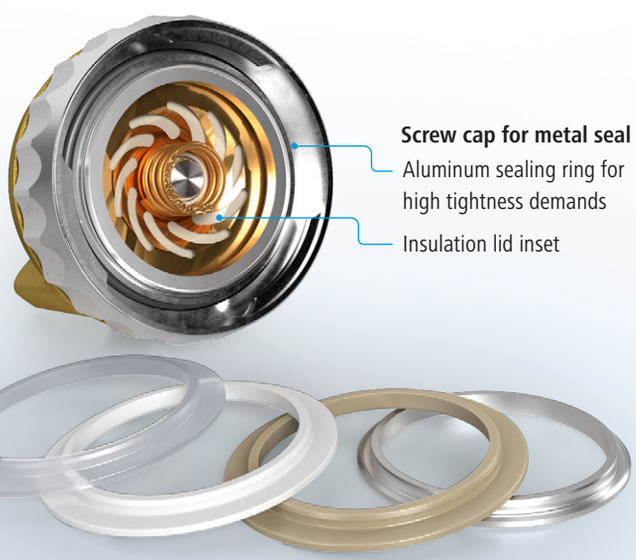
Features

- **Cableless test cell with all advantages of the PAT-Core** at elevated temperatures
- Continuous operating temperature: up to 200 °C
- Glass-to-metal seals for improved temperature resistance
- 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

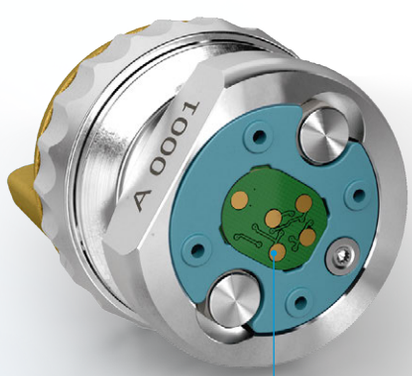
Insulation lid inset

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 for automatic cell detection with any PAT battery tester!

PAT-Adapters

New!

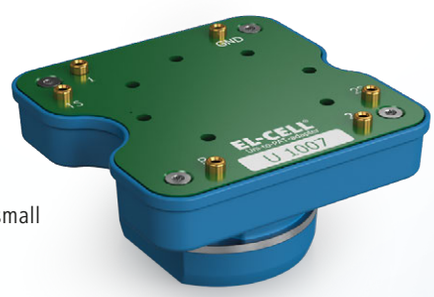
Adapter for other cell formats

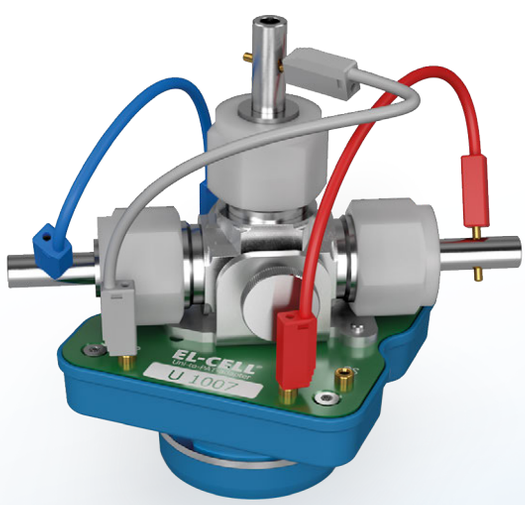
In addition to our PAT test cells, we also offer a variety of cell adapters to connect T-cells, split cells, coin cells or any other custom test cell to our PAT system. The PAT-Adapters are inserted into the PAT socket just like any PAT series test cell.

Each adapter is equipped with an integrated PAT-Button, which enables automatic cell identifiation when connected to an EL-Cell potentiostat like the PAT-Tester-i-16.

3E-Coin-PAT-Adapter

For coin cells with 2- or 3-electrodes
Fits for all coin cells with up to 32 mm in diameter and 5.5 mm in height.





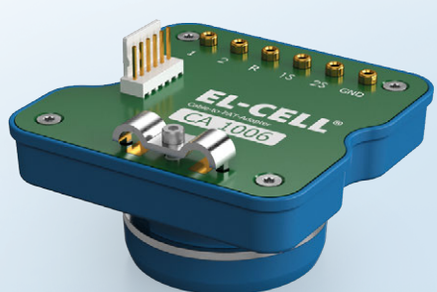
Example shows mounted T-Cell

Uni-to-PAT-Adapter

Universal adapter for mounting any small battery format test cell.

Coin-PAT-Adapter

For coin cells with 2 electrodes
Variants available for coin cells with 12, 16, 20, 24 and 32 mm diameter and a maximum height of 4 mm.



Cable-to-PAT-Adapter

Provides 2 mm jacks for banana plugs and a 6-way connector (Molex) to connect small test cells like small pouch cells.

PAT Docking Stations

PAT test cells are cableless. To connect them with a battery tester they are simply inserted into the PAT socket of a docking station or PAT tester. The docking station can be left permanently wired to the potentiostat in use. This way wiring mistakes when connecting test cells are minimized.

Most often, PAT docking stations are used to power the PAT-Cell with a third-party battery tester. However, they are also very useful in combination with a PAT-Tester if you want to use them e.g. in a climatic chamber or directly inside a glove box environment.

Our docking stations for the PAT series support up to 16 test cells, and offer additional features such as data loggers and integrated temperature controlled cell chambers that allow battery tests up to 200° C.

	# Cell connections (PAT Socket)	Measurements in mm Height / Width / Length			Weight in kg	Operational temperature	Charge / Discharge / EIS*	Data Logger**	Temperature controlled cell chamber
PAT-Clamp-1	1	21	62	80	0.12	-20 - 70 ° C	✓		
PAT-Stand-1	1	80	113	105	0.5	-20 - 70 ° C	✓		
PAT-Stand-4	4	84	119	301	1.5	-20 - 70 ° C	✓		
PAT-Stand-16	16	120	315	315	7	-20 - 70 ° C	✓	✓	
PAT-Heater-4	4	230	265	400	14		✓		up to 200 ° C***
PAT-Chamber-16	16	375	640	380	24		✓	✓	10 - 80 ° C

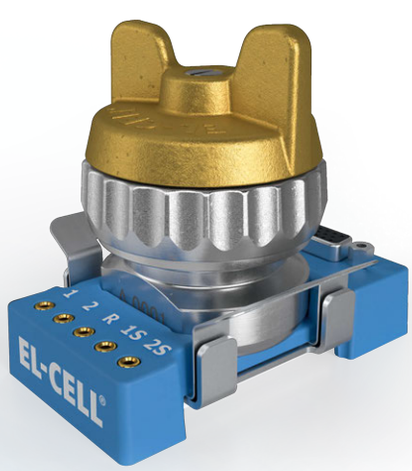
* Compatible with any PAT series test cell
** Independent data acquisition of cell data (current, full- and half-cell voltages), pressure (only PAT-Chamber-16) and temperature. EC-Link monitoring software is provided.
*** 10 ° C above average room temperature to 200 ° C

PAT-Clamp-1

Docking station with minimized dimensions

The PAT-Clamp-1 is a single cell docking station for tight space constraints. The cell is inserted and removed by bending up the clamp.

