

# User Manual

Release 2.0

## Electrochemical Test Cell PAT-Cell



05. October 2015

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# 1 Product Description

The PAT-Cell is the new leadless housing of the PAT-Core. Two different docking stations are available: the PAT-Single-Stand and the PAT-Tray accommodating up to 16 PAT-Cells. Its small footprint make this combination the ideal choice for high-throughput testing of Li-ion battery materials. PAT-Tray and PAT-Single-Stand are covered by separate manuals (<http://el-cell.com/downloads/downloads-manuals>).

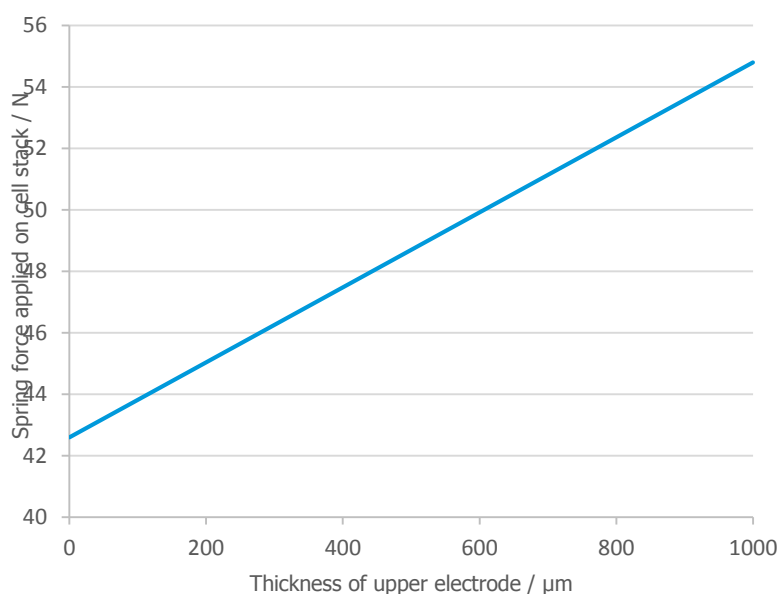


**PAT-Tray  
with 16 PAT-Cells**

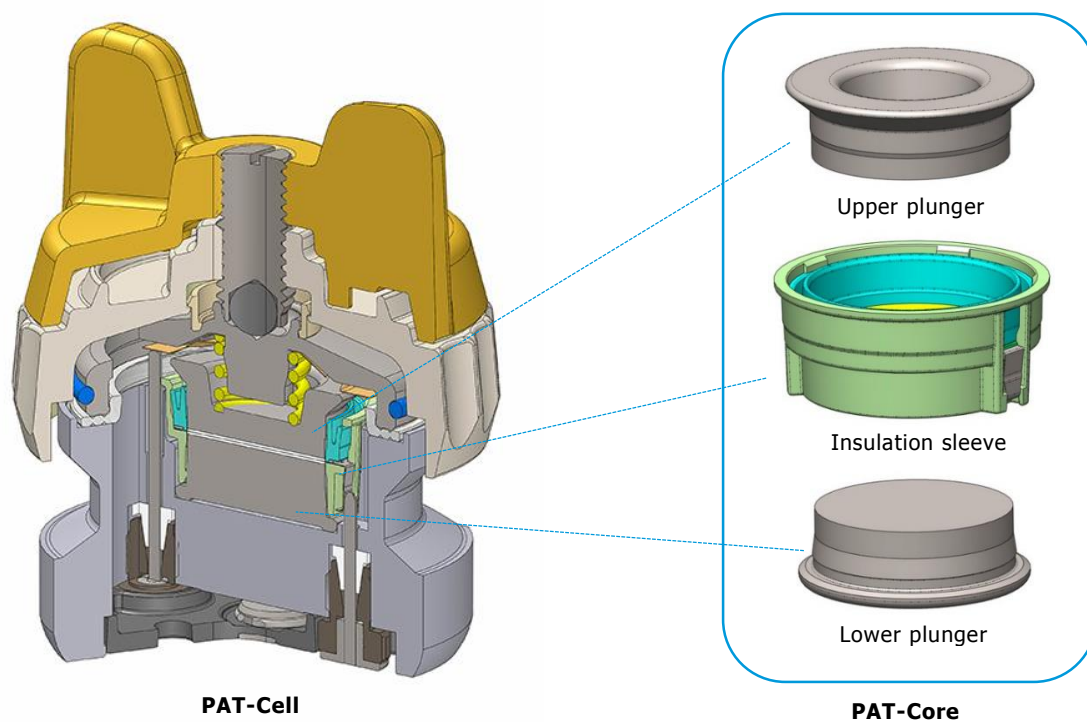
The PAT-Core is comprised of three components:

