EL-CELL®
electrochemical test equipment



Instrumentation for Battery Research

Product Overview 2026

Results. Simply Achieved.



3-electrode Testing

Dilatometry

Solid-state

Force and Pressure Measurements

Gas Analysis

EIS

OEMS

Real-time Plotting

High-throughput Testing

Long-term Measurements

Testing Services

Optical, Raman and XRD Characterisation

EL-CELL®

electrochemical test equipment

We Advance Battery Research.

EL-Cell GmbH was founded in 2010 in Hamburg, Germany. Since then, we have been developing laboratory equipment to research energy storage systems, focusing on lithium-ion technology. We are distinguished by our expertise in both electrochemistry and engineering and our eager ambition to create innovative products.

For us, 3-electrode measurements are the most efficient way to develop new battery materials. Based on this belief, we designed the PAT (**PA**rallel **T**esting) series with the highest efficiency and ease of use standards in mind. It is a modular test cell system that comprises a growing variety of in situ test cells and potentiostats specifically tailored to meet the unique requirements of battery research. Our product range is rounded off by tools and accessories for manufacturing battery components, which significantly simplify the daily work steps in the laboratory. With our wide selection of products, we can offer our customers a complete set-up for electrochemical experiments from a single source.

However, we do not just offer products but also a range of services. Our fully equipped battery laboratory performs measurements for our customers at the highest scientific level. Our potentiostats, with hundreds of available test channels, and our entire range of measuring instruments are available for this purpose. We also offer practical seminars where you can learn how to work with our devices and benefit from our expertise.

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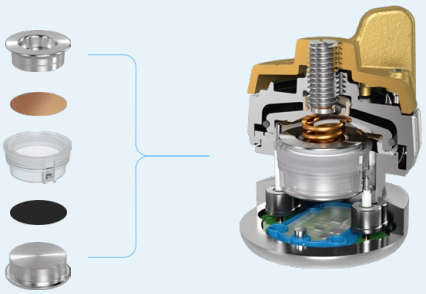
The PAT Series

Our modular system for testing 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 more accessible than ever before.

PAT-Core

The PAT-Core is the core component of each PAT-Cell, which contains the 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. This way, the test cell can be quickly and easily adapted to various test purposes.



PAT Series Test Cells

Our battery test cells consist of various cell housings that contain the cell stack and enable electrical contact with the potentiostat. Different variants with additional sensors or abilities are available for a variety of testing purposes. All models are designed for three-electrode measurements with a reference electrode.
Unlike other products, all PAT test cells are cableless. They are simply inserted into the socket of a PAT battery tester or docking station. This eliminates the risk of incorrectly connected cables or interference.



PAT Series Docking Stations

PAT docking stations are used to power PAT-Cells with a third-party battery tester. However, they are also instrumental 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 support up to 16 test cells, and offer additional features like data loggers or integrated temperature-controlled cell chambers.



PAT Series 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 modern system architecture. The devices can be flexibly installed and operated almost anywhere, with full control via LAN connection.
Each test channel of the PAT-Tester contains a fully equipped potentiostat / galvanostat and impedance analyser and is perfectly suited for high-precision coulometry and impedance spectroscopy.



EL-Software

EL-Software is the 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 worldwide patented, essential part of the PAT-Cell. It holds the electrodes under test in place and allows 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 batteries and other battery materials, as well as supercapacitors. The easy assembly of the PAT-Core minimises 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 customisable insulation sleeve with a built-in separator and ring-shaped reference electrode. Different reference materials, such as lithium, sodium, or partly delithiated LFP, and various separator materials, such as glass fibre or microporous polyolefin, are available. The single-use concept reduces lab lead times and minimises the risk of cross-contamination.

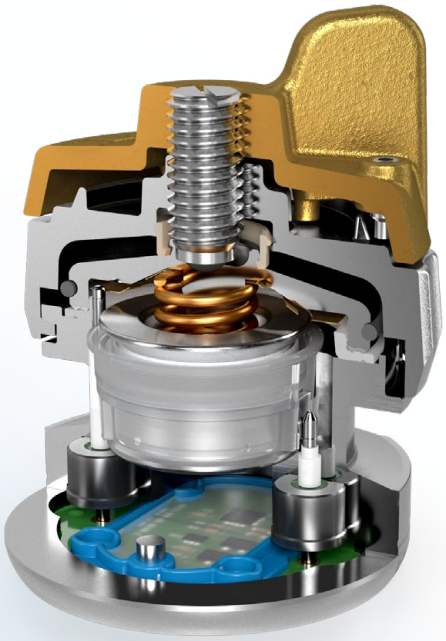
The insulation sleeve is preassembled under a protective argon atmosphere at the EL-CELL factory to ensure consistent quality for reproducible battery tests. PEEK is an alternative insulation sleeve material; this way, we can also offer a reusable version for self-assembly.

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 and nickel, or precious metals such as gold or platinum for specific applications. The PAT-Core is suitable for aprotic and aqueous electrolytes. In addition, the PAT-Solid-Core and PAT-HT-Core variants offer solutions for specialized applications, such as the characterisation of solid-state batteries and high-temperature applications, further expanding the capabilities of the PAT-Core system.

Highlights of the PAT-Core

- High-precision concentric geometry of cell stack without manual alignment
- Modular concept adaptable for various configurations
- Long-term (>10000 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

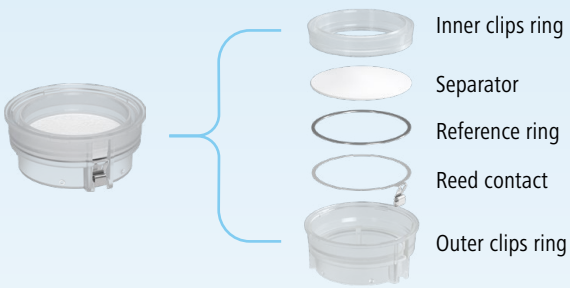
Different test cases require flexible cell configurations. PAT-Core components are available in various materials to perfectly match the needs of your investigation. **The examples shown below provide an overview of only the most common applications.** We continuously expand the PAT system to include 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 as current collector	Stainless steel or aluminum
Upper plunger	Stainless steel or copper	PEEK with gold as 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	Stainless steel	Gold plated stainless steel	Stainless steel

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

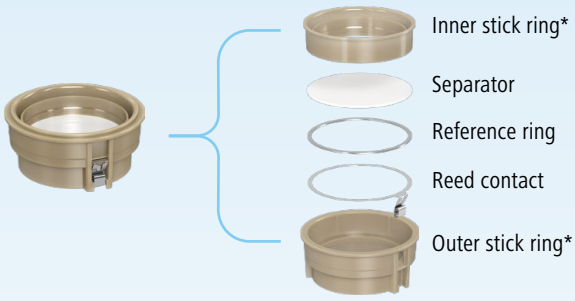
There are two types of insulation sleeves for the PAT-Core. The variant made of polypropylene is a single-use item with a built-in separator, ring reference, and reed contact. The single-use concept lowers lead times in the lab and is the perfect choice for high-throughput testing. On the other hand,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



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

PAT-Core Configurations

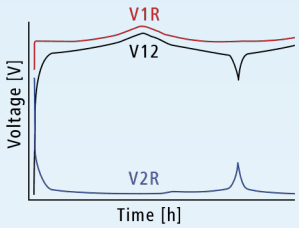
Different separator materials for your test case

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

Separator types	**FS-5P** (Freudenberg Viledon FS 2226E + Gore Heerlen Solupor 5P09B)	**Whatman GF/A**	**Celgard QT17P2HX**
Thickness	220 µm	260 µm	16.5µm
Material	PP fibre / PE membrane	Borosilicate glass fibre	PVDF/PP/PE/PP/PVDF
Porosity	FS: 67 % / 5P: 86 %	91 %	54%
Wettability	Good	Excellent	Good
Resistance to dendrites	Good	Modest	Good
Ability for full cell cycle tests	Good	Good	Good
Ability for half cell cycle tests (vs. Li)	Good	Good	Modest
Ability for full cell EIS	Excellent	Excellent	Excellent
Ability for individual electrode EIS	Modest	Good	Modest

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. We consider insulation sleeves with Li metal reference and a glass fibre separator the most robust and versatile solution for Li-ion-based systems. Many variants of the insulation sleeve are available for other battery chemistries, including Mg, Na-ion, and supercapacitors. When used with a 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.

PAT-Core Components

The PAT-Core is a modular and interchangeable system that meets the requirements of almost any test scenario. Its components are compatible with all PAT series test cells that utilize the standard PAT-Core design. Custom materials are available upon request.

Separators

FS-5P



Double layered separator:
PP fibre + PE membrane

Whatman GF/A



Borosilicate glass fibre

Celgard QT17P2HX



PVDF / PP / PE / PP / PVDF

Customized



Provided by customer

Reference rings



Reed contacts

Stainless Steel



Gold



Insulation sleeves



PP

- Single-use
- Preassembled

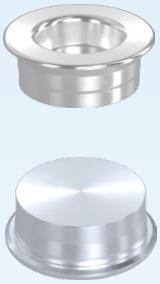


PEEK

- 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



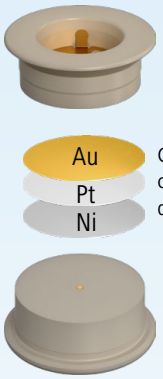
- Reusable
- Stainless steel (316L, 1.4404)

Nickel



- Reusable
- Nickel (Ni > 99 %)

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

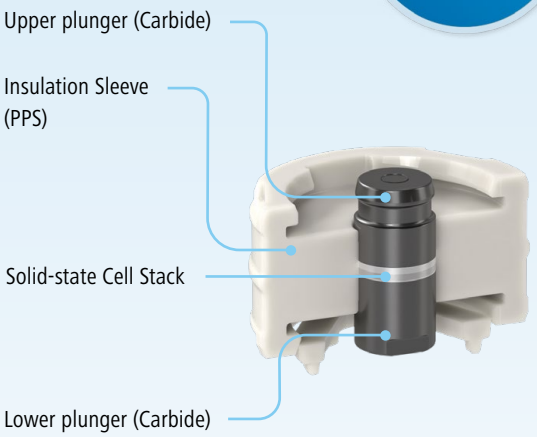
PAT-Solid-Core

The PAT-Core variant for solid-state batteries

The PAT-Solid-Core is a new variant of the PAT-Core. It has been developed to enable the easy assembly and characterisation of cell stacks with powdered solid-state electrolytes. The cell stack is pressed directly in the PAT-Solid-Core using the Solid-state Pressing Device in a multi-stage process outside the glovebox. It is then inserted into the test cell, for example, the PAT-Cell-Solid, for measurement.

The PAT-Solid-Core features carbide plungers to withstand high pressing loads. It is available in two variants that support electrode diameters of 6 and 10 mm, thus enabling different pressure levels during cycling. The PAT-Solid-Core can be used in PAT-Cell-Force and PAT-Cell-Solid battery test cells.

New!





PAT-Solid-Core E-10
(10 mm electrode diameter)

PAT-Solid-Core E-6
(6 mm electrode diameter)

New Sealing Rings for PAT Series Test Cells



The cell's tightness against the ambient atmosphere is crucial for successful long-term measurements. PAT series test cells use a single seal between the lid and the cell base. In addition to the proven PE, PTFE and aluminium seals, two new variants are now available. Made of copper and aluminium, these seals are no longer inserted into the lid but placed on top of the cell base. They offer excellent sealing performance and are significantly more cost-effective than their predecessors thanks to their simplified design. **This means more high-quality measurements for the same budget!**

Sealing Rings	Suited for long-term testing	Order no.
Sealing ring PE	Modest (≤ 150 hrs)	ECC1-00-0232-A
Sealing ring PTFE	Modest (≤ 150 hrs)	ECC1-00-0232-B
Sealing ring Al New!	Excellent (> 10000 hrs)	ECC1-00-0232-N
Sealing ring Cu New!	Excellent (> 10000 hrs)	ECC1-00-0232-M

Comparing Seal Materials

Metal seals provide the highest level of cell tightness for long-term measurements

The battery test cells in the PAT series are characterised by their high impermeability to the outside atmosphere. This increases the long-term stability of the cell chemistry and enables long-term measurements over thousands of hours. The lid seal plays a particularly important role here. Variants in different materials are available to provide the optimum solution depending on the application. In the example measurement below, we tested PAT-Cells equipped with aluminum sealing rings against our standard version made of PE, looking in particular at capacity retention and Coulomb efficiency.



Aluminum sealing ring and compatible cell lids

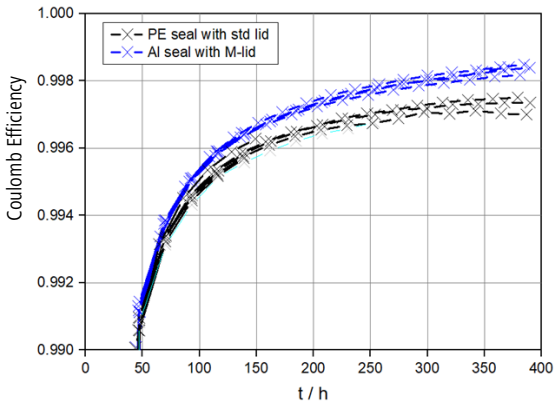
	Ready for Metal Lid Seals*
✓ PAT-Cell M	✓ PAT-Cell-Solid
✓ PAT-Cell-Force	✓ PAT-Cell-Gas-HT
✓ PAT-Cell-Press (all variants)	✓ PAT-Cell-Gas (all variants)

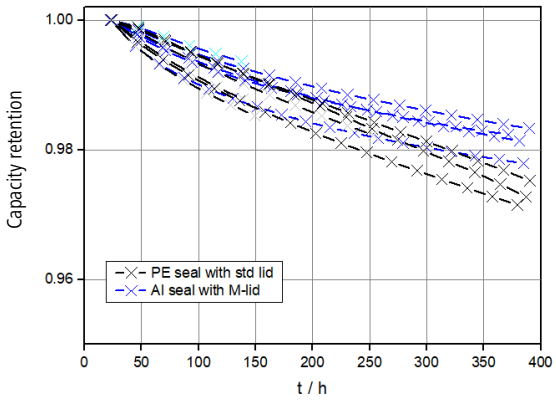
* All other PAT-Cells can be easily retrofitted.