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.



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

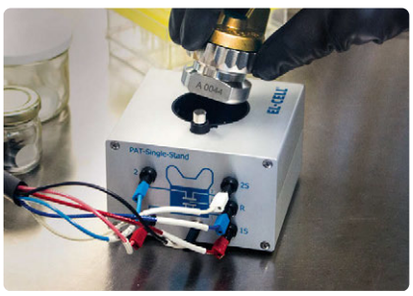
Height / Width / Length	21 / 80 / 62 mm
Weight	0.12 kg
Cell connections	1
Operational temperature	-20 to 70 °C

Product website:

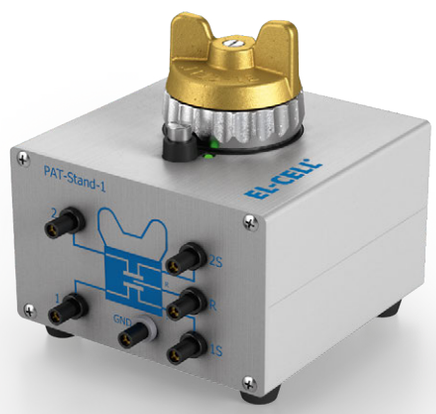
PAT-Stand-1

PAT-Cell docking station for individual battery testing

The PAT-Stand-1 is a docking station for a single PAT series test cell. It fits into any climate chamber with a cable feed-through and can be placed inside a glovebox. The stand can be left connected permanently to a common potentiostat or battery tester using 4 mm banana sockets or a Sub-D connector.



PAT-Stand-1 inside a glove box



Height / Width / Length	81 / 105 / 113 mm
Weight	0.6 kg
Cell connections	1
Operational temperature	-20 to 70 °C

Product website:

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 stand is connected to a common potentiostat or battery tester using 2 mm or 4 mm banana sockets.

Height / Width / Length	21 / 80 / 62 mm
Weight	0.12 kg
Cell connections	4
Operational temperature	-20 to 70 °C

Product website:

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). A typical setup comprises the PAT-Stand-16 placed inside a temperature chamber and an external 16-channel battery tester.

Height / Width / Length	120 / 315 / 315 mm
Weight	6.9 kg
Cell connections	16
Operational temperature	-20 to 70 °C
Data logger (recorded cell data)	- Current - Voltage (full and half cell) - Temperature (docking station)

Product website:

Accessories for the PAT-Stand-16

Height / Width / Length	106 / 334 / 195 mm
Weight	6.9 kg
Operational temperature	-20 to 70 °C
Connectors (2 mm banana sockets)	WE, WE-Sense, CE, CE-Sense, RE
Connectors (Sub-D)	buffered half cell voltages, temperature, sensor signals

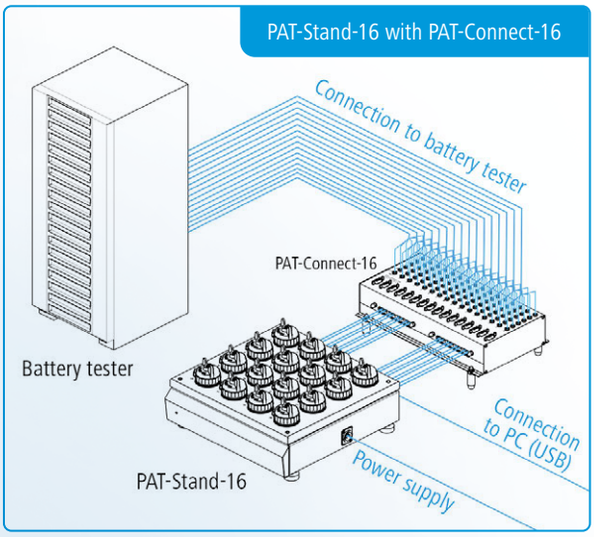
Product website:

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.

PAT-Stand-16 with PAT-Connect-16



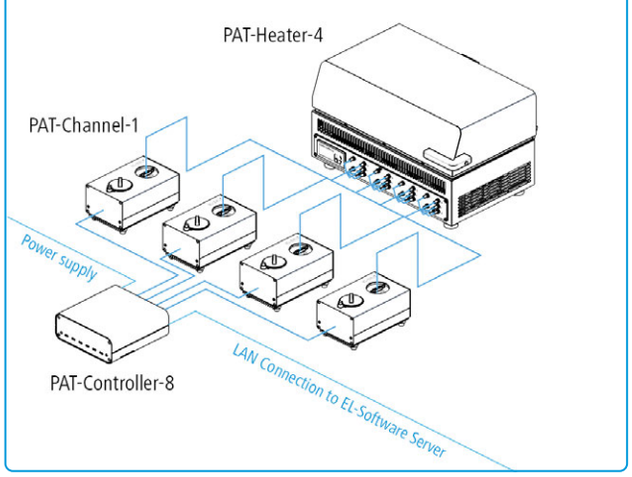
PAT-Heater-4

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 slightly above 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.

Sample setup with PAT-Tester-x-8



Features

- Heated cell chamber up to 200 °C
- 4 x1 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

Height / Width / Length	230 / 400 / 265 mm
Weight	14 kg
Cell connections	4
Temperature control range (cell chamber)	up to 200 °C *

Product website:

* 10 ° C above average room temperature to 200 ° C

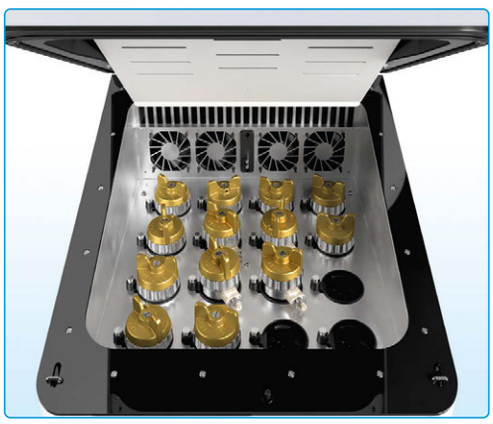
PAT-Chamber-16

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.