- 1. Insulation sleeve:** The polypropylene insulation sleeve with a ring-shaped reference electrode and a separator, both pre-installed at the factory, sealed and ready for use in the glovebox. Several different versions are available for special purposes. The insulation sleeve is also available in the disassembled state, so that the customer can use his own separator or reference.
- 2. Lower plunger:** The lower plunger serves as the positive current collector. Different gap sizes are available to match electrodes and separators with different thicknesses. When using the proper gap size, the lower electrode can have a maximum thickness of 800  $\mu\text{m}$ .
- 3. Upper plunger:** The upper plunger serves as the negative current collector. The maximum thickness of the upper electrode is 800  $\mu\text{m}$ . Note that the spring force applied on the cell stack will depend slightly on the thickness of the upper electrode.

## Spring force in relation to the thickness of the upper electrode:



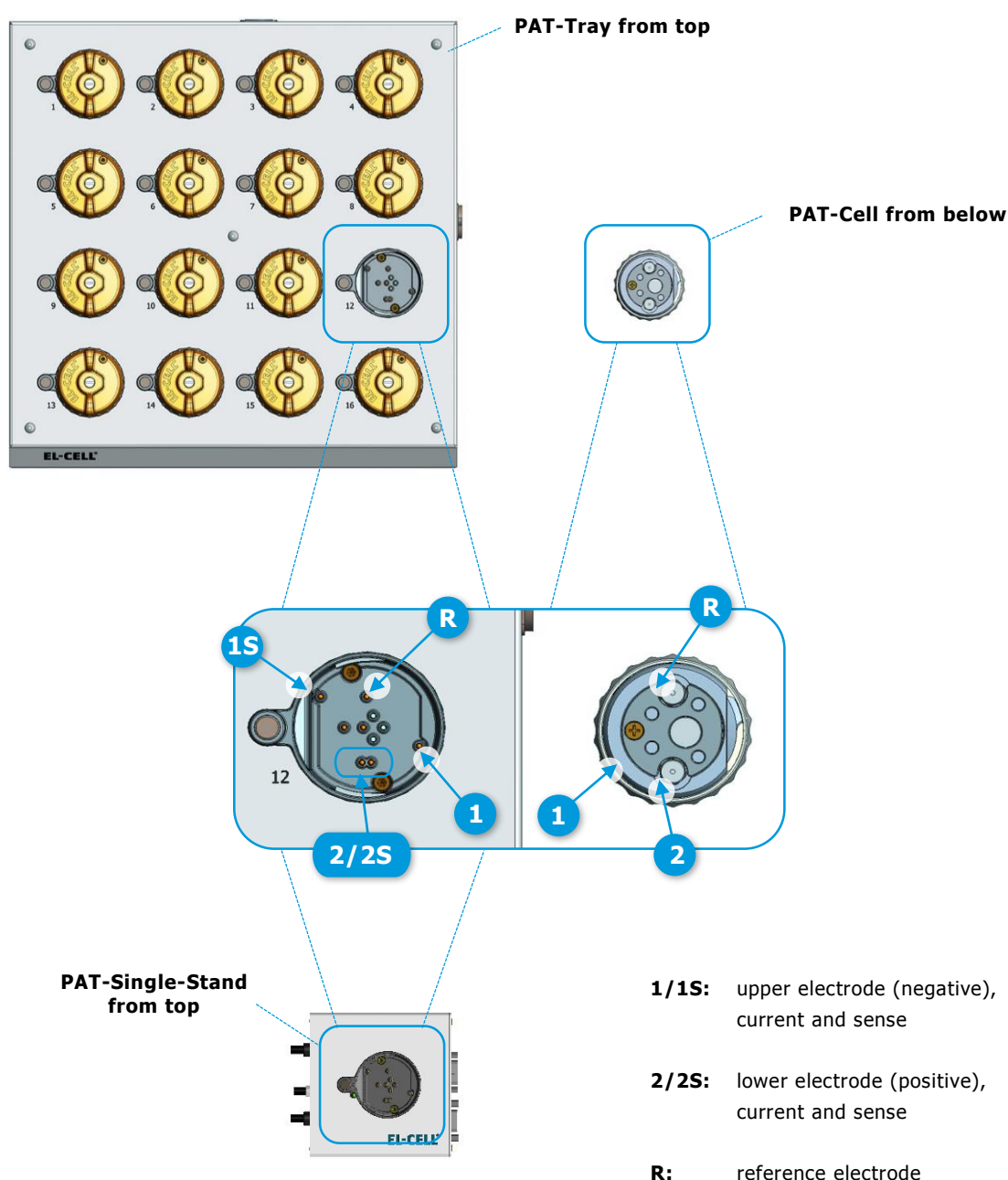
The insulation sleeve is a single-use component, which has to be disposed after use. In contrast, the plungers are available as both single-use components (made of battery grade copper and aluminium) and as reusable components (made of stainless steel 316 L/ 1.4404). Other materials are available on request.