Sample test result

Test setup:

- 6 PAT-Cells (Three cells each are built with PE or Al seals.)
- Electrodes: NCM111 vs graphite
- Electrolyte: LP32
- Temperature: 25 °C
- Test procedure used: CC-CV cycles at 0.1C
- Duration: 400 hrs
- Potentiostat: PAT-Tester-i-16





Test results:

The evaluation of the measurement results shows that the standard PE sealing performs very well up to approx. 100 hours. Only when the test duration is extended does the impact of improved sealing with the aluminum version become evident in the results. After 400 hours, we measured an excellent Coulomb Efficiency of over 99.8% with aluminum seals compared to the 99.6% of the PE seals.

A look at the capacity retention also shows the advantages of the aluminum seal with a longer test duration. After 400 hours, it is still over 98%, while the cells with PE seals range between 97-98%.

Conclusion:

The test results show excellent performance of PAT-Cells with aluminum lid seals. Therefore, we recommend using metal seals for long-term measurements and all experiments in which the gas pressure is determined.

For all other applications, however, the standard lid seal made of PE is still a very good choice, performing very similarly in experiments with shorter durations.

PAT Battery Test Cells

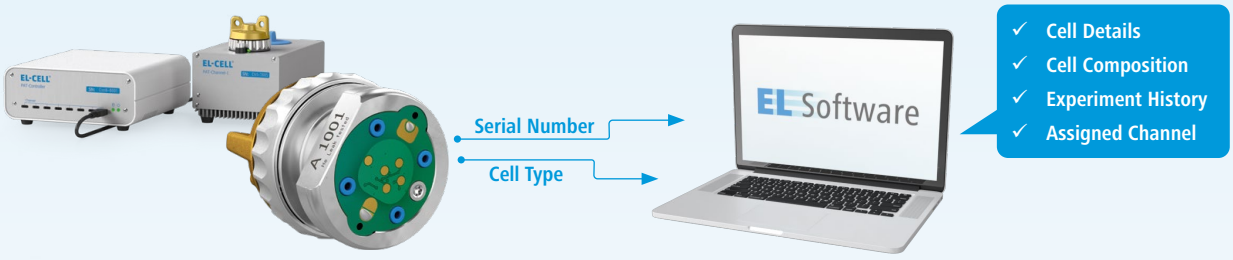
The battery test cells in the PAT series enable electrochemical measurements for a wide range of applications. For this purpose, cell housings that offer different capabilities such as pressure or force sensors or gas connections are available.

	2- / 3-electrode Testing	Testing Purpose	Built-in Sensors	Additional Capabilites	PAT-Core	Specialized PAT-Core	PAT-Button
PAT-Cell	✓	High-Throughput / Long-term testing			✓		✓
PAT-Cell-Press II	✓	Gas Evolution / Consumption	• Gas Pressure • Temperature	Gas Sample Port	✓		✓
PAT-Cell-Force	✓	Testing under applied pressure (up to 60 MPa)	• Force • Gas Pressure • Temperature	Adjustable force up to 1700 N	✓	PAT-Solid-Core	✓
PAT-Cell-Solid	✓	Testing under applied pressure (up to 300 MPa)	• Force • Gas Pressure • Temperature	• Adjustable force up to 9000 N • Gas Connections • Gas Sample Port	✓	PAT-Solid-Core	✓
PAT-Cell-HT	✓	Testing at elevated temperature (up to 200 °C)			✓		
PAT-Cell-Gas II	✓	Gas Analysis in flow-through setup	• Gas Pressure • Temperature	• Gas Connections • Gas Sample Port	✓		✓
ECD-4-nano	✓	Electrode expansion	• Dilatometry • Gas Pressure • Temperature				✓
PAT-Cell-Opto	✓	Optical characterisation		Light, Raman and X-ray supported			✓

The PAT-Button: Speed up your workflow!

The PAT-Button is located at the cell bottom of most PAT series test cells. It stores information like the cell ID and type and transmits it to EL-Software when the cell is inserted into a PAT-Tester. The software recognizes the cell and all the information stored about it in the past, such as the cell chemistry used, the components of the cell stack or the experiments carried out with this cell. This eliminates the need for additional labels or barcodes. The system will recognize a test cell, even if it is removed from the PAT-Tester between experiments.

The PAT-Button speeds up your workflow and prevents operating errors.



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 is equipped with a PAT-Button. The wireless cell is connected directly to a PAT battery tester or via a docking station to any commercially available battery tester / potentiostat. Thanks to its corrosion-resistant cell base, it is compatible with both aprotic and aqueous electrochemistry and is equally suitable for high-throughput scenarios and small test series. The PAT-Cell M variant can be fitted with metal seals to meets the highest demands for cell tightness and is particularly suitable for long-term measurements.

Features

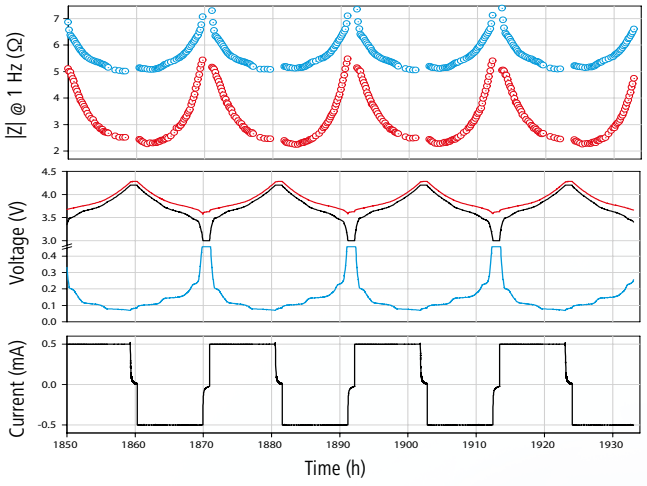
- Cableless test cell with all advantages of the PAT-Core
- For long-term testing (>5000 hrs) with two or three electrodes
- Proven cell design for easy handling and fast assembly
- Compatible with aprotic as well as aqueous electrochemistry
- PAT-Button for automatic cell identification in EL-Software

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

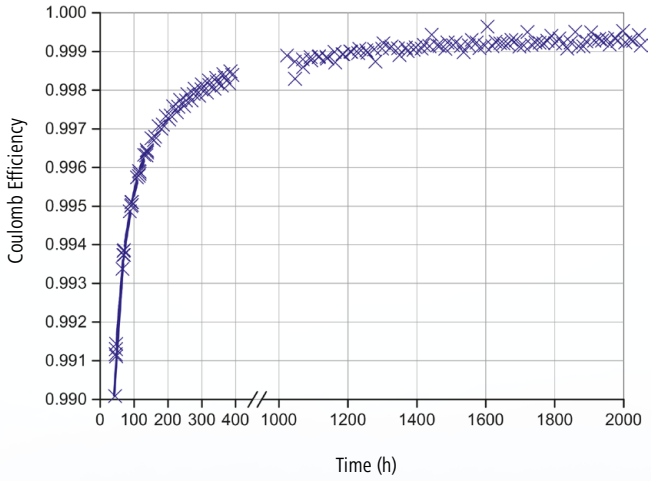
Product website:

Sample test results

Monitoring of half cell voltages over 2000 hours (NCM 111 vs. Graphite, Al seal)



Corresponding Coulomb efficiency





PAT-Cell PAT-Cell M

Variants

	Ready for Metal Seals
PAT-Cell	
PAT-Cell M	✓

Sample Test Case

Long-term stable and ready-to-use: Examining partly delithiated lithium iron phosphate as reference material

Lithium iron phosphate ($LiFePO_4$, LFP) is an established cathode material in lithium-ion batteries (LIB) due to its excellent electrochemical stability, intrinsic safety, non-toxicity, and low cost. Beyond its commercial success, $LiFePO_4$ has gained increasing attention for use as a reference electrode material due to its highly stable electrode potential in non-aqueous, lithium-based electrochemical systems. In this work, we show that partially delithiated (modified) LFP is a stable and reliable alternative to metallic lithium. Controlled chemical delithiation of LFP allows the setting of a precisely defined and reproducible electrode potential of 3.420 V vs. Li. The chemical pretreatment replaces the otherwise necessary step of in-situ electrochemical delithiation after the assembly of the 3-electrode test cell. As a result, the LFP reference electrode is immediately ready for use and offers long-term potential stability without parasitic side reactions or measurement inaccuracies.

Results:

Here we show results for the PAT-Cell M with NCM622 | Graphite and a $LiPF_6$-based electrolyte. We compare the modified LFP reference with a classic lithium metal reference in a 1000-hour cycle test. To ensure long-term stability, the cells were sealed with aluminum metal seals.

The modified LFP reference exhibits excellent potential stability, as demonstrated in the differential capacity curves (Figure 1 and 2).

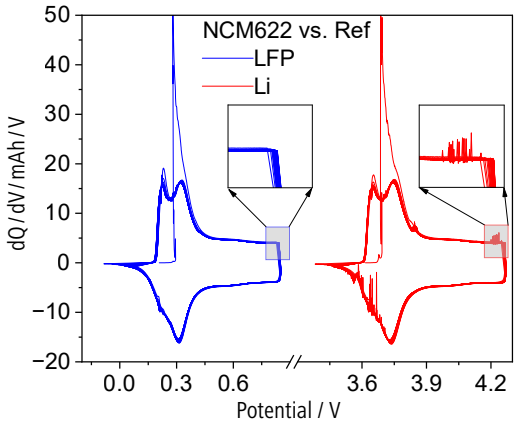


Figure 1: Differential Cathode Capacity

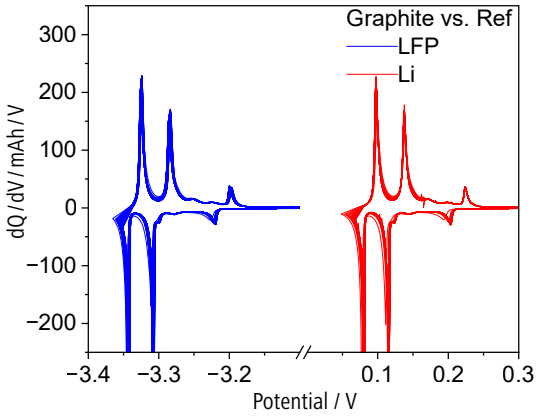


Figure 2: Differential Anode Capacity

The modified LFP potential is long-term stable at 3.420 V vs. Li. Uncertainty is < 5 mV over 1000 hours of cycling.

Due to the chemical pre-treatment, no upfront in-situ lithiation of the LFP reference is needed, making modified LFP a ready-to-use alternative for the standard Li metal reference electrode.

Thanks to its stability, modified LFP shows minimal parasitic reactions with the electrolyte. LFP is highly stable and compatible with a wide range of electrolytes and additives, including acetonitrile, in contrast with Li metal.

Voltage fluctuations, which are sometimes seen with Li metal reference electrodes during ultra-long-term cycling (Figure 2) and are presumably caused by dendrites, do not occur with modified LFP.

Conclusion:

The advantages of using chemically delithiated LFP as a reference material are, among others:

- Chemical stability against most battery components, and thus fewer side reactions
- Ready-to-use electrode; no in-situ delithiation required
- Excellent long-term stability (1000+ hours)

New!

Partially delithiated LFP as reference material is now available for the PAT-Core and ready for use in all PAT series test cells.

PAT-Cell-Press II

Pressure test cell for the PAT series

The PAT-Cell-Press II is a pressure test cell for measuring gas evolution and drawing gas samples (option). For this purpose, it is equipped with advanced digital pressure and temperature sensors. Its wireless connection to the potentiostat reduces interference and minimizes setup time. With laser-welded sensors, glass-to-metal electrode feedthroughs, and metal seals, the PAT-Cell-Press II ensures maximum cell tightness against the ambient atmosphere. It utilizes the modular PAT-Core system, offering flexible, time-saving cell stack configurations suitable for both aprotic and aqueous electrochemistry.

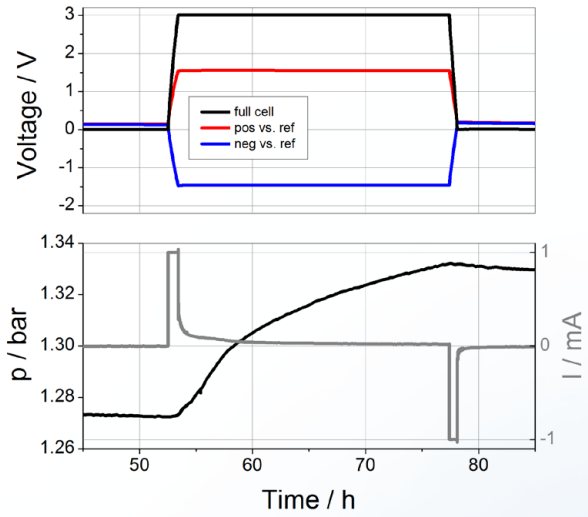
The PAT-Cell-Press II is designed for use with EL-CELL potentiostats to fully utilize all sensor functions.