Features

- Temperature-controlled docking station for up to 16 PAT series test cells
- Integrated Peltier device for temperature control between +10 and +80°C
- Full support of PAT-Cell-Press for pressure monitoring
- Compatible with all of today's potentiostats and battery testers
- Flexible wiring possible with optional PAT-Connect-16



Height (opened / closed cover)	600 / 375 mm
Height with PAT-Connect-16 (opened / closed cover)	600 / 449 mm
Width / Length	380 / 640 mm
Weight	24 kg
Cell connections	16
Temperature control range (cell chamber)	10 to 80 °C
Data logger (recorded cell data)	- Current - Voltage (full and half cells) - Temperature (docking station) - Cell pressure

Product website:

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, this allows alternating between full-cell and half-cell control at runtime without having to change even a single cable.

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 virtually the same time!
All test channels feature a connection matrix for software-controlled switching between half- and full-cell measurements without reconnecting any cables.

Features

- Up to 16 independent test channels with fully equipped PStat / GStat / EIS (no multiplexing) and unique features
- Temperature-controlled cell chamber for up to 16 PAT series test cells
- Integrated Peltier device for temperature control between +10 and +80°C
- Smallest possible footprint, no cell wiring required

Height (opened / closed cover)	600 / 375 mm
Width / Length	380 / 640 mm
Weight	26 kg
Cell connections	16
Temperature control range (cell chamber)	10 to 80 °C

Product website:

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 / cm^2)
- CE: Graphite (CCI, approx. 2 mAh / cm^2)
- 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.

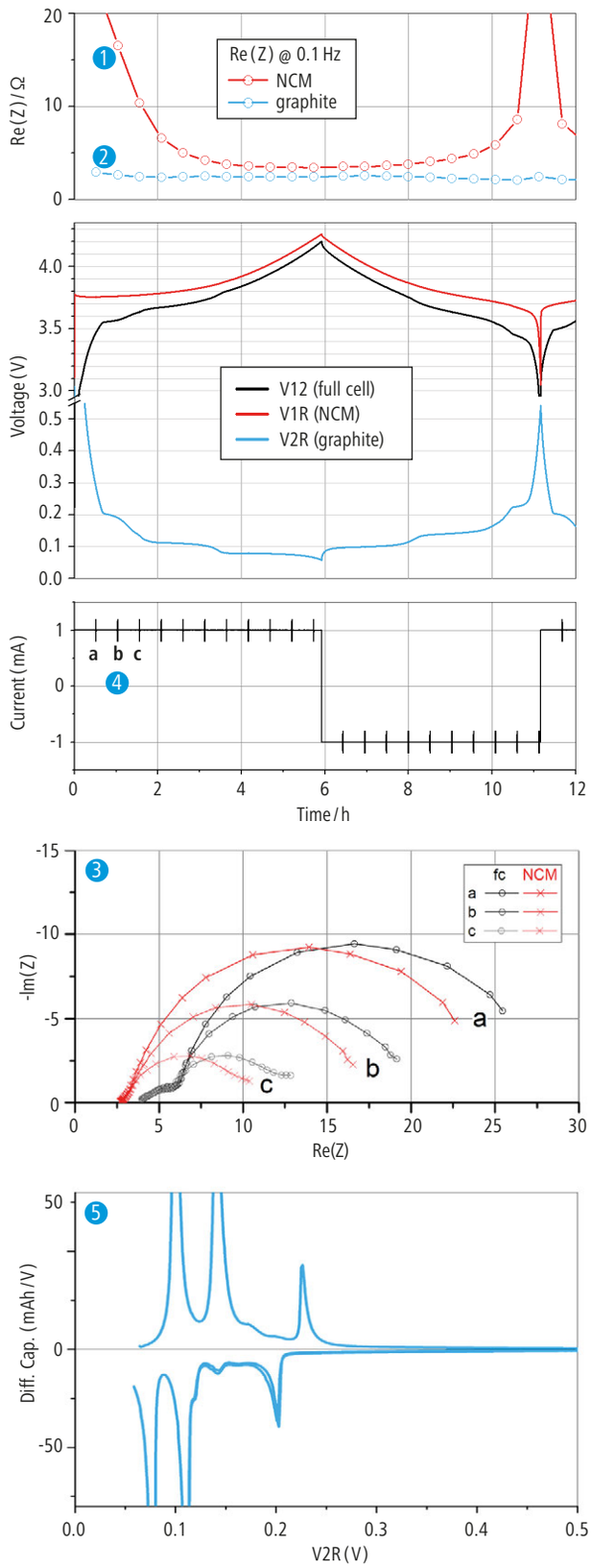
The first diagram shows the real part of the two half cell impedances (1 and 2) at 100 mHz extracted from the complete set of impedance data gathered during the experiment.

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 virtually the same time.



PAT-Tester-x-8

The individual and flexible 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 test channels are separated into individual devices.

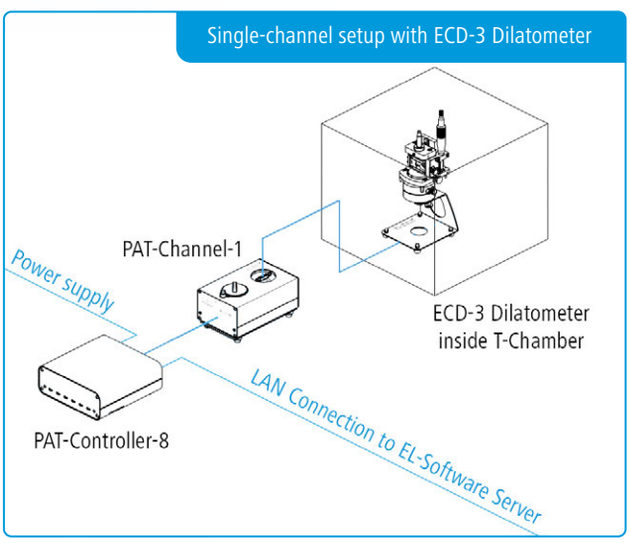
The **PAT-Controller-8** is the control unit for up to eight individually connectable PAT-Channel-1 boxes containing the actual measurement equipment. The PAT-Controller serves as a buffer for the measurement data and enables direct communication between the test channels and the EL-Software server. That way each test channel of the PAT-Tester-x-8 can be controlled from any client PC in the same network via the EL-Software.