## Electrical Contacts of the PAT-Cell and Interfacing with the PAT-Tray and PAT-Single-Stand

The PAT-Cell is a leadless 3-electrode test cell, so it does not feature any sockets where cables may be plugged into. Instead, the electrical connection towards the battery tester is made through contact areas at the cell bottom, once the PAT-Cell is inserted into one of the sockets of the PAT-Tray.

The detail view below shows the contact areas at the cell bottom (on the right), and the corresponding spring-loaded contact pins in the cell socket of the PAT-Tray. The same cell socket is used with the PAT-Single-Stand.



**1/1S:** upper electrode (negative), current and sense

**2/2S:** lower electrode (positive), current and sense

**R:** reference electrode

The 5 pins in the center are for cell detection and special (future) functions.

## 2 Features

The PAT-Cell is a test cell to accurately characterize aprotic lithium-ion battery materials over long periods of times. The standard PAT-Core is composed of a lithium metal ring reference and a separator (either glass fiber or a nonwoven polyester pasted with  $\text{Al}_2\text{O}_3$ ). Both the reference and the separator are pre-installed in a single-use insulation sleeve. This concept has got several advantages:

- Ability for conducting long-term measurements with a reliable reference electrode over more than one thousand hours of battery operation.
- Ability for measuring full AND half cell impedance spectra throughout the battery's life time.
- Increase of testing productivity by single-use concept.
- Less mistakes that may result from corrosion or cross-contamination when working with re-use cell components.
- No need for cleaning or drying cell components.
- Fast assembly and dismantling lowers lead times of experiments.
- Easy and reliable electrolyte filling upon assembly (defined electrolyte volume down to  $0.05 \text{ cm}^3$ ).
- Reliable leakage-proof sealing with PE-Seal and double cutting ring.
- Reproducible and homogeneous mechanical pressure on electrodes.
- High precision 18 mm diameter sandwich geometry with a concentricity better than 0.1 mm (electrode and separator dimensions are compatible with other test cells of the ECC series).
- The PAT-Cell is designed for use in the temperature range from  $-20$  to  $+70^\circ\text{C}$ .

## 3 Safety Precautions

Use proper safety precautions when using hazardous electrode materials and electrolytes. Wear protective glasses and gloves to protect you against electrolyte that may accidentally spill out during disassembly. Upon cell disassembly, dispose all materials properly. Metallic lithium and some insertion compounds may decompose heavily in contact with water and other solvents, and can cause fire.