Features

- Cableless test cell with all advantages of the PAT-Core
- Digital gas pressure sensor, pressure range of 0 to 3 bar abs.
- Optional gas sample port (PAT-Cell-Press II S)
- Compatible with aprotic as well as aqueous electrochemistry
- Built-in digital temperature sensor, -20 to 80 °C
- PAT-Button for automatic cell identification in EL-Software
- Ready for use with metal lid seals

Sample test result

Pressure response during cc/cv cycling of a supercapacitor*



Variants	Gas Pressure sensor	Gas sample port
PAT-Cell-Press II	✓	
PAT-Cell-Press II S	✓	✓

Height / Width / Length	61 / 49.5 / 49.5 mm
Width with sample port (PAT-Cell-Press II S)	70 mm
Weight	0.5 kg
Separator diameter	21.6 mm
Electrode diameter	18 mm
Dead volume (with / without PAT-Core)	3.6 / 8.1 ml
Operational temperature	-20 to 80 °C
Digital temperature sensor	-20 to 80 °C
Digital gas pressure sensor	
Range	0 to 3 bar abs.
Accuracy	< 5 mbar
Resolution	< 0.1 mbar

Product website:



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

PAT-Cell-Force

Versatile test cell for solid-state and liquid cell chemistries

The PAT-Cell-Force is a specialized operando test cell that enables adjustment and measurement of the mechanical force applied to the cell stack. With a wide force range of up to 1700 N, a pressure of up to 60 MPa can be applied on the cell stack, depending on the electrode diameter. This makes the PAT-Cell-Force ideal for characterising solid-state batteries, but it can also be used for other aprotic lithium-ion battery chemistries with liquid electrolytes. For testing with liquid electrolytes, the PAT-Cell-Force uses the patented PAT-Core system to build perfectly aligned cell stacks.

PAT-Core components with 18 mm electrode diameter are available for performing 2- and 3-electrode measurements. For solid-state electrolytes, a new variant of the PAT-Core, the PAT-Solid-Core, is available. This variant is specifically designed for measurements on solid-state batteries. The PAT-Solid-Core is available in electrode diameters of 6 and 10 mm. In addition, built-in sensors enable simultaneous monitoring of gas pressure and temperature. Thanks to its advanced sealing design, the PAT-Cell-Force is ideal for stable long-term measurements.

Features

- Force adjustment and measurement, max. 1700 N
- Modular cell stack configuration with PAT-Core and PAT-Solid-Core
- Up to 60 MPa pressure on cell stacks using PAT-Solid-Core
- Up to 5.9 MPa pressure on cell stacks using with PAT-Core
- Built-in temperature, force and gas pressure sensors



Different PAT-Cores for your application



PAT-Core for aprotic chemistries with liquid electrolytes

Electrode diameter: 18 mm



PAT-Solid-Core for solid-state electrolytes.

Electrode diameter: 6 or 10 mm

Height / Diameter	104 / 49.5 mm
Weight	0.4 kg
Separator diameter	21.6 mm (PAT-Core)
Electrode diameter (PAT-Core)	18 mm
Electrode diameter (PAT-Solid-Core)	6 mm / 10 mm
Temperature sensor	-20 to 80 °C
Force sensor	up to 1700 N
Gas pressure sensor	0 to 3 bar abs.
Operational temperature	-20 to 80 °C

Product website:

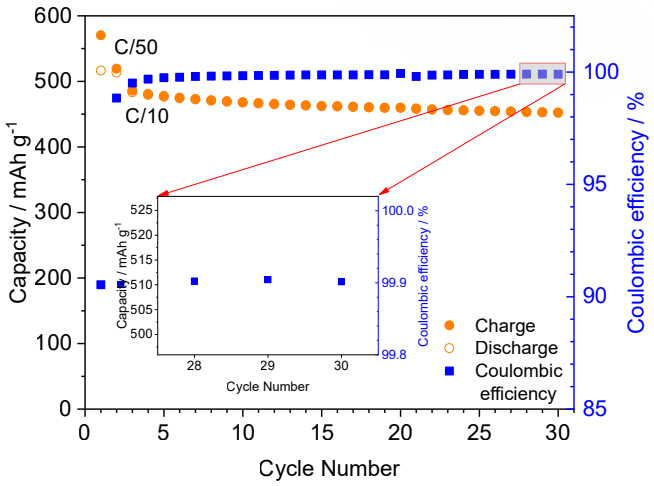
PAT-Cell-Force Configurations

The PAT-Cell-Force is available in various configurations, depending on your requirements.

Use case: Solid-state battery testing

Test solid-state cell chemistries at pressures of up to 60 MPa using the new PAT-Solid-Core. It is available for cell stacks with electrode diameters of 6 and 10 mm.

Sample test: Half cell SiC480 + LPSCl vs. In/InLi



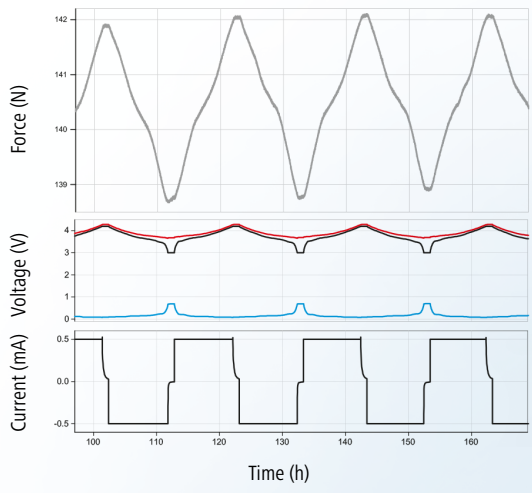


PAT-Cell-Force assembled with PAT-Solid-Core

Use case: Testing with liquid electrolytes

The modular components of the PAT-Core can be used to characterise aprotic cell chemistries with liquid electrolytes. The electrode diameter here is 18 mm, which means that a pressure of up to 4.9 MPa can be applied and measured.

Sample test: NCM 111 vs Graphite in LP30





PAT-Cell-Force assembled with PAT-Core

PAT-Cell-Solid

For testing solid-state cell chemistries with up to 300 MPa applied pressure!

The PAT-Cell-Solid is an electrochemical battery test cell capable of applying an adjustable force of up to 9000 N on the cell stack. It is designed to characterise solid-state batteries and can be equipped with the PAT-Solid-Core, enabling pressing and cycling of solid-state cell stacks with diameters of 6 or 10 mm. When using the PAT-Solid-Core with 6 mm components, pressures up to 300 MPa can be applied to the cell stack. Additionally, the PAT-Cell-Solid enables cycling with aprotic liquid electrolytes using the proven PAT-Core components.

The PAT-Cell-Solid includes a built-in temperature sensor and, optionally, a gas pressure sensor and gas connections for flow-through operation. Its design ensures excellent sealing against the ambient atmosphere using proven metal lid seals and laser-welded electrode feed-throughs. Electrical connection is made without cabling by inserting the test cell directly into the PAT-Tester-x-8 potentiostat or PAT docking station, thereby preventing interference and simplifying operation.

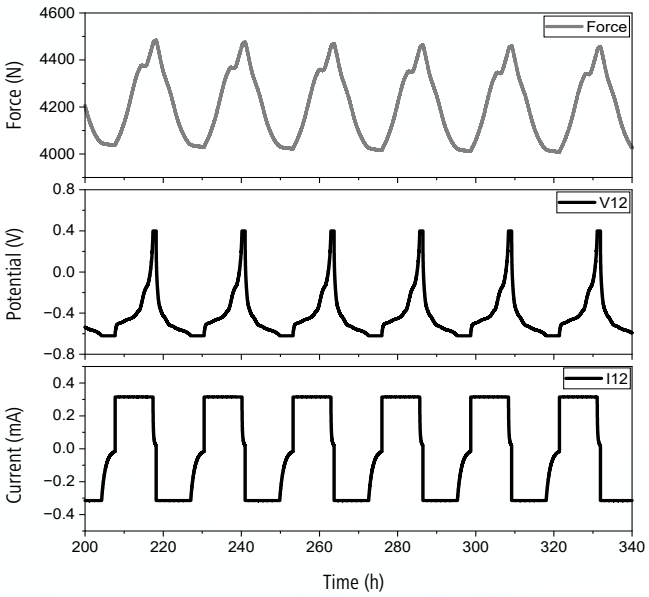
Features

- Force adjustment and measurement, max. 9000 N
- Up to 300 MPa pressure on cell stack (PAT-Solid-Core, 6 mm)
- Built-in temperature, force and gas pressure sensors (optional)
- Optional gas in- and outlet and sample port



Sample test result

Half cell SiC480 + LPSCl vs. In/InLi



Height / Width / Length	218 / 104.5 / 80 mm
Weight	3.5 kg
Separator diameter	21.6 mm (PAT-Core)
Electrode diameter (PAT-Core)	18 mm
Electrode diameter (PAT-Solid-Core)	6 mm / 10 mm
Temperature sensor	-20 to 80 °C
Force sensor	up to 9000 N
Gas pressure sensor	0 to 3 bar abs.
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

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 than PP) and is especially useful for the study of solid-state electrolyte membranes. The PEEK insulation sleeve can be equipped with different reference materials like the standard sleeve. The familiar 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

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:





PAT-Cell-Gas II

PAT-Cell for in-situ gas analysis in a flow-through setup

The PAT-Cell-Gas II is a test cell dedicated to in-situ gas analysis of battery materials in a flow-through set-up. For this purpose, the test cell features gas inlet and outlet ports with self-locking couplings compatible with 1/16-inch Swagelok tube fittings. In addition, options include built-in digital gas pressure and temperature sensors or a septum port for gas sampling 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 to allow 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 gas from the flowfield into the headspace and is thus very suitable for time-resolved gas analysis with a mass spectrometer, for example. All PAT-Cell-Gas II variants are designed for use with EL-CELL potentiostats to fully utilize all sensor functions.

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 spiral-shaped flow field for optimised plug-flow available.
- Optional digital gas pressure sensor, 0 to 3 bar abs.
- Optional gas sample port
- Electrode feedthroughs with glass-to-metal seals
- PAT-Button for automatic cell identification in EL-Software

Variants

	Gas connections	Digital gas pressure sensor	Gas sample port
PAT-Cell-Gas II SP	✓	✓	✓
PAT-Cell-Gas II P	✓	✓	
PAT-Cell-Gas S	✓		✓
PAT-Cell-Gas	✓		

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 digital gas pressure sensor	0 to 3 bar abs.
Accuracy of digital gas pressure sensor	< 5 mbar
Resolution of digital gas pressure sensor	< 0.1 mbar
Operational temperature	-20 to 80 °C

Product website:



*Depending on the lower plunger used

PAT-Cell-Gas II Working Modes

Mode 1: Air mode



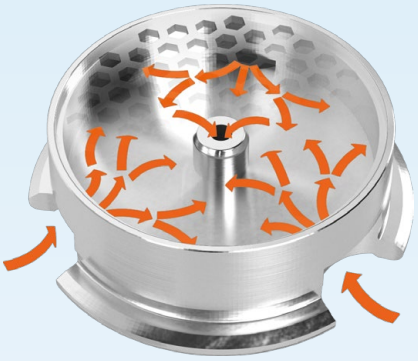
Upper plunger (current collector), stainless steel

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 a perforated plate allows for electrochemical characterisation 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 between the cell headroom and the gas volume below the perforated plate effectively prevents back-mixing. The relatively large volume below the perforated plate is at the expense of time resolution but makes this solution robust against clogging of the gas path.

Mode 2: OEMS mode



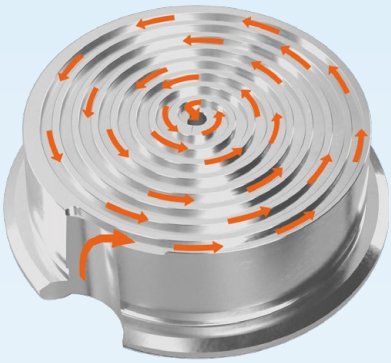
Upper plunger (current collector), stainless steel

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 a flow field provides an almost perfect plug-flow of the purge gas, essential for quantitative time-resolved analysis. Gases evolved or consumed at the working electrode may be analyzed 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 the best possible time resolution.

ECD-4-nano

Electrochemical dilatometer for measuring electrode expansion in the nanometer range

The ECD-4-nano is a high-resolution electrochemical dilatometer. It offers a capacitive parallel plate sensor system with a resolution of better than 5 nanometers. This makes it the perfect instrument for detecting thickness changes of the individual electrode or the full cell stack during the electrochemical cycle. The ECD-4-nano's test cell features a corrosion-resistant cell base and an advanced sealing concept for high tightness against the ambient atmosphere.

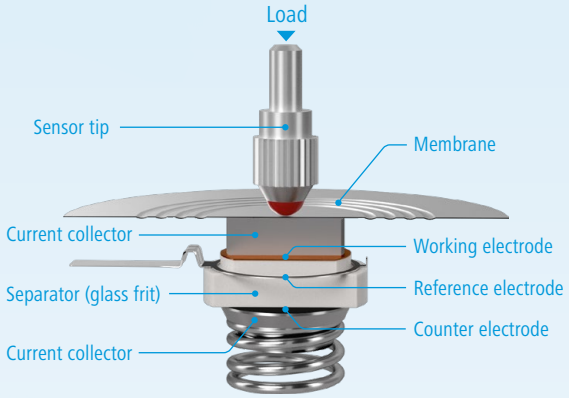
This enables stable long-term operation and the use of a wide range of electrolytes. To further improve workflow and handling, the ECD-4-nano is fully integrated into the PAT system. It can be inserted directly into a PAT-Tester-x or a docking station like the PAT-Stand-1. This allows for a space-saving, fast setup of the instrument. The integrated PAT-Button also ensures automatic recognition of the test cell in EL-Software .