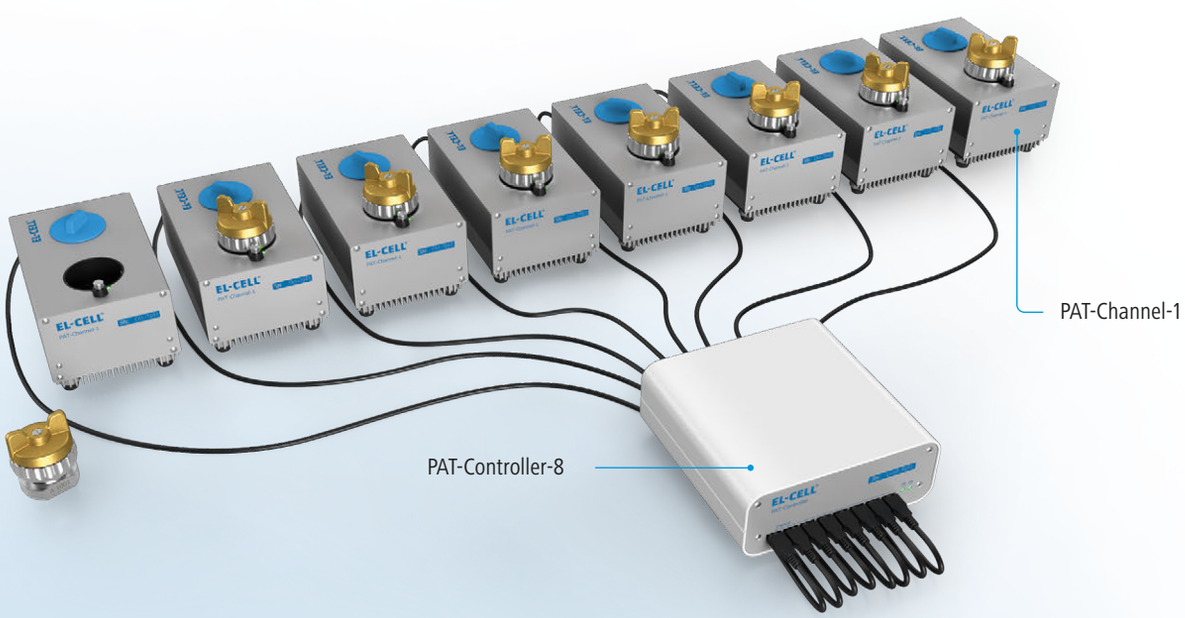
Each **PAT-Channel-1** contains a fully featured, independent galvanostat / potentiostat / impedance analyzer. Just like the test channels of the PAT-tester-i-16, there is no multiplexing. The PAT-Channels can be placed where they are needed: on the bench, in a climate chamber, or inside the glove box. While tailored for PAT-Cells, each PAT-Channel-1 can also connect to almost any other test cell including the ECD dilatometer and optical in-situ cells.

PAT-Controller-8 (control unit)	
Height / Width / Length	78 / 170 / 168 mm
Weight	1.7 kg
Test channels	up to 8
Operational temperature	0 to 40 °C

PAT-Channel-1 (test channel)	
Height / Width / Length	97 / 105 / 164 mm
Weight	1.3 kg
Operational temperature	-20 to 40 °C

Product website:

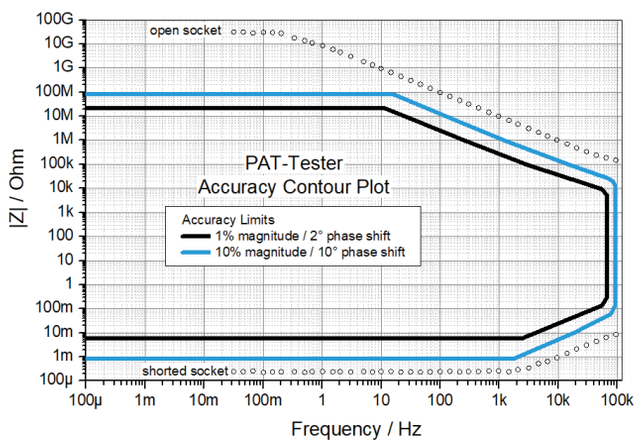




PAT Battery Tester Specifications

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
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)
Voltage	
Acquisition of ...	Full cell voltage, Both half cell voltages, Auxiliary voltage
Measurement accuracy	±0.02% of FSR
Control resolution	57 µV (18 Bit)
Impedance (each channel)	
Frequency range	100 µHz to 100 kHz
Impedance mode	PEIS and GEIS (simultaneous measure- ment of full- and half-cell impedances)
Impedance range	1 mΩ to 100 MΩ

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 num- ber stored in EEPROM



EL-Software

EL-Software is the software platform to design, manage and monitor experiments on all EL-CELL battery testers, be it single-channel or multi-channel systems. It offers many features like a central, conveniently searchable database, networking capabilites or the Composer,a powerful yet easy-to-use visual test script editor.

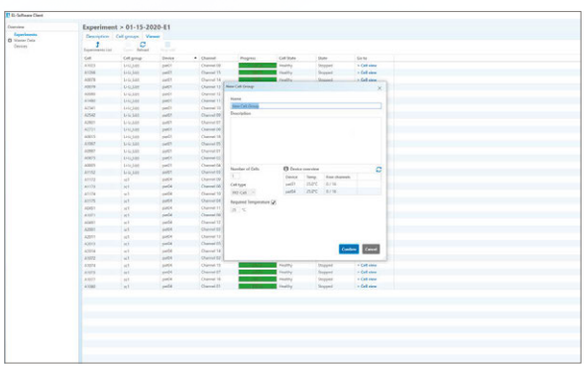
It also provides you with state-of-the-art graphics capabilities for visualizing your test results, while the open export interfaces allow seamless integration into existing software pipelines.

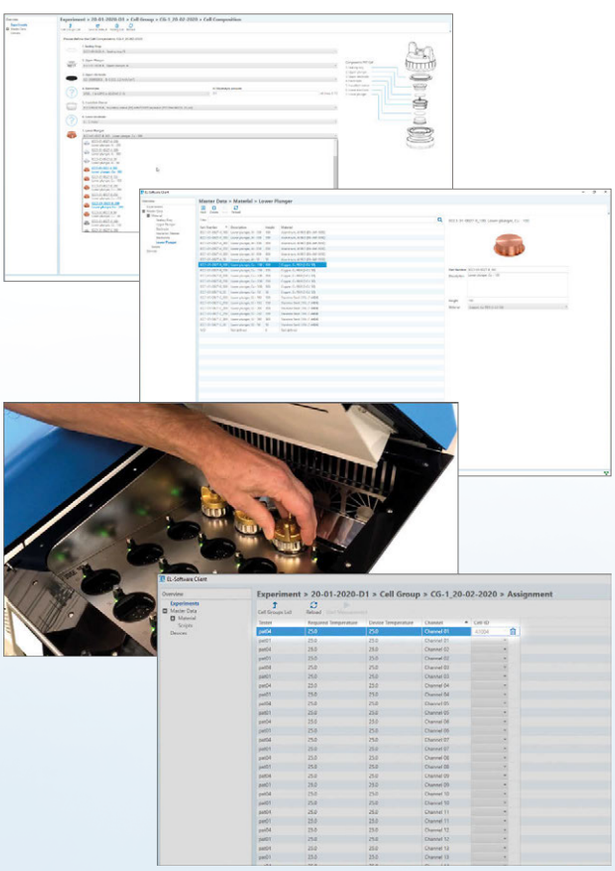
EL-Software guides you through the individual steps of testing with the PAT system and other test cells.