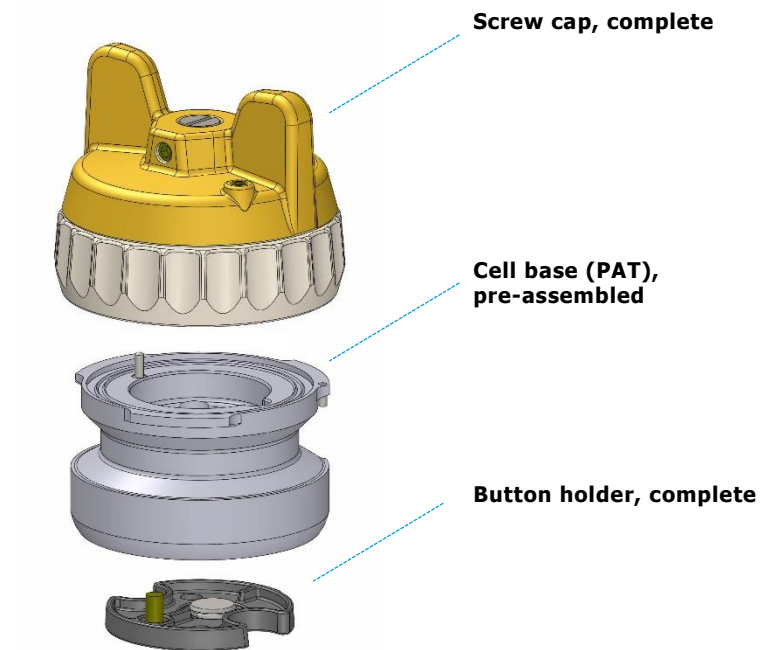
## 4 Unpacking

Check the contents of the packages against the list given below to verify that you have received all of the required components. Contact EL-CELL, if anything is missing or damaged. **NOTE:** Damaged shipments must remain within the original packaging for freight company inspection.

## List of Components:

- PAT-Cell test cell without PAT-Core (to be ordered separately)

**Note:** The components of the PAT-Core (insulation sleeves and plungers) must be purchased separately.





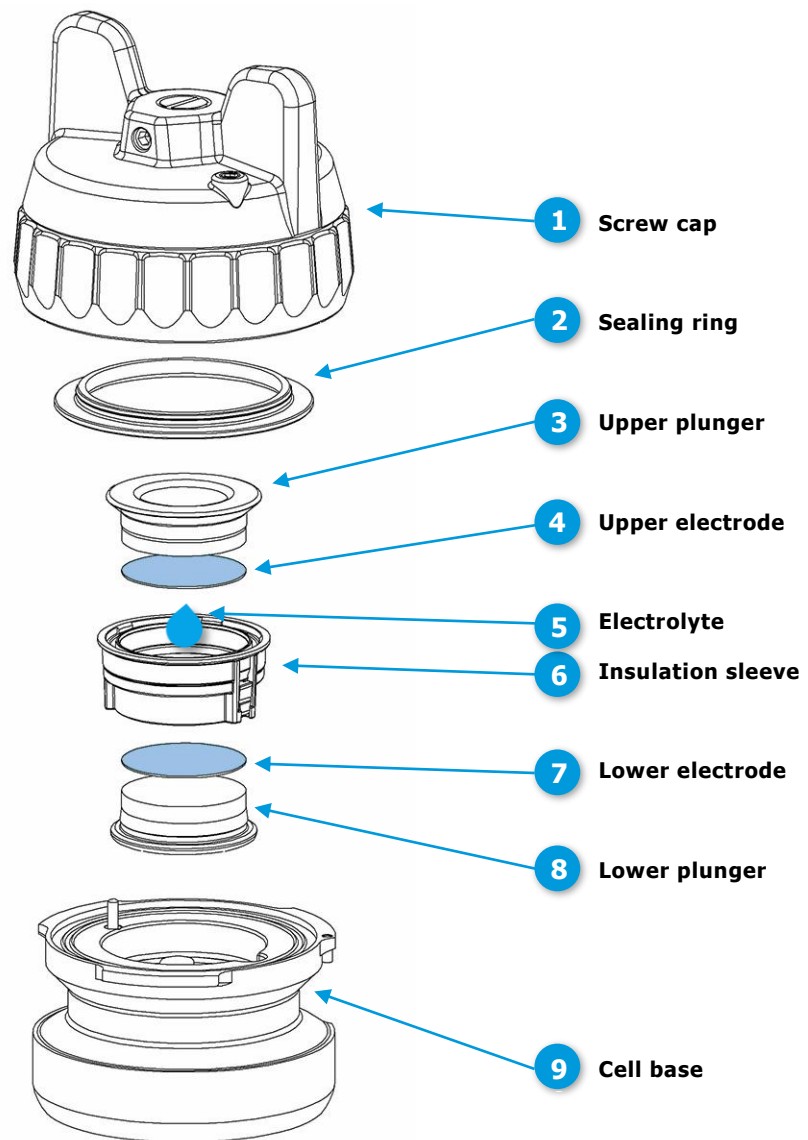
## 5 Cell Assembly

This section describes how the PAT-Cell has to be assembled in order to conduct proper battery tests. Please note that the assembly has to take place under the protective atmosphere in a glove box.