Features

- Capacitive displacement sensor (range 250 µm, resolution better than 5 nm)
- Additional digital gas pressure (0 to 3 bar) and temperature sensors (-20 to 80 °C)
- Adjustable force on electrode / cell stack (1 to 15 N)



Working principle (Half cell mode)



The working electrode (WE) and the counter electrode (CE) are separated by a stiff glass frit soaked with electrolyte. The WE is sealed using 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 WE is being detected without interference from the CE.

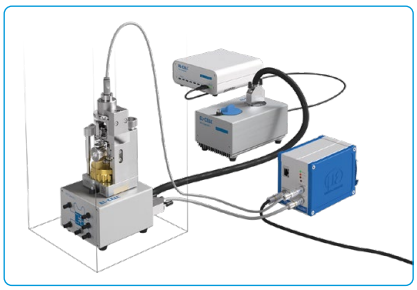
Product website:

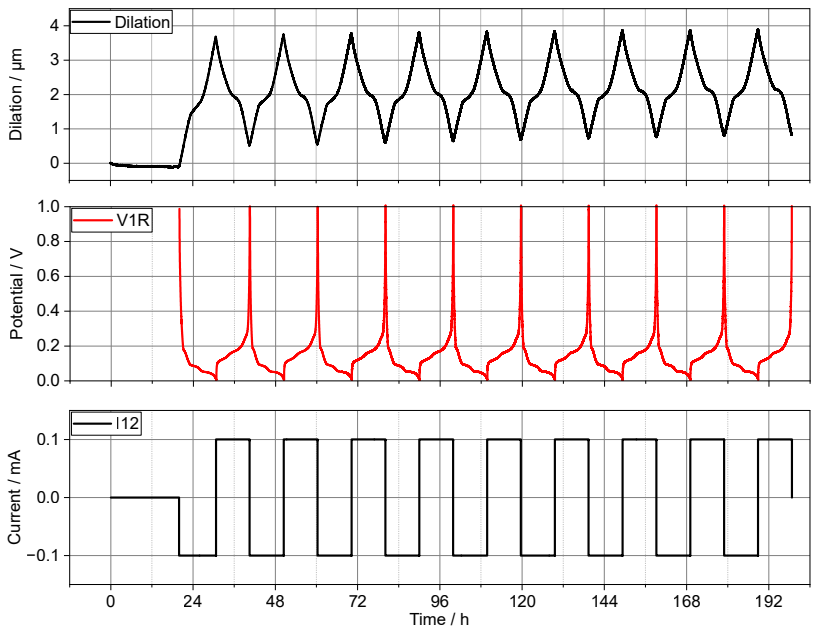
ECD-4-nano Specifications

Specifications	
Width / Depth in mm	68 / 77
Height with / without attached sensor cable	272 / 173 mm
Electrode setup	2- electrode / 3-electrode (ring-shaped reference)
Dead volume	6,2562 ml
Weight	2 kg
Glass T-Frit (Separator) dimensions	12.5 / 10 mm x 3.5 mm
Electrode diameter	≤ 10 mm
Electrode thickness	Half cell mode: max. 1 mm Full cell mode: max. 1 mm
Adjustable force on test specimen	1-15 N
Digital gas pressure sensor range	0 to 3 bar abs.
Chemical compatibility	Aprotic organic electrolytes
Cell electrolyte volume	Half cell mode: approx. 240 µl Full cell mode: approx. 40 µl
Operational temperature range (cell and sensor)	-20 to 80 °C
Operational temperature range (sensor box)	0 to 40 °C
Displacement sensor system	capacitive
Displacement range	250 µm
Displacement resolution	better than 5 nm

Sample test result

The diagrams on the right show the graphite electrode's expansion and shrinkage during lithium insertion and extraction.
For this experiment, we placed an ECD-4-nano inside a temperature chamber. The connection to the PAT-Tester-x-8 potentiostat and the ECD sensor box was established by using a PAT-Stand-1 docking station.





ECC-Opto-10

Advanced optical battery test cell

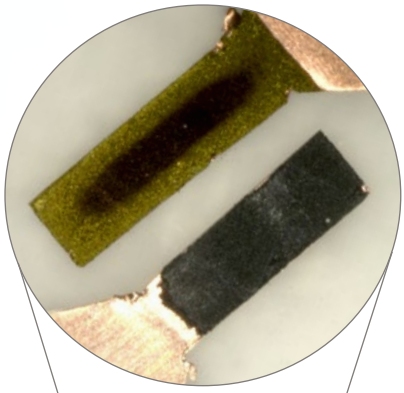
The ECC-Opto-10 test cell is an advanced next-generation battery test cell. It is designed for the operando characterisation of electrodes using optical methods such as light microscopy or Raman spectroscopy in reflection mode.
A newly developed sealing concept utilizing laser-welded glass-to-metal electrode 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 and potentiostats and battery testers from third-party manufacturers.

Features

- High cycling stability due to the improved sealing concept
- Dedicated sample holders for different electrode arrangements are 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))

Height / Width / Length	21.5 / 55 / 77.5 mm
Weight	0.2 kg
Separator diameter	10 mm
Electrode diameter	up to 10 mm
Operational temperature	-20 to 70 °C

Product website:



Graphite electrode during lithiation



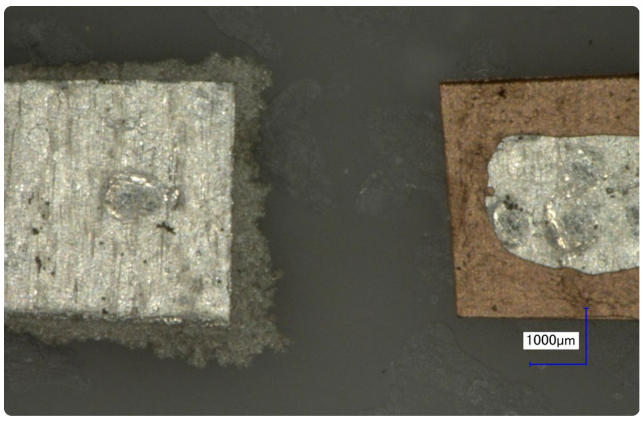


PAT-Cell-Opto-10

Advanced PAT-Cell for optical characterisation

The PAT-Cell-Opto-10 is an advanced next-generation battery test cell. It is designed for in-situ characterisation of electrodes using optical methods such as light microscopy or Raman spectroscopy in reflection mode. The design of the test cell is 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 fibre 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

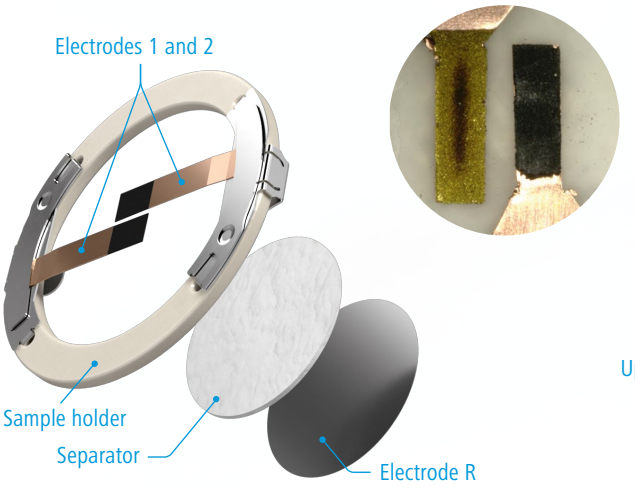
Product website:



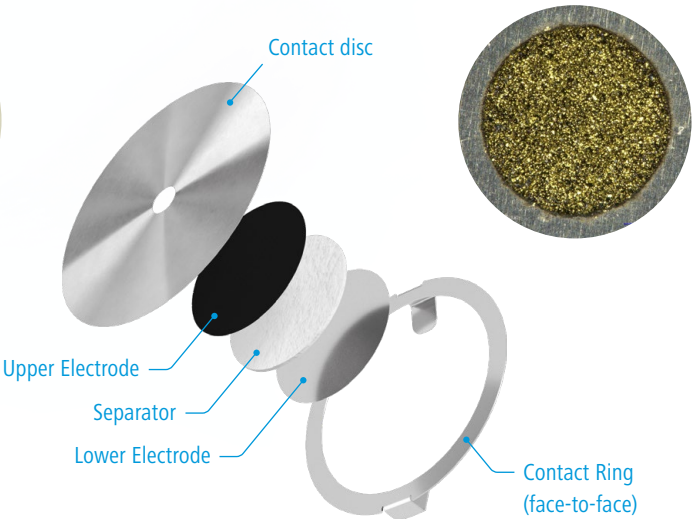
Sample Holders for Opto-10 Test Cells

Improve your workflow and save time with our sample holders for side-by-side and face-to-face arrangements of electrodes. They enable quick assembly of the test cell and are suitable for investigations using light microscopy, Ramanand X-ray.

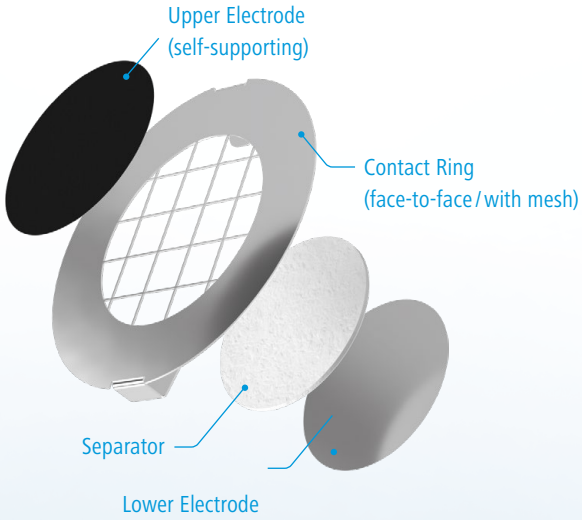
Sample holder (side-by-side)



Sample holder (face-to-face)



Sample holder (face-to-face with mesh)

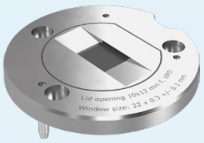


Windows and Cell Lids

Lid units with different openings and window materials are available for the Opto-10 test cells. They allow the cells to be used in a wide variety of applications. All units come preassembled with a window and are ready to use. Spare windows are available upon request.



Lid unit with sapphire window
Lid opening: 18 mm



Lid unit with beryllium window
Lid opening: 10 x 12 mm
Theta > 5° (1 mm)



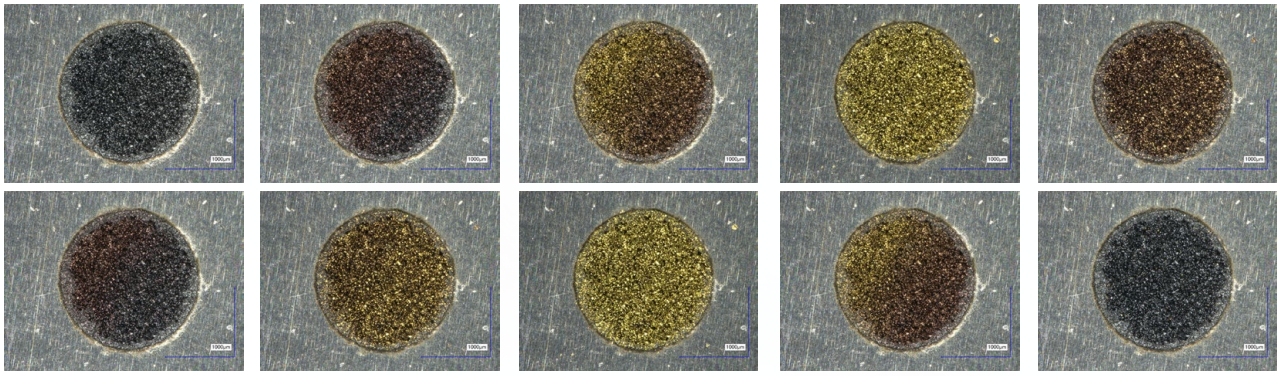
Lid unit with borosilicate window
Lid opening: 10 mm



Lid unit with customizable slit mask (no window included)
Lid opening: 18 mm
Suitable for unstable window materials such as PET

Sample Test Case

Cycling a graphite electrode vs. lithium metal in a PAT-Cell-Opto-10

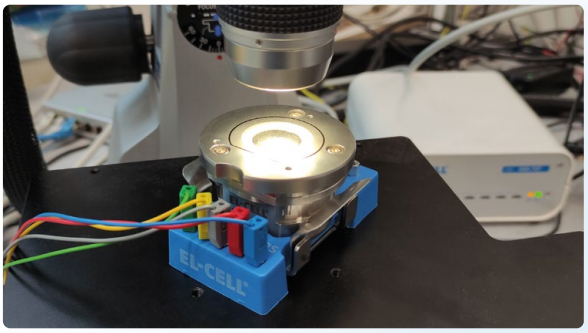


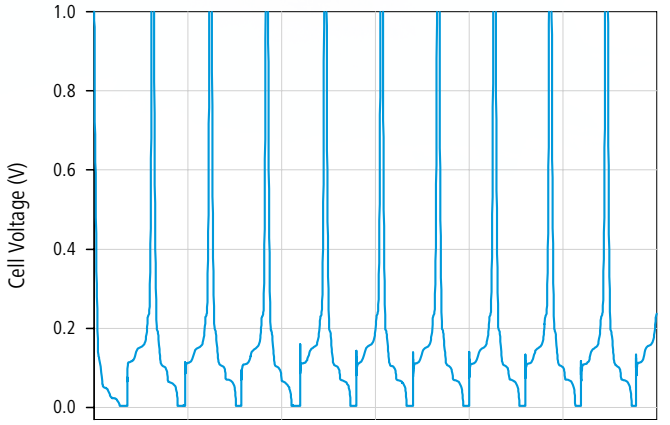
In this battery test, we demonstrate the outstanding cycling stability and tightness of the Opto-10 test cells.