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 experiments with just a single cell.





Convenient experiment design and cell management

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.

Test cells are accompanied by the software throughout their entire life cycle. This provides permanent access to a wide range of information, such as the history of the experiments performed, the cell components used, and data for post-mortem analysis.

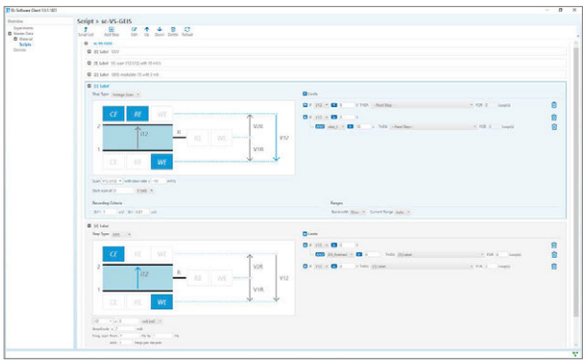
As soon as a test cell with an integrated **PAT-Button** is inserted into a PAT-Tester, EL-Software recognizes this cell via the stored ID and can immediately provide information about all linked information such as the content of the cell. In this way, the researcher always keeps an overview and can more easily combine cells from different test groups in new experiments. Manual labeling with pens or QR codes has thus become superfluous.

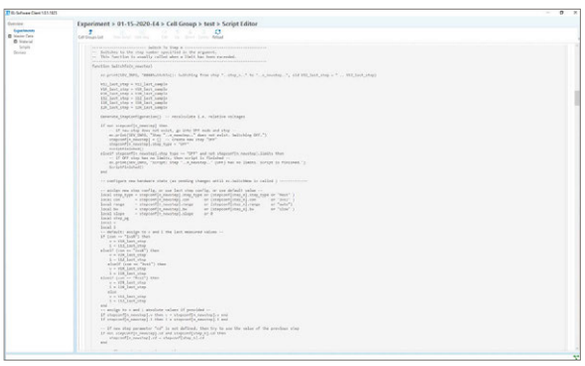
Compose test scripts

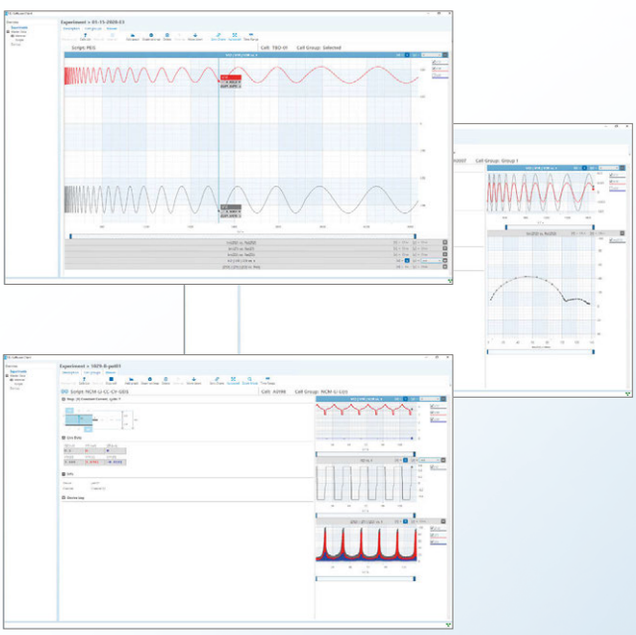
Visual script editor: Create your test scripts comfortably and efficiently in the Composer, a powerful visual editor integrated into EL-Software. The Composer uses an easy-to-learn modular principle to create even complex test procedures in a very short time. As a unique feature, the connection between 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.

Custom scripts: 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.

On-the-fly editing: Test sequences can even be changed during the runtime of the experiment. To do this, you simply edit the Lua script in question and upload this script again. In that way, set-points and step limits can be changed, in a way never possible before.







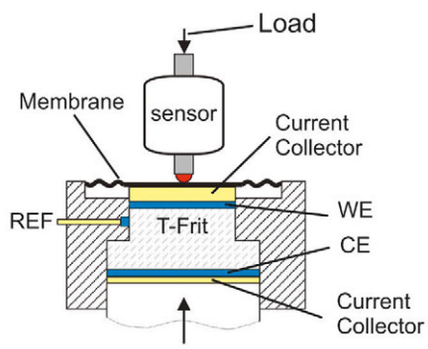
Experiment monitoring: Always keep the overview

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

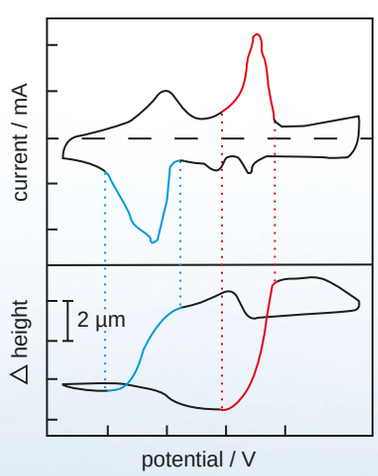
Watch your electrodes breathe

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.

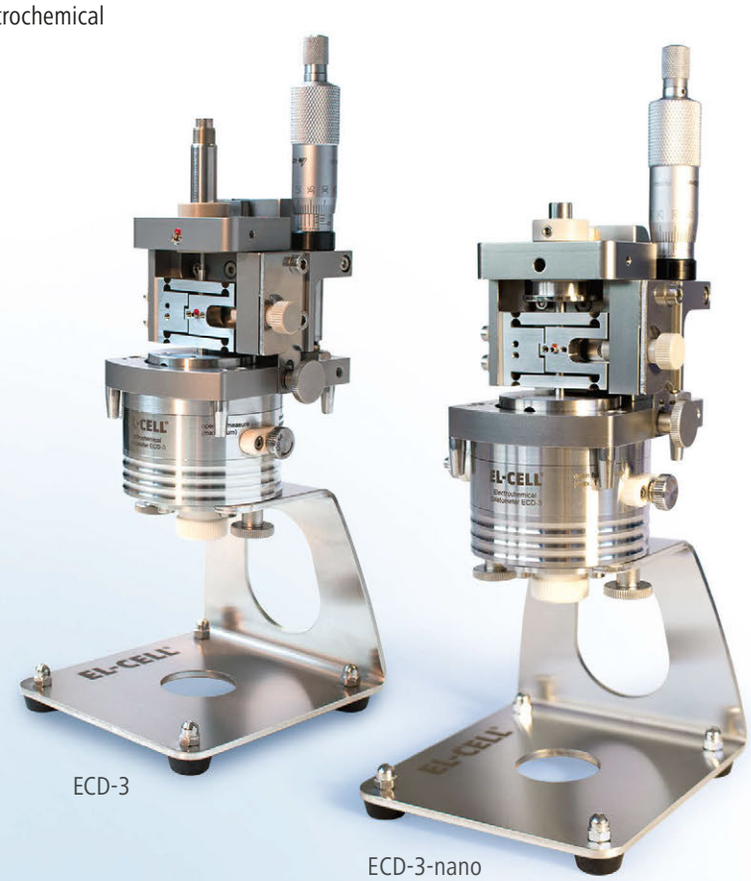


Current response and height change of layered ruthenium oxide in 2 M H_2SO_4 during slow scan voltammetry. Courtesy of Prof. Wataru Sugimoto, Shinshu University, Japan.