1. Put the **insulation sleeve (6)** onto the worktop with the smaller side pointing upwards. Different insulation sleeves are available for different test purposes, see chapters 6 and 7.
2. Insert the **lower electrode (7)** into the sleeve with the active layer facing downwards.
3. Attach the **lower plunger (8)**. The lower plunger is available in different gap sizes in order to account for the thickness of the electrodes and separator used, see chapters 6 and 7.
4. Turn the assembly upside down.
5. Align the contact spring of the sleeve with the horizontal contact pin inside the **cell base (9)**. Then insert the assembly into the cell base.
6. Evenly dispense approx. 100  $\mu\text{L}$  of **electrolyte (5)** on top of the separator with a pipette. Note: The optimum amount of electrolyte will depend on the thickness and porosity of the separator and the electrodes used.
7. Insert the **upper electrode (4)** into the insulation sleeve with the active layer facing downwards.
8. Attach the **upper plunger (3)**.
9. Attach the **screw cap (1)** to the cell base with the wing nut fully released.
10. Tighten the wing nut clockwise in order to seal the cell.
11. Attach the cell into a free socket of the PAT-Tray.
12. The EC-Link software will detect the cell and ask you to start the measurement. Follow the instructions.
13. Start the electrochemical test of the associated battery tester channel.

Operation of the PAT-Tray and the interplay with the connected battery tester are described in more detail in the manual of the PAT-Tray (<http://el-cell.com/downloads/downloads-manuals>).

**NOTE:** We recommend replacing the sealing ring attached to the lid inside the screw cap right after cell disassembly.



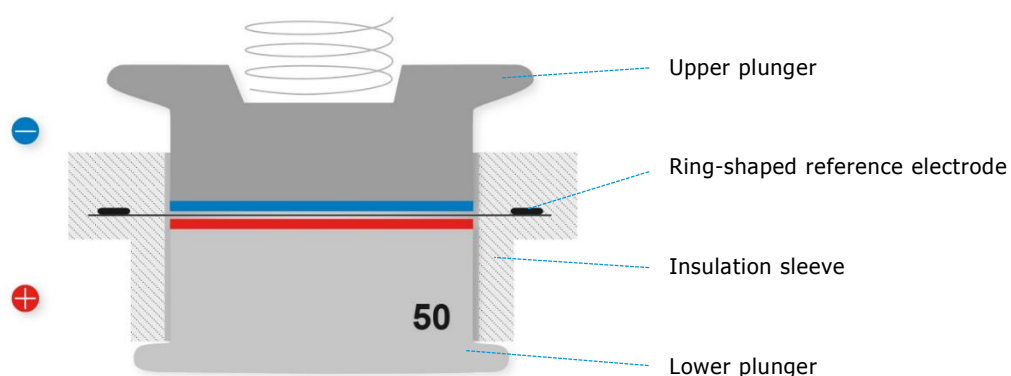
### Further recommended tools for working with the PAT-Cell:

- |                                |  |
|--------------------------------|--|
| <a href="#">ECC1-02-0005-A</a> | ECC-LiPunch 18 mm (for punching lithium metal foil)        |
| <a href="#">ECS1-00-0100-A</a> | EL-Cut Cutting Pliers 18 mm (for cutting electrode sheets) |

## 6 Different Test Cases

The PAT-Core may be used for many different battery and capacitor types. The table below summarizes some of the most common test cases. In general, we recommend sleeves with built-in glass fiber separator rather than thin technical separators (such as Viledon or Celgard) when lithium metal is used as the negative electrode, and when measuring half cell impedances.