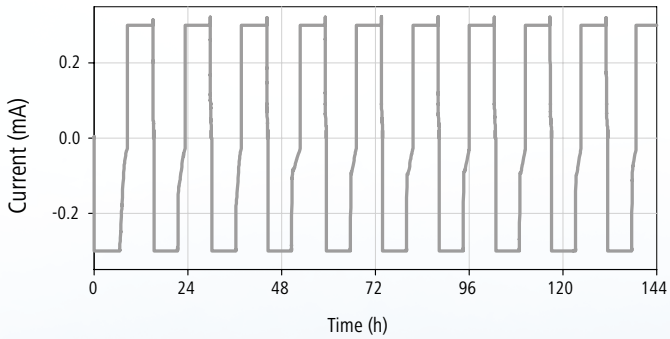
For this purpose, we cycled graphite against lithium in a PAT-Cell-Opto-10 in face-to-face setup for approx. 400 hours (25 cycles). A PAT-Tester-x-8 potentiostat was used while the data was evaluated in EL-Software.
As you can see from the curves shown, the die capacity retention of the test cell at the end of the experiment was still around 80%, with a Coulomb efficiency of almost 100%.

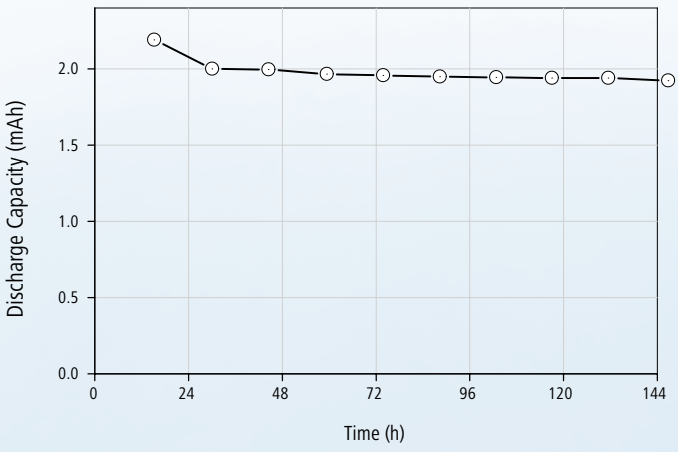
Test setup:

- WE: Free-standing graphite electrode, 10 mm in diameter, 60 µm thick, 2 mAh/cm²
- CE: Lithium metal foil, 10 mm in diameter, 200 µm thick
- Separator: Glass fibre, Whatman GF/A, 260 µm thick
- Electrolyte: 1 M $LiPF_6$ in EC / DMC (1:1) with 2 % VC
- Microscope: Keyence VHX-700FD with VHX-1020 camera and 100x VH-Z20R zoom
- Potentiostat: EL-Cell PAT-Tester-x-8









ECC-Opto-Std

Processes on your working electrode will become directly visible

The ECC-Opto-Std test cell monitors the optical properties of electrode material in the course of electrochemical charging. It is dedicated to inspecting electrodes using visual methods such as light microscopy or Raman spectroscopy in reflection mode. 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 is equipped with a borosilicate glass window as standard. Depending on your testing purposes, different cell lids and window materials are available as accessories.



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.

Features

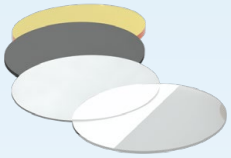
- 2- and 3-electrode cell with optical window for aprotic electrochemistry
- Full delivery scope for light microscopy, windows kits for XRD and Raman are available.
- Materials in contact with electrolyte are stainless steel 1.4404, PEEK, and the window material.

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:

Accessories for the ECC-Opto-Std

The ECC-Opto-Std's wide range of accessories allows it to be used with various microscopes, spectrometers, and X-ray devices.



Windows

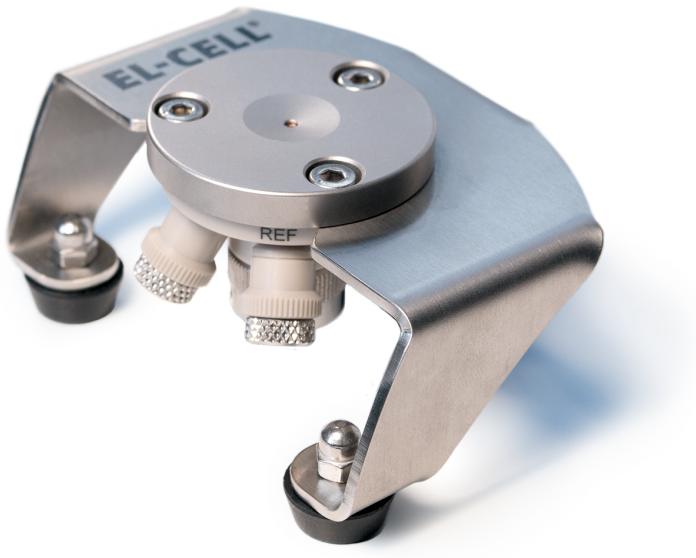


Lids



Cell holders

Discover more:



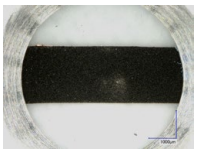
Sample Test Case

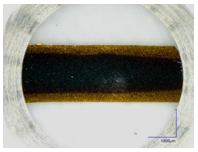
Visualizing the potential gradient

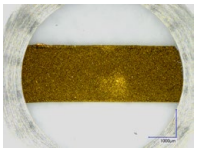
In this battery test, we show how the ECC-Opto-Std test cell can be used to visualize a potential gradient inside graphite just by using a standard graphite electrode with a continuous copper foil as the current collector (rather than a current collector with a hole).

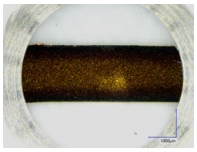
Test setup:

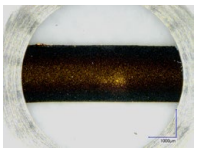
- WE: Strip of graphite electrode (CCI, 1.1 mAh / cm², 50 µm thick, 2 mm wide), with the Cu foil current collector pointing to the counter electrode
- CE: Lithium iron phosphate electrode (CCI, 3.6 mAh / cm², 9 mm in diameter)
- Separator: Glass fibre, 10 mm in diameter, 0.5 mm thick
- Electrolyte: 1 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

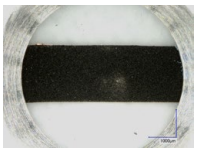

After 1 hour

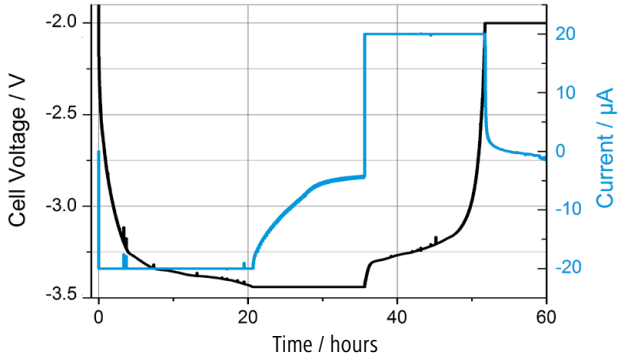

After 15 hours


After 30 hours


After 40 hours


After 43 hours


After 53 hours



ECC-Opto-Std-Aqu

Optical test cell for use with aqueous electrochemistry



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:

ECC-Opto-Gas

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



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:

PAT Battery Testers

EL-CELL operates its own fully equipped electrochemical laboratory, where we perform a wide variety of test measurements for our customers and 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 developing 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 analyzer and 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.

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

The EL-Software supports the researcher through all vital steps, from experiment design and test monitoring to test result analysis. 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 fact guarantees the highest performance for PAT-Cells and all other EL-CELL test cells, coin cells, and other cell formats.



PAT-Tester-i-16



PAT-Tester-x-8

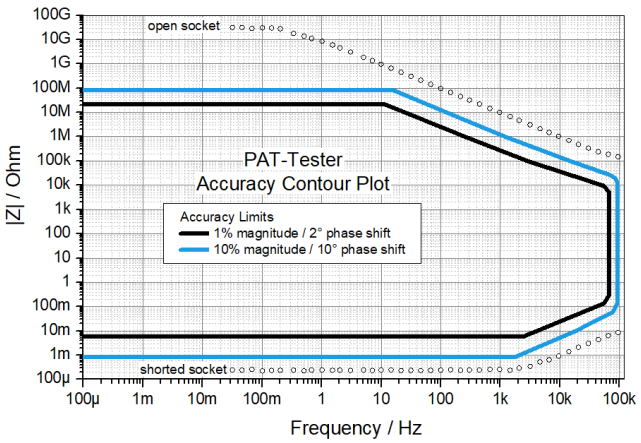
Highlights

- Multi-channel battery cycler / potentiostat / galvanostat / impedance analyzer with fully independent test channels
- Latest 24-bit hardware for the 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 are available:
  - **PAT-Tester-i-16** with 16 channels and temperature control for high-throughput testing
  - **PAT-Tester-x-8** with 1 to 8 channels for special purposes and maximum flexibility

PAT Battery Tester Specifications

General	
Channels per device	**1 to 16 (PAT-Tester-i-16),** **1 to 8 (PAT-Tester-x-8)**
Control Voltage	-7 V to + 7 V
Compliance Voltage	-8 V to +8 V (no load)
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	500 kHz, 50 kHz, 5 kHz
Slew rate	2.5 V / µs
Sampling interval (rate)	1 ms (1000 samples per second) with intelligent data recording
Input Impedance	>100 MΩ ‖ 20 pF
Internal sampling buffer	100 GB
Computer interface	1 GBit Ethernet, Multiuser, Device runs standalone (immune to network interruptions)
Current	
Current ranges	± 100 mA ± 10 mA ± 1 mA ± 100 µA Auto range
Measurement accuracy	± 0.05 % of FSR (Full Scale Range)
Measurement noise floor	< 1 µA @ 100 mA < 100 nA @ 10 mA < 10 nA @ 1 mA < 1 nA @ 100 µA
Control resolution	1 nA min. (18 Bit)

Voltage	
Acquired voltages	Full cell voltage, Both half cell voltages, Auxiliary voltage
Measurement accuracy	± 0.02% of FSR
Measurement Noise floor	30 µV peak-peak typical
Control resolution	57 µV (18 Bit)
Impedance (each channel)	
Frequency range	100 µHz to 100 kHz
Impedance mode	PEIS and GEIS (each with simultaneous measurement of full- and half-cell impedances)
Impedance range	1 mΩ to 100 MΩ
EIS quality indicator	SFDR (Spurious Free Dynamic Range)
EIS drift correction	Yes
EIS adaptive amplitude	Yes
Other	
Temperature Chamber (PAT-Tester-i-16 only)	+10 °C to +80°C, setpoint control in EL-Software
Additional measurement (each channel)	Digital (I²C) sensor signal, e.g. for cell temperature, Analog sensor signal, e.g. for gas pressure
Calibration	Fully automatic self-test and self-calibration with internal voltage references and internal calibration cells (maintenance-free)
Cell Identification	Supports PAT-Button for reading the unique test cell serial number



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 cables to a potentiostat / galvanostat outside.
Such modular and distributed setups are flexible but have severe drawbacks such as an enormous footprint, extensive cable harness, and susceptibility to experimental mistakes.
With the PAT-Tester-i-16, we integrate all functions of a multi-channel battery tester and a temperature-controlled test chamber into one single instrument. The worldwide 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 analyzer can simultaneously record both half-cell impedances while running constant current cycles or voltammetric experiments. Acquire 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

- **True multichannel testing:** Sixteen independent test channels, each with fully equipped PStat / GStat / EIS (no multiplexing) and unique features
- **Integrated temperature chamber:** Temperature-controlled cell chamber (Peltier) with a range of +10 °C to +80 °C
- **Highest accuracy:** Outstanding measurement precision with an excellent signal-to-noise ratio, perfectly suited for high-precision coulometry!
- **Deployable anywhere, easy to setup:** No fixed installation or cell wiring required. Smallest possible footprint.
- **Full remote control via LAN:** Set up and monitor measurements involving a single or multiple PAT-Testers without being on-site.

Height (opened / closed cover)	600 / 375 mm
Width / Length	380 / 640 mm
Weight	26 kg
Cell connections	up to 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.

The 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.