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. To overcome the iR drop across the frit, a reference electrode REF can be placed at the edge of the frit near the working electrode.

Options

Various add-ons are available for special testing requirements: for the use of aqueous electrolytes, for the use of single grains or crystals instead of bonded electrode films, and for measuring the change in thickness of the entire battery stack instead of just the working electrode.



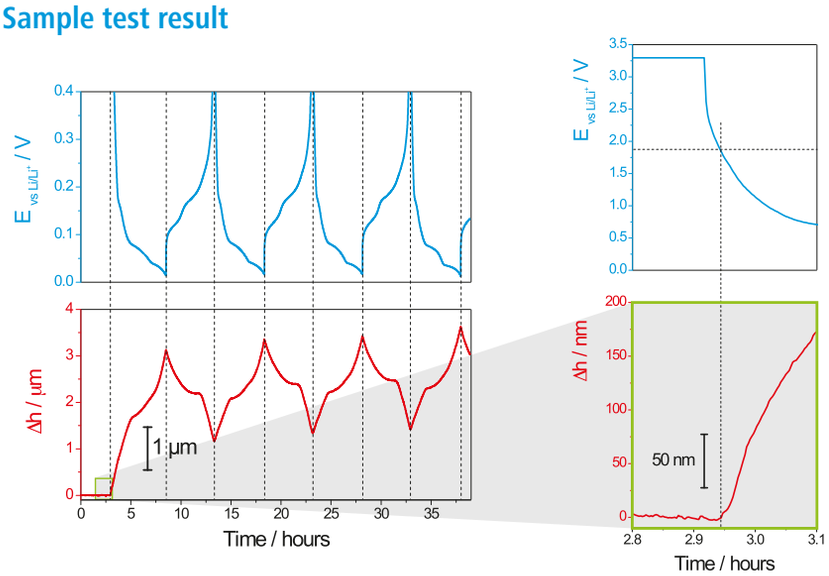
ECD-3

ECD-3-nano

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	
Operational temperature	-20 to +70 °C (Cell and Sensor) 0 to +40 °C (Conditioning electronics and data logger)	
Measurements (Height / Width / Length)	265 / 100 / 110 mm	230 / 100 / 110 mm
	Product website:	Product website:

Sample test result



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).

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.

Height / Width / Length	46 / 88 / 63 mm
Weight	0.2 kg
Separator diameter	10 mm
Electrode diameter	10 mm
Operational temperature	-20 to 70 °C

Product website:

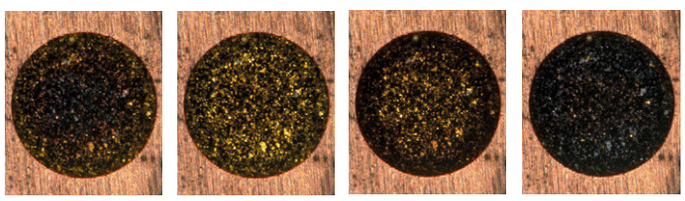
Sample Test Results

I. Electrochemical lithiation of a graphite electrode

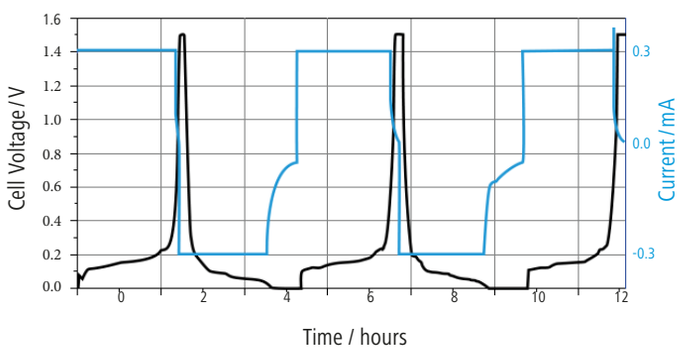
In this experiment, the ECC-Opto-Std test cell has been used to visualize the colour change of a graphite electrode during electrochemical lithiation.

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

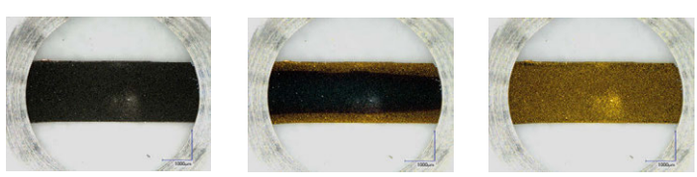


II. Visualizing the potential gradient

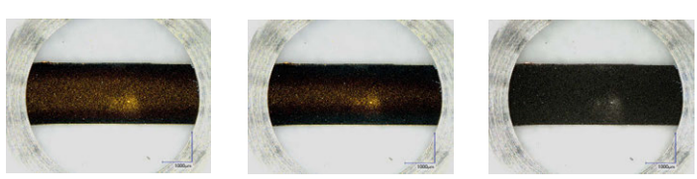
In this battery test, we show how the ECC-Opto-Std test cell can be used to visualize a potential gradient inside graphite just by using a standard graphite electrode with a continuous copper foil as the current collector (rather than a current collector with a hole).

Test setup:

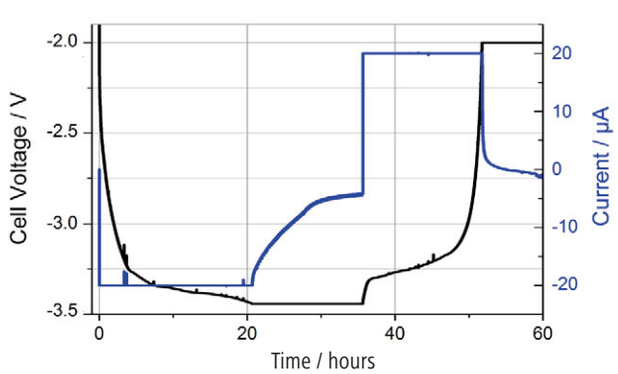
- WE: Strip of graphite electrode (CCI, 1.1 mAh / cm^2, 50 µm thick, 2 mm wide), with the Cu foil current collector pointing to the counter electrode
- CE: Lithium iron phosphate electrode (CCI, 3.6 mAh / cm^2, 9 mm in diameter)
- Separator: Nonwoven glass fibre, 10 mm in diameter, 0.5 mm thick
- Electrolyte: 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. Components in direct electrolyte contact are made of gold, PEEK, EPDM and the window material.