Battery Type	Lower electrode (+)	Upper electrode (-)	Lower plunger single-use/re-use	Upper plunger single-use/re-use	Separator
Li-metal	LCO, NCA, NCM or LFP	Li	Al/SS	Cu/SS	GF
Li-metal	Graphite or silicon	Li	Cu/SS	Cu/SS	GF
Li-metal	LTO	Li	Al or Cu/SS	Cu/SS	GF
Li-ion	LCO, NCA, NCM, or LFP	Graphite	Al/SS	Cu/SS	GF or thin
Li-ion	LFP	LTO	Al/SS	Al or Cu/SS	GF or thin
EDLC	AC	AC	Al/SS	Al/SS	GF or thin
Li-ion cap	AC	Lithiated graphite	Al/SS	Cu/SS	GF or thin

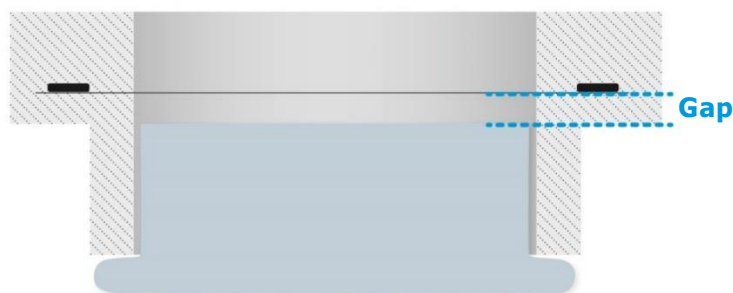


The lower electrode can have a thickness of up to 800  $\mu\text{m}$  provided that the proper gap size of the lower plunger is chosen. The maximum thickness of the upper electrode is 800  $\mu\text{m}$ .

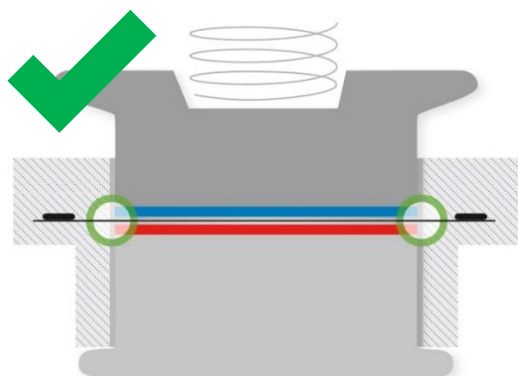
## 7 PAT-Core Components

### Lower Plunger:

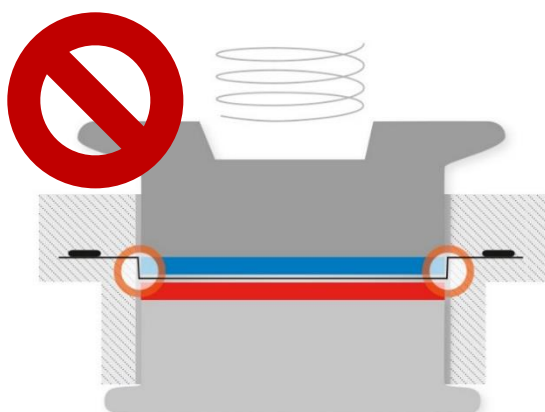
The lower plunger is available in different materials (SS 1.4404, Al 99.5%, Cu 99.9%) and with different gap sizes. The different gaps are necessary in order to account for the different thicknesses of the lower electrode and the separator used. The term '**gap**' refers to the distance between the lower face of the built-in separator (thought of as having zero thickness) and the upper face of the lower plunger when attached to the insulation sleeve, see sketch below.



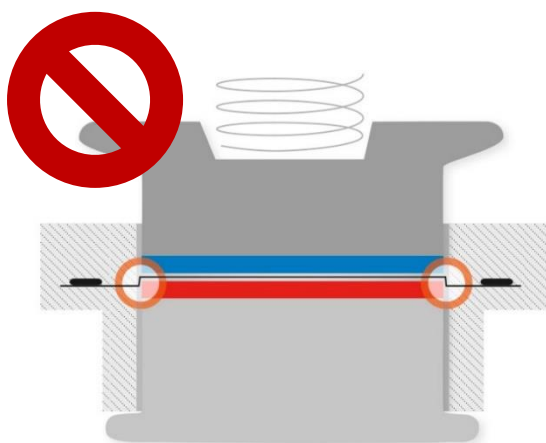
If you use a wrong plunger gap, you may get trouble with your battery test. The below figures illustrate this point.