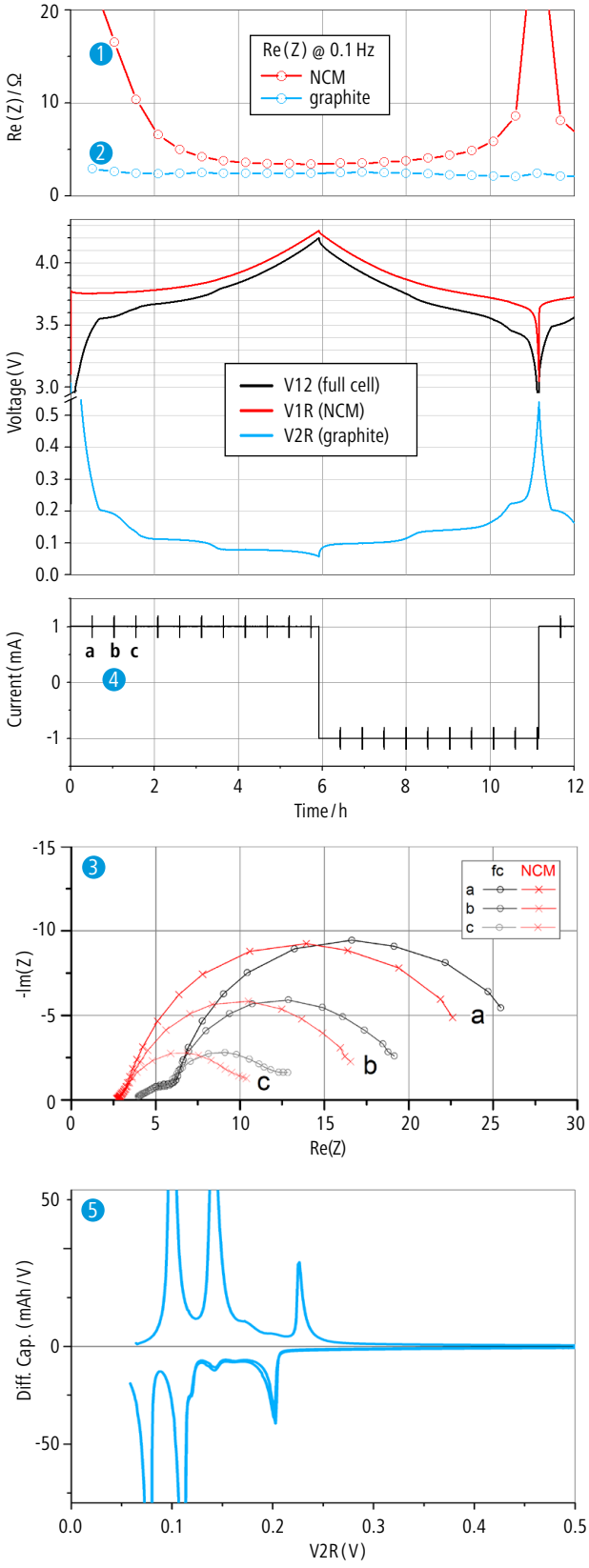
The first diagram shows the real part of the two half cell impedances (1 and 2) at 100 mHz extracted from the complete set of impedance data gathered during the experiment.

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 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** controls up to eight individually connectable PAT-Channel-1 or PAT-Terminal-1 boxes containing the actual measurement equipment. The PAT-Controller manages the connected devices and enables direct communication between the test channels and the EL-Software server. That way, the operator can control each test channel of the PAT-Tester-x-8 from any client PC in the same network via 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. Place the PAT-Channels where needed: on the bench, in a climate chamber, or inside the glove box.

While tailored for PAT-Cells, each PAT-Channel-1 can connect to almost any other test cell, like our ECC-Opto-10 optical test cell, via various available adapters and cell cables.

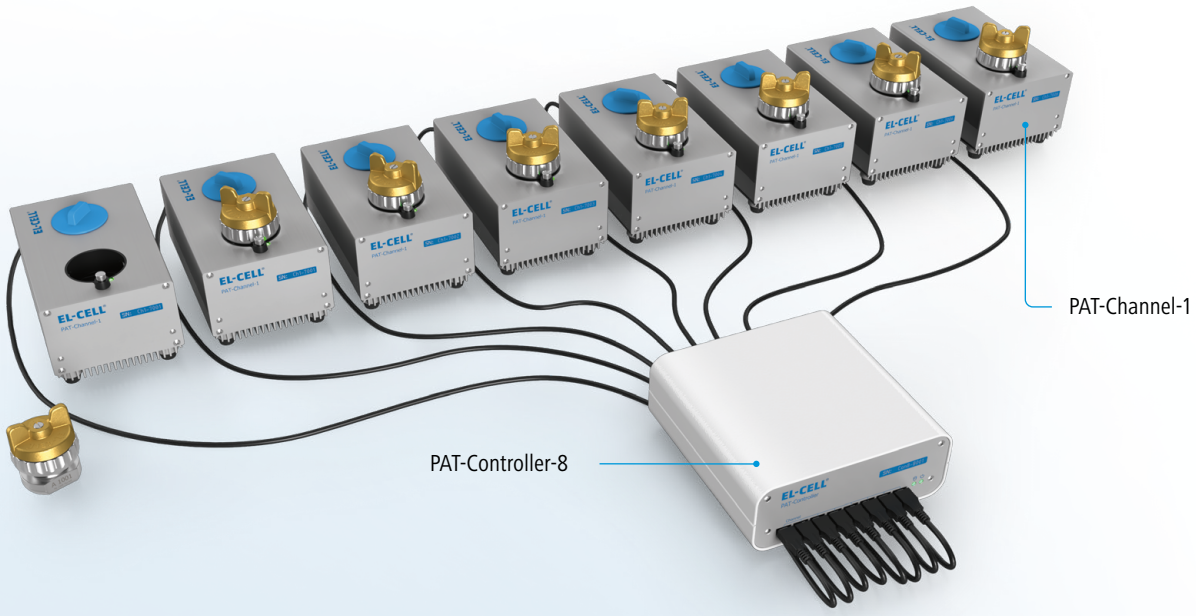
PAT-Controller-8 (Control Unit)	
Height / Width / Length	78 / 170 / 168 mm
Weight	1.7 kg
Test channels	up to 8
Operational temperature	0 to 40 °C

Product website:

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

Features

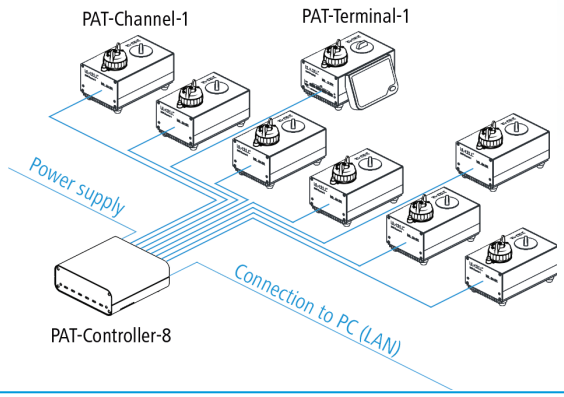
- Up to 8 independent test channels with fully equipped PStat / GStat / EIS (no multiplexing) and unique features
- Individual test channels can be operated in a temperature chamber or directly in the glove box.
- The flexible testing solution is ideal for small-scale setups with operando and special purpose test cells.



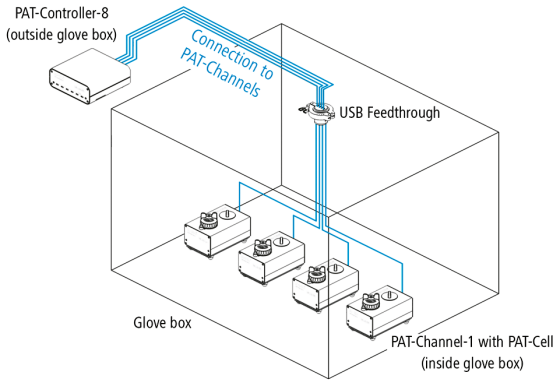
PAT-Tester-x Sample Setups

Here you can see a few exemplary configurations of the PAT-Tester-x-8. Depending on your specific requirements, you can set up the device in many different ways. Plug the cells directly into the PAT-Socket or connect them via cable to cells in a temperature chamber or separate docking station. You can even operate test channels directly in the glove box, for example, to check the functionality of your test cells directly after assembly.

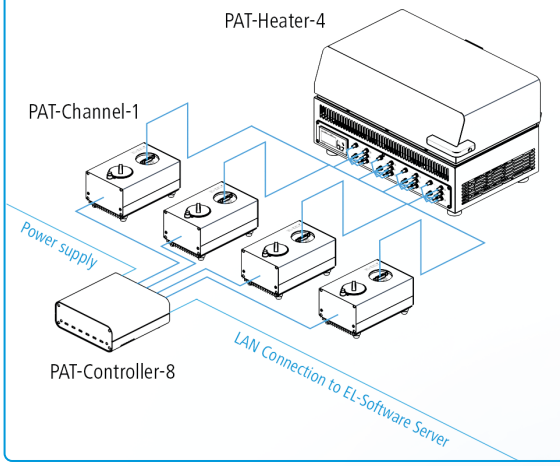
Sample setup with PAT-Cells



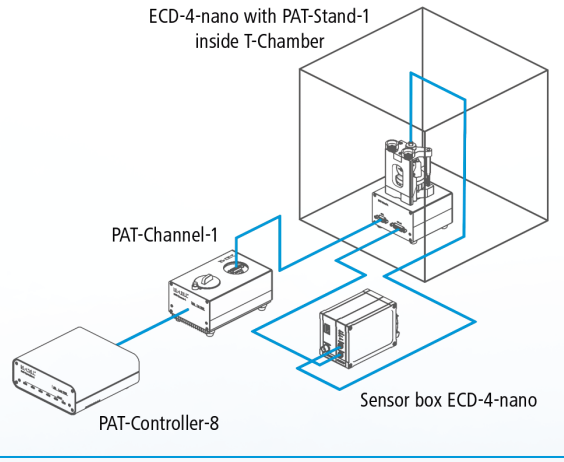
Sample setup inside the glove box



Sample setup with PAT-Heater-4



Sample setup with ECD-4-nano



Advanced Use Cases with the PAT-Core and PAT-Tester-x-8

Testing with a mesh-shaped reference electrode

Sometimes a reference electrode formed as a mesh can be better than our standard ring-shaped reference electrode. The mesh reference measures the electrical potential across the surface of the cell stack rather than at the outer edge. This can help to minimise artifacts caused by inhomogeneities of the electric field. The mesh is made of stainless steel, different geometries are available.

The mesh-shaped reference electrode is considered helpful for several scenarios:

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

Our PAT battery testers and EL-Software perfectly support all these scenarios. This is shown here using the example of a cell consisting of NCM and graphite. After building the cell, the stainless steel mesh is first electroplated with lithium utilizing the NCM electrode as the lithium source. The lithiated mesh is used as a reference electrode when cycling the NCM / graphite cell In the second step. Switching between the two modes is easy to do in the test script. No cable connections need to be changed, as necessary, with a conventional battery tester.

PAT-Core with mesh-shaped reference electrode



Upper plunger, stainless steel

Upper electrode, graphite

Inner clips ring, PP

First layer of separator, glass fibre

Reed contact with mesh-shaped reference electrode

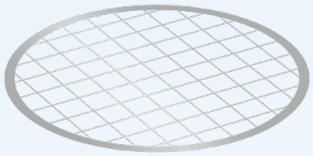
Second layer of separator, glass fibre

Outer clips ring (PP) with reed contact

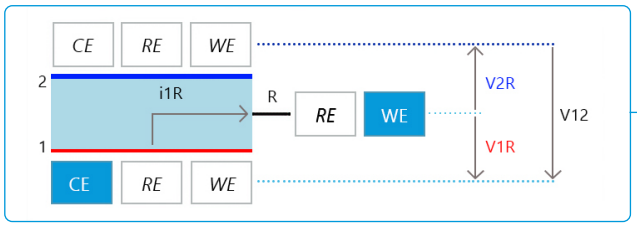
Lower electrode, NCM

Lower plunger, stainless steel

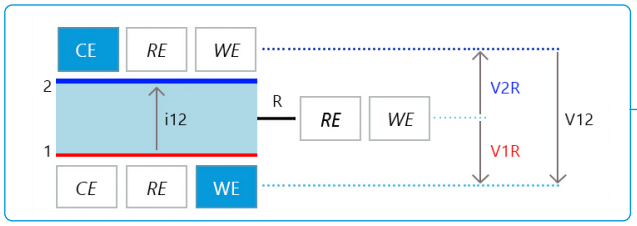
Mesh-shaped reference electrode



EL-Software makes pre-lithiating a simple task.



Step 1: Pre-lithiation of the mesh-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.

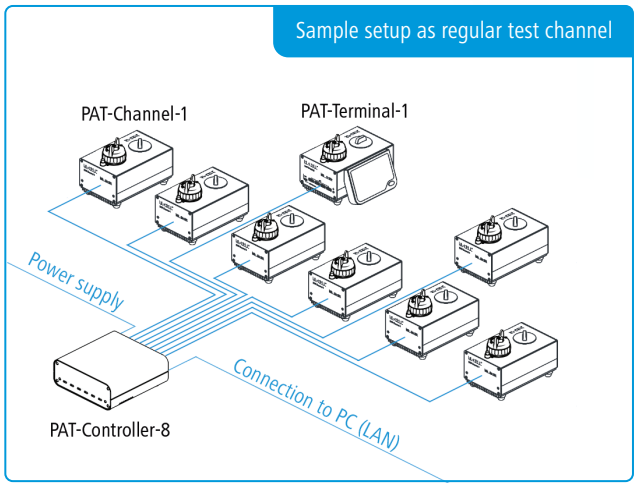


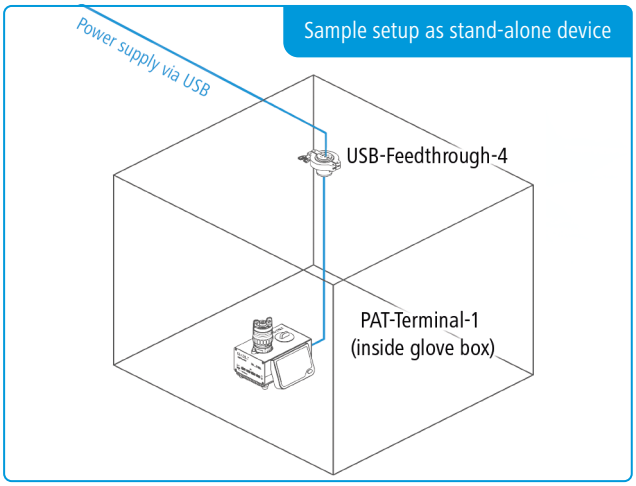
PAT-Tester-x-8 running the EL-Software test script with a PAT-Cell.