Height / Width / Length	46 / 88 / 63 mm
Weight	0.2 kg
Separator diameter	10 mm
Electrode diameter	10 mm
Operational temperature	-20 to 70 °C

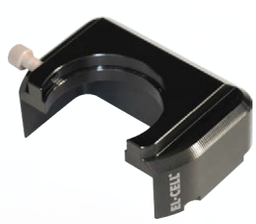
Product website:

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

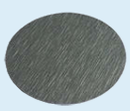
The Cell holder III is designed for use in a Bruker FTIR Hyperion 2000 microscope.

- 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

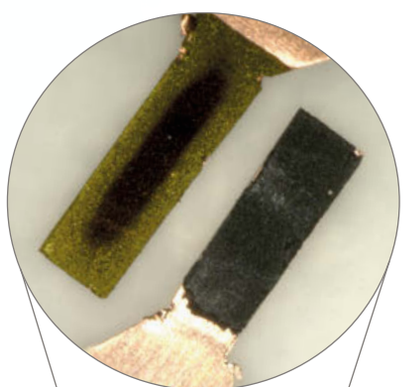
ECC-Opto-10

Advanced optical battery test cell

The ECC-Opto-10 test cell is an advanced next generation battery test cell. It is designed for operando characterization of electrodes using optical methods such as light microscopy or Raman spectroscopy in reflection mode.
A newly developed sealing concept utilizing laser-welded glass-to-metal electrode feedthroughs and foil seals substantially increases cycle stability compared to the previous generation. The much more compact and low profile design allows use under a wide range of microscopes. We further optimized the cell design for easy assembly. Dedicated sample holders for side-by-side and sandwich arrangements of electrodes vastly improve the handling.
The ECC-Opto-10 is connected to the battery tester via 2 mm cell cable with banana plugs. It can be used with the PAT-Tester-x-8 as well as potentiostats and battery testers from third-party manufacturers.

Features

- High cycling stability due to improved sealing concept
- Dedicated sample holders for different electrode arrangements available
- Fast assembly and dismantling and easy cleaning of cell components
- Electrodes are easily accessible for post-mortem analysis
- Low cell height of 21.5 mm for trouble-free use under many light microscopes
- Fits well on standard microscope sample stages (76 × 26 mm (DIN ISO 8037-1))



Graphite electrode during lithiation

Height / Width / Length	46 / 88 / 63 mm
Weight	0.2 kg
Separator diameter	10 mm
Electrode diameter	up to 10 mm
Operational temperature	-20 to 70 °C

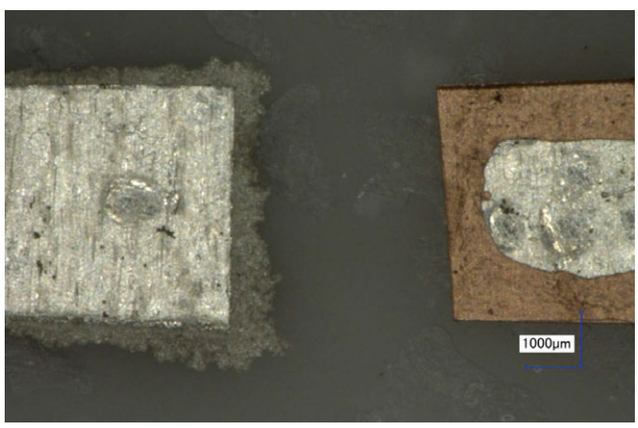
Product website:

PAT-Cell-Opto-10

Advanced PAT-Cell for optical characterization

TThe PAT-Cell-Opto-10 is an advanced next generation battery test cell. It is designed for in-situ characterization of electrodes using optical methods such as light microscopy or Raman spectroscopy in reflection mode. The design of the test cell is basically identical to that of the ECC-Opto-10, featuring an advanced sealing concept for high cycling stability and an easy-to-assemble cell design. In contrast to wired contacting, the PAT-Cell-Opto-10 is inserted cable-free via PAT socket directly into a PAT battery tester or docking station.

Sample test result



Lithium metal electrodes embedded into a glass fiber separator soaked with electrolyte. Applying a current of 20 µA for 5 hours makes the lithium to dissolve from the supporting copper foil (right electrode) and to plate as dendrites on the opposite side (left electrode).

Features

- High cycling stability due to improved sealing concept
- Dedicated sample holders for different electrode arrangements available
- Fast assembly and dismantling and easy cleaning of cell components
- Electrodes are easily accessible for post-mortem analysis
- Cableless cell connection via PAT socket
- PAT-Button for automatic cell identification in EL-Software

Height / Width / Length	32 /55 /55 mm
Weight	0.3 kg
Separator diameter	10 mm
Electrode diameter	up to 10 mm
Operational temperature	-20 to 70 °C

Product website:

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.

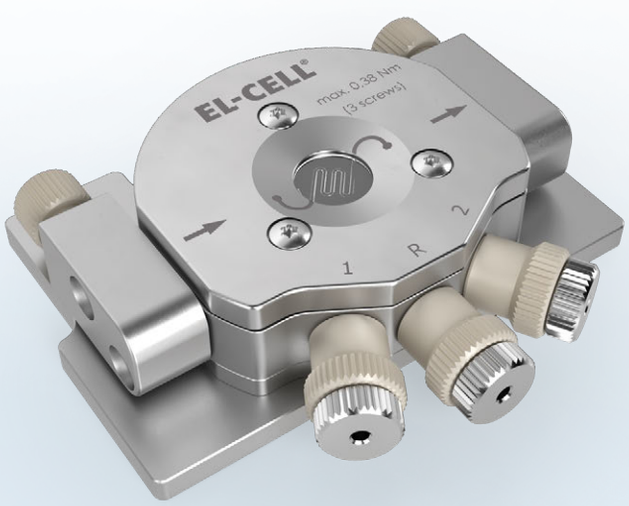
The ECC-Opto-Gas can be mounted on the stage of almost any light or Raman microscope in order to "look" through the transparent window onto the backside of the GDE. The cell is equipped for use with aprotic organic electrolytes.