PAT-Terminal-1

Powerful assistance in the glovebox

The PAT-Terminal-1 will significantly simplify your workflow when assembling PAT series test cells in the glovebox. It is an advanced PAT-Channel-1 that can be placed directly in the glovebox and used as a standalone device to perform impedance measurements and other quick functional tests of your test cells. The large display shows all relevant data of the inserted test cell. Check values such as half and full cell voltages, currents, and impedances, but also sensor values like pressure, temperature, or applied force immediately after assembly to detect faulty cells right away. Standard errors, such as a forgotten filling with electrolytes, can thus be easily avoided. The PAT-Terminal-1 is also an invaluable aid in adjusting sensors of in-situ cells, like the force sensor of the PAT-Cell-Force. Of course, it is also a fully equipped test channel with all PStat / GStat / EIS abilities and can be connected as usual to the controller unit of a PAT-Tester-x-8.





Features

- Fully equipped test channel with PStat / GStat / EIS
- Can perform cell functionality checks (e.g. impedance) as stand-alone device or operate as regular test channel in a PAT-Tester-x-8 setup
- Integrated display showing live data of inserted test cell
- Can be operated directly in the glovebox

PAT-Terminal-1	
Height / Width / Length	97 / 105 / 164 mm
Weight	1.3 kg
Operational temperature	-20 to 40 °C

Product website:



EL-Software

EL-Software is a free software platform that allows you to design, manage, and monitor experiments on all EL-CELL battery testers, whether they are single-channel or multi-channel systems. It comes with a range of features, such as a central and easily searchable database, networking capabilities, and a powerful yet user-friendly visual test script editor called Composer.

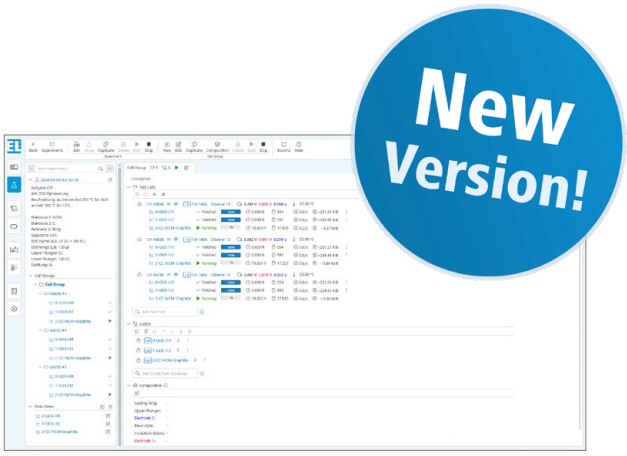
Additionally, you can benefit from state-of-the-art graphics capabilities to visualize your test results, and the open export interfaces enable you to integrate with existing software pipelines seamlessly.

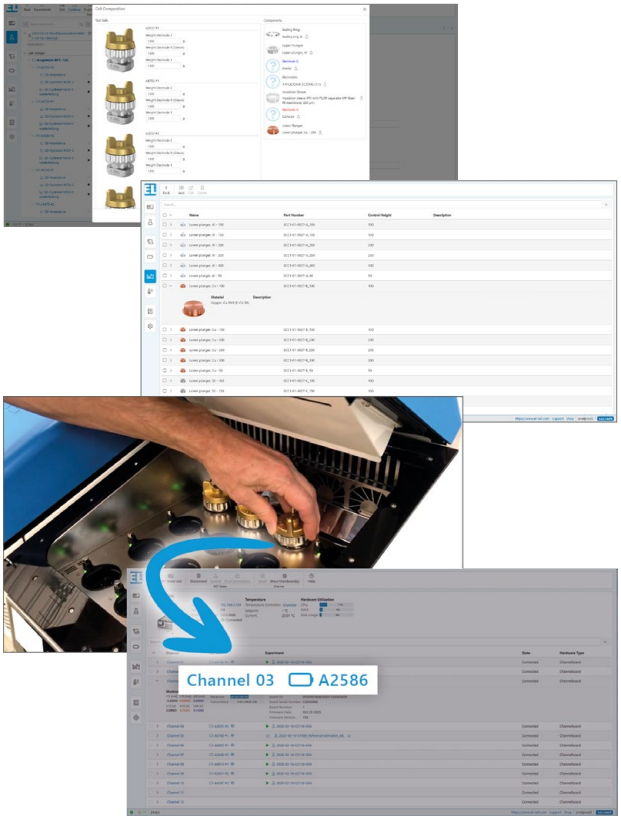
EL-Software guides you through the individual testing steps with the PAT system and other test cells.

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 efficient tests with high throughput and experiments with just a single cell.





Convenient experiment design and cell management

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

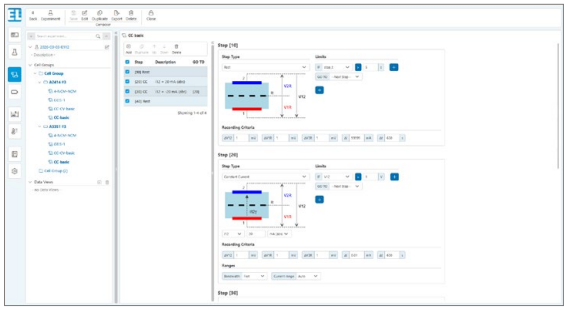
The software's database already contains all available cell components of the PAT series. It can easily be extended by additional components such as own separator materials or electrolytes and other cell types. Configure your test cells according to your application in our convenient modular system.

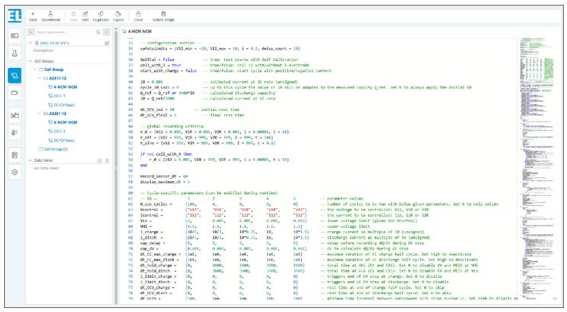
The software accompanies test cells throughout their entire life cycle. This provides permanent access to a wide range of information, such as the experiments' history, the cell components used, and additional data for post-mortem analysis.

When you insert a test cell with an integrated **PAT-Button** into a PAT-Tester, EL-Software recognizes this cell via the stored ID and can immediately provide you with all linked information, such as the cell's content. In this way, the researcher 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

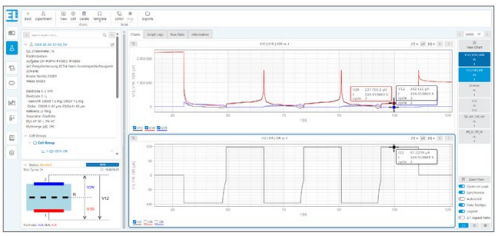
Visual script editor: Create your test scripts comfortably and efficiently in the Composer, a powerful visual editor integrated into EL-Software. The Composer uses an easy-to-learn modular principle to create even complex test procedures in a very short time. The connection between the test cell and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

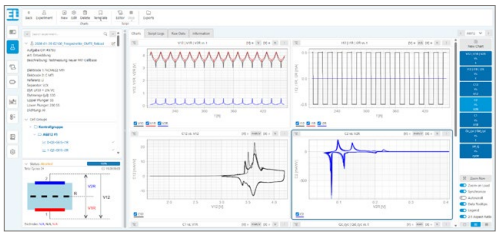




Custom scripts: Besides the Composer, you can create scripts directly in the Lua programming language. This means that you can implement even very sophisticated test sequences quickly. The scripts can be created in the integrated editor or imported from external sources. It is also possible to convert scripts created in the Composer into Lua. EL-software sets no limits to your creativity.

On-the-fly editing: This feature allows you to change test sequences during the runtime of the experiment. To do this, edit the relevant script and apply the changes directly to the measurement in progress. In that way, you can change setpoints and step limits like never before.





Experiment monitoring: Always keep the overview

The well-structured data views give you feedback on your ongoing measurements. Forget about the time when measurement results had to be processed before you were able to conclude anything from them. Instead, plot your measurement data in real-time, and compare and calculate the various parameters directly in the running measurement using freely configurable graphs.

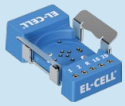
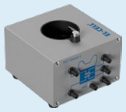
Learn more on our website:

PAT Docking Stations

PAT test cells are cableless. To connect them with a battery tester, simply insert them into the PAT socket of a docking station or battery tester. The docking station can be left permanently wired to the potentiostat in use, and this way, you minimise wiring mistakes when connecting test cells.

Most often, PAT docking stations are used to power the PAT-Cell with a third-party battery tester. However, they are also instrumental 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 support up to 16 test cells, and offer additional features like 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**	Temperated cell chamber
 PAT-Clamp-1	1	27	62	86	0.12	-20 - 70 °C	✓		
 PAT-Stand-1	1	81	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	400	265	14		✓		up to 200 °C***
 PAT-Chamber-16	16	375	380	640	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

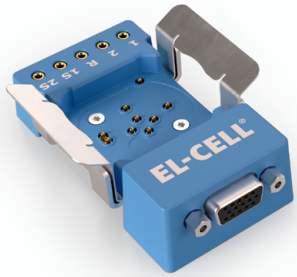
PAT-Clamp-1

Docking station with minimised 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 analyzer.

Features

- Socket for one PAT series test cell (charge / discharge / EIS compatible)
- Compatible with any other potentiostat and battery tester
- Can be used inside a glove box environment
- Flexible wiring via 2 mm banana sockets or Sub-D connector
- Smallest docking station for PAT series test cells



PAT-Clamp-1

Height / Width / Length	27 / 86 / 62 mm
Weight	0.12 kg
Cell connections	1
Operational temperature	-20 to 70 °C

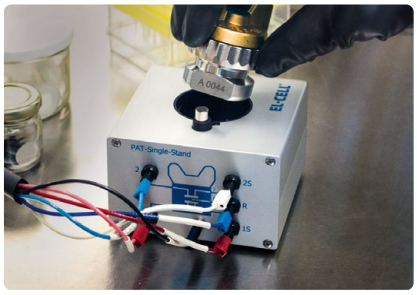
Product website:



PAT-Stand-1

PAT 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 feedthrough 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	84 / 119 / 301 mm
Weight	0.67 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

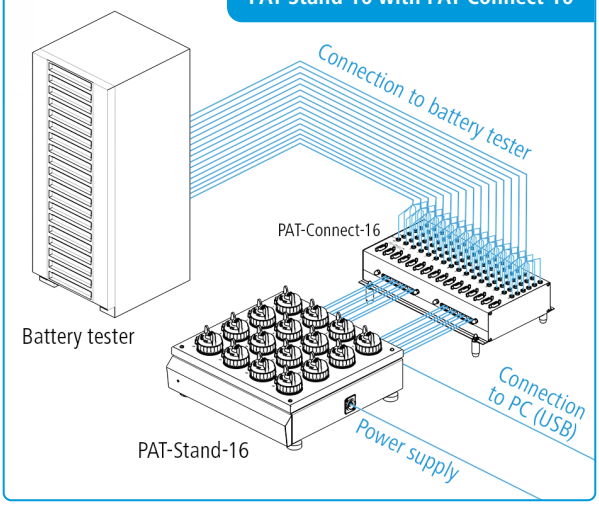
Product website:

PAT-Connect-16

Adapter box for flexible wiring connections

The PAT-Connect-16 is an intermediate box between PAT-Stand-16 / PAT-Chamber-16 and potentiostat / battery tester. It enables flexible switching between operation modes.

PAT-Stand-16 with PAT-Connect-16



PAT-Chamber-16

Temperature-controlled PAT series docking station

The PAT-Chamber-16 features a temperature-controlled cell chamber for up to 16 PAT series test cells. The integrated Peltier device lets you test at the exact temperature you need, between +10 °C and +80 °C. 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
- 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:



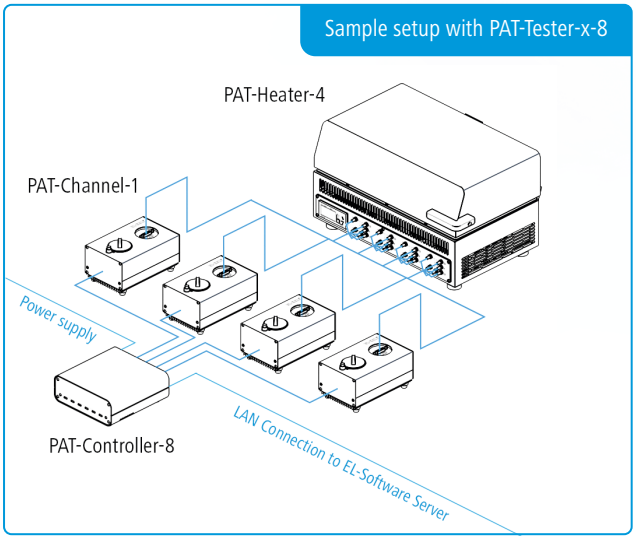
PAT-Chamber-16 with top-mounted PAT-Connect-16

PAT-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 unnecessary 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.