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

Height / Width / Length	21 / 75 / 67 mm
Weight	0.3 kg
Separator diameter	12.5 mm
Electrode diameter	12 mm
Operational temperature	-20 to 70 °C

Product website:

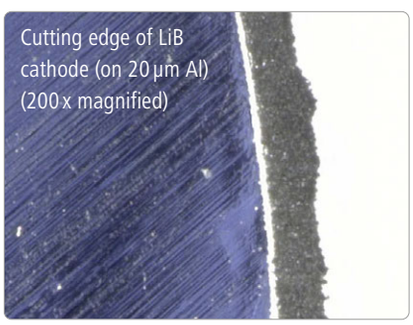


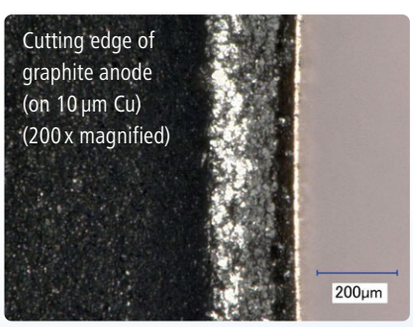
Tools

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 of LiB cathode (on 20 µm Al) (200 x magnified)



Cutting edge of graphite anode (on 10 µm Cu) (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)
- The permanently installed cutting tool can have any size (diameter) from **6 to 40 mm**. Different shapes (e.g. squared) are available upon request.

Height / Width / Length	140 / 380 / 60 mm
Weight	3 kg
Supported materials	Coated Al and Cu foil

Product website:

ECC-LiPunch

Punching tool for lithium foil

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

Features

- For punching precise and flat lithium metal 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

Length / Diameter	100 / 39 mm
Weight	0.7 kg

Product website:

What is the right tool for you?

Test cells	ECC-LiPunch (recommended diameter)	EL-Cut (recommended diameter)
PAT-Cell. PAT-Cell-Press, PAT-Cell-Gas, PAT-Cell-HT	**ECC-LiPunch 18** (18 mm)	**EL-Cut 18** (18 mm)
ECD-3, ECD-3-nano	**ECC-LiPunch 12** (12 mm)	**EL-Cut 10** (10 mm)
ECC-Opto-Std	**ECC-LiPunch 10** (10 mm)	
ECC-Opto-Std-Aqu	-	
ECC-Opto-Gas	**ECC-LiPunch 10** (10 mm)	**EL-Cut 12** (12 mm)

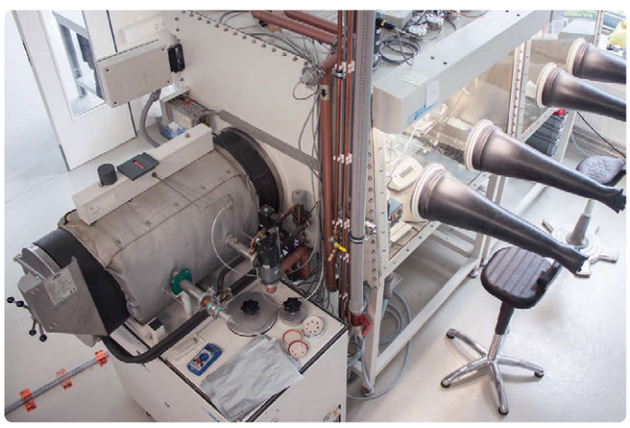
Services

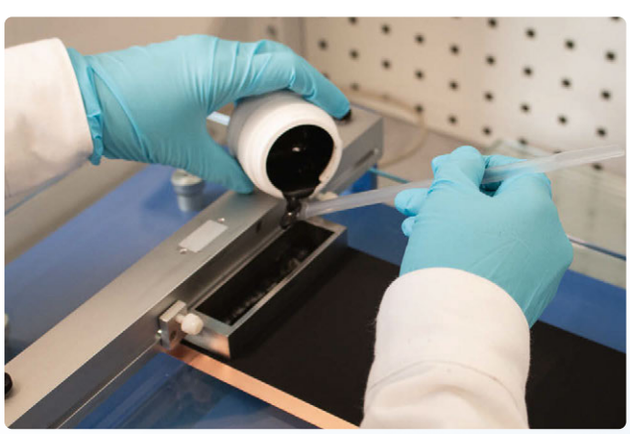
In addition to our hardware we also offer a wide scope of services like hands-on seminars or electrochemical service measurements in our own research laboratory.

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 with or without reference electrode (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 operando techniques with
  - ECC-Opto-Std: Visualizing the state of charge of and concentration gradients inside electrodes
  - PAT-Cell-Press: Quantifying the gassing during battery formation
  - ECD-3-nano: Measuring electrode dilation during charge and discharge

Facts:

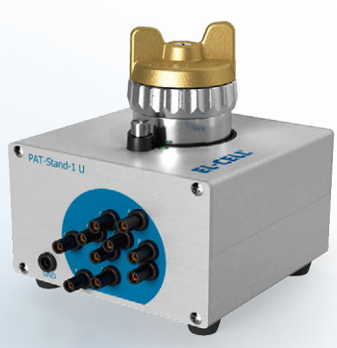
- Duration: two days (8 hours per day)
- Location: Tempowerkring 8 - 21079 Hamburg, Germany
- Pricing: regular registration: 1,300 Euro (1,200 Euro*)
  PhD-students**: 650 Euro (600 Euro*)

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

EL-CELL® delivers worldwide directly and through its distributors.

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

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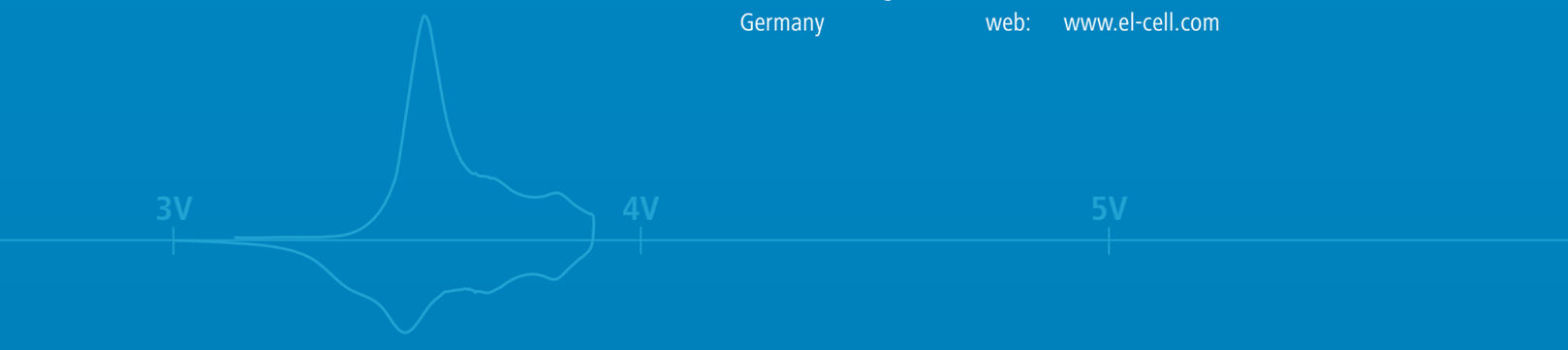

EL-CELL®

electrochemical test equipment