Features

- Heated cell 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

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



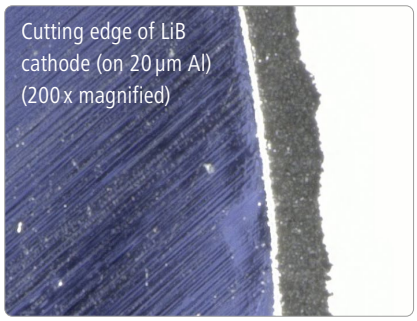
Tools & Accessories

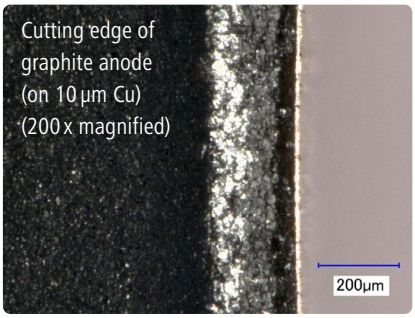
EL-Cut

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

The proper cutting of the electrodes is often a neglected factor in battery testing. Although invisible to the bare eye, torn and chipped electrode edges 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 is 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

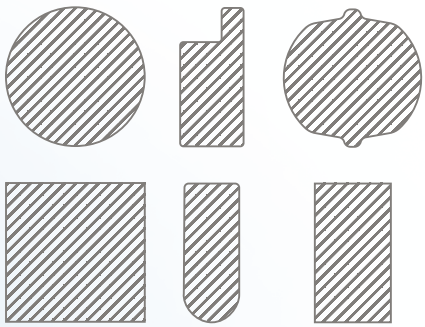
- Perfectly cut electrodes
- Electrode thickness: max. 300 µm for coatings on Al and Cu foil (may vary for other support materials)
- The permanently installed cutting tool can have any size (diameter) from **5 to 40 mm**. Different shapes are available upon request.

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

Product website:



Sample cutting tool shapes





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. Punching sizes range from 6 to 20 mm.

Length / Diameter	100 / 39 mm
Weight	0.7 kg

Product website:



Solid-State Pressing-Device

The solid-state pressing device enables direct pressing of powdered solid-state cell stacks in the PAT-Solid-Core. The housing is airtight, enabling use outside the glove box.

Height / Diameter	96 / 52 mm
Max. load	5 tons

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, PAT-Cell-Force	**ECC-LiPunch 18** (18 mm)	**EL-Cut 18** (18 mm)
ECD-4-nano	**ECC-LiPunch 9.5** (9.5 mm)	**EL-Cut 10** (10 mm)
ECC-Opto-10, PAT-Cell-Opto-10, 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)

PAT-Adapters

Adapter for other cell formats

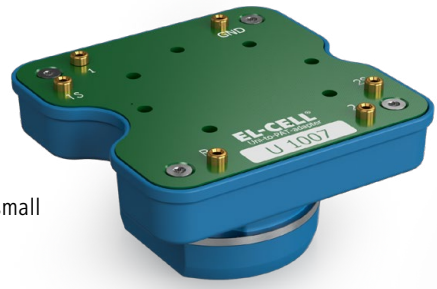
In addition to our PAT test cells, we also offer a variety of cell adapters to connect T-cells, split cells, coin cells, or any other custom test cell to our PAT system. The PAT-Adapters are inserted into the PAT socket like any PAT series test cell.

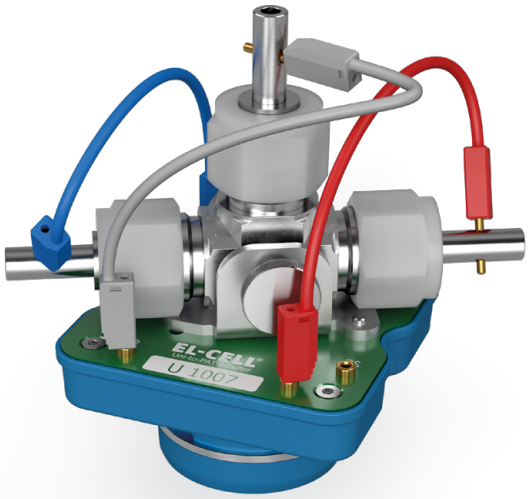
Each adapter features an integrated PAT-Button, enabling automatic cell identification when connected to an EL-Cell potentiostat like the PAT-Tester-i-16.



3E-Coin-PAT-Adapter

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





Example shows mounted T-Cell.

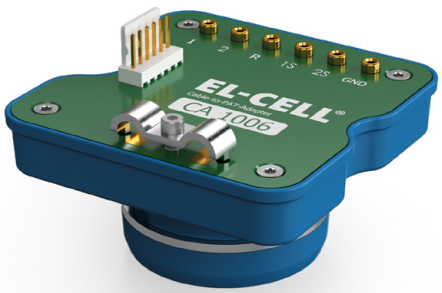
Uni-to-PAT-Adapter

Universal adapter for mounting any small battery format test cell



Coin-PAT-Adapter

For coin cells with two electrodes
Variants are available for coin cells with a diameter of 12, 16, 20, 24, and 32 mm 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.

Services

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

Lithium Battery Application Lab

Our state-of-the-art battery lab provides fast and reliable electrochemical measurements, conducted by a team of experienced laboratory professionals who ensure that every test is performed with precision and care.



Our Services

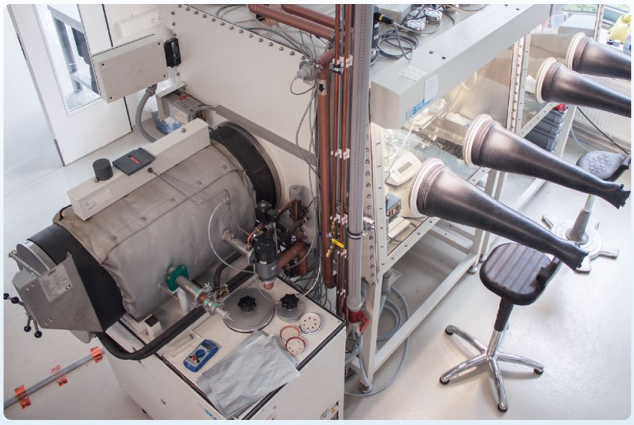
- Cycle life and impedance tests on half and full cells
- Quantifying electrode expansion during charge and discharge
- Quantifying gas evolution during battery formation
- Measuring the stack force during charge and discharge
- Visualizing electrode processes by optical microscopy
- Tests for solid-state batteries on request



Our Equipment

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

- Modern PAT-Tester potentiostats with more than 250 test channels
- All kinds of battery test cells from EL-CELL
- MBraun glove box system for test cell assembly
- Temperature controlled test cabinets (-40 °C to +80 °C)
- Digital microscope Keyence VHF 700F
- Tools and handling equipment for electrochemical experiments (e.g., cutting and punching tools)
- All standard consumables such as lithium metal, $LiPF_6$ based electrolytes, anode and cathode materials for lithium and sodium based batteries



Services website:

Hands-on Seminars

Researchers can learn about the latest devices and applications in our seminars 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-10:** Visualizing the gradients of electrode potential and lithium concentration
  - **PAT-Cell-Force:** Measuring the stack pressure during charge and discharge
  - **PAT-Cell-Press:** Quantifying the gassing during battery formation
  - **ECD-4-nano dilatometer:** Measuring electrode dilation during charge and discharge

Facts:

- Duration: two days (8 hours per day)
- Location: Tempowerkring 7 - 21079 Hamburg, Germany
- Target audience: Customers as well as PhD students, battery research novices, career changers from other subjects (maximum 6 participants)

Check our website **el-cell.com** for upcoming dates and prices. Early bird and student discounts are available.

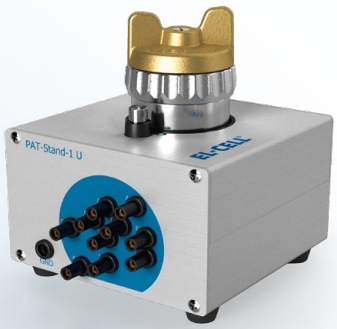


Customizations

Our primary 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 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

Contact us

EL-CELL delivers worldwide directly and through its distributors. For further information, please visit us at www.el-cell.com or contact us directly!

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The EL-CELL Sales Team


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Dr. Sebastian Müller

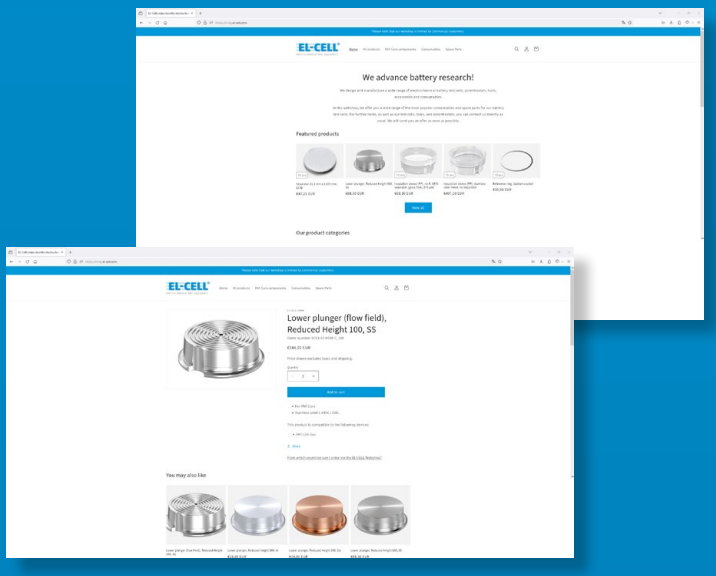

Inês Didier


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Visit the EL-CELL Webshop!

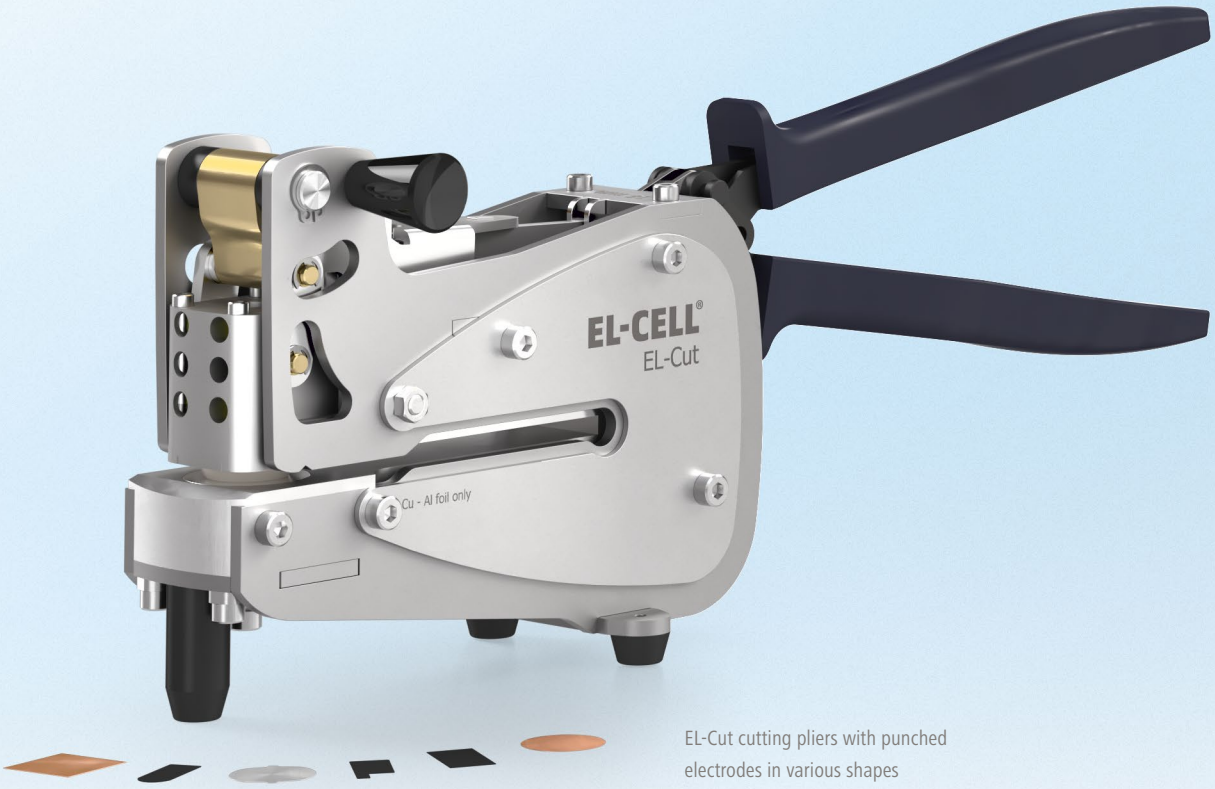
Visit the new EL-CELL webshop today. It offers a simple and convenient way for our customers to order from us or explore our products. We offer a wide and constantly growing range of products here, especially consumables and spare parts for our battery test cells.

shop.el-cell.com





EL-CELL®
electrochemical test equipment



EL-Cut cutting pliers with punched electrodes in various shapes

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