**Good case:** No bending of built-in separator; reference ring is in plane with separator.



**Gap too large:** Excessive downward bending of built-in separator; reference ring is out of plane with separator.



**Gap too small:** Excessive upward bending of built-in separator; reference ring is out of plane with separator.

### Available lower plungers:

The lower plunger is available with gap sizes between 50 and 800 in steps of 50  $\mu\text{m}$ . For ordering, just append the step size to the article code, see table below.

For lower electrodes having a thickness of around 100  $\mu\text{m}$ , we recommend a gap size of 100 when using thin separators such as Viledon or Celgard, and a gap size of 200 when using our standard glass fiber separator. In general, for glass fiber, the gap size must be approx. 100  $\mu\text{m}$  larger than the electrode thickness because of the compression of the built-in separator.

Gap of lower plunger (in $\mu\text{m}$ )	50	100	150	200	..	800
Article code lower plunger (SS)	ECC1-01-0027-C_50	ECC1-01-0027-C_100	ECC1-01-0027-C_150	ECC1-01-0027-C_200		ECC1-01-0027-C_800
Article code lower plunger (Al)	ECC1-01-0027-A_50	ECC1-01-0027-A_100	ECC1-01-0027-A_150	ECC1-01-0027-A_200		ECC1-01-0027-A_800
Article code lower plunger (Cu)	ECC1-01-0027-B_50	ECC1-01-0027-B_100	ECC1-01-0027-B_150	ECC1-01-0027-B_500		ECC1-01-0027-B_800

## Upper Plunger:

The upper plunger is available in different materials: Stainless steel 1.4404, Al 99.5% and Cu 99.9%. Other materials on request.

	<b>type of utilization</b> (single-use vs. reusable)	article no. <b>upper plunger</b>
<b>copper</b> Cu 99.9 (E-CU 58)	single-use	<a href="#">ECC1-01-0026-A</a>
<b>aluminium</b> Al 99.5 (EN-AW- 1050)	single-use	<a href="#">ECC1-01-0026-B</a>
<b>stainless steel</b> 316L (1.4404)	reusable	<a href="#">ECC1-01-0026-C</a>

## Insulation sleeve:

The insulation sleeve is available with and without a ring-shaped lithium metal reference ring, and with two different types of separator: borosilicate glass fiber separator (Whatman GF/A) having a thickness of 260 µm, and nonwoven polyester pasted with Al<sub>2</sub>O<sub>3</sub> (Freudenberg Viledon FS 3005-25) having a thickness of 25 µm. Other separators and customized solutions are available on request. Furthermore, the sleeve is available in the disassembled state, either with or without the lithium reference ring. The table below comprises the four standard versions only.

	article no.	<b>type of testing</b> (2 or 3 electrodes)
Insulation sleeve <b>with lithium metal ring reference, with glass fiber separator (260 µm)</b>	<a href="#">ECC1-00-0210-O/x</a>	3 electrodes
Insulation sleeve <b>with lithium metal ring reference, with Viledon separator (25 µm)</b>	<a href="#">ECC1-00-0210-A/x</a>	
Insulation sleeve <b>with glass fiber separator (260 µm)</b>	<a href="#">ECC1-00-0210-P/x</a>	2 electrodes
Insulation sleeve <b>with Viledon separator (25 µm)</b>	<a href="#">ECC1-00-0210-B/x</a>	

## 9 Disassembly and Cleaning

After disassembly, dispose all single-use components and electrodes properly. If the cell base has got contaminated with electrolyte, clean it with plenty of water and dry with compressed air. Use less electrolyte for subsequent tests. Plungers made of stainless steel have to be cleaned with plenty of water. If necessary, remove persistent dirt with aqueous nitric acid (20%, 2 hours at room temperature). All other cell components are for immediate re-use without cleaning.

## 10 Consumables

### Plunger (single-use):

- Upper plunger (Al) [ECC1-01-0026-B](#)
- Upper plunger (Cu) [ECC1-01-0026-A](#)
- Lower plunger (Al), gap  $x = 50$  to  $800$  [ECC1-01-0027-A\\_x](#)
- Lower plunger (Cu), gap  $x = 50$  to  $800$  [ECC1-01-0027-B\\_x](#)

### Insulation sleeves (single-use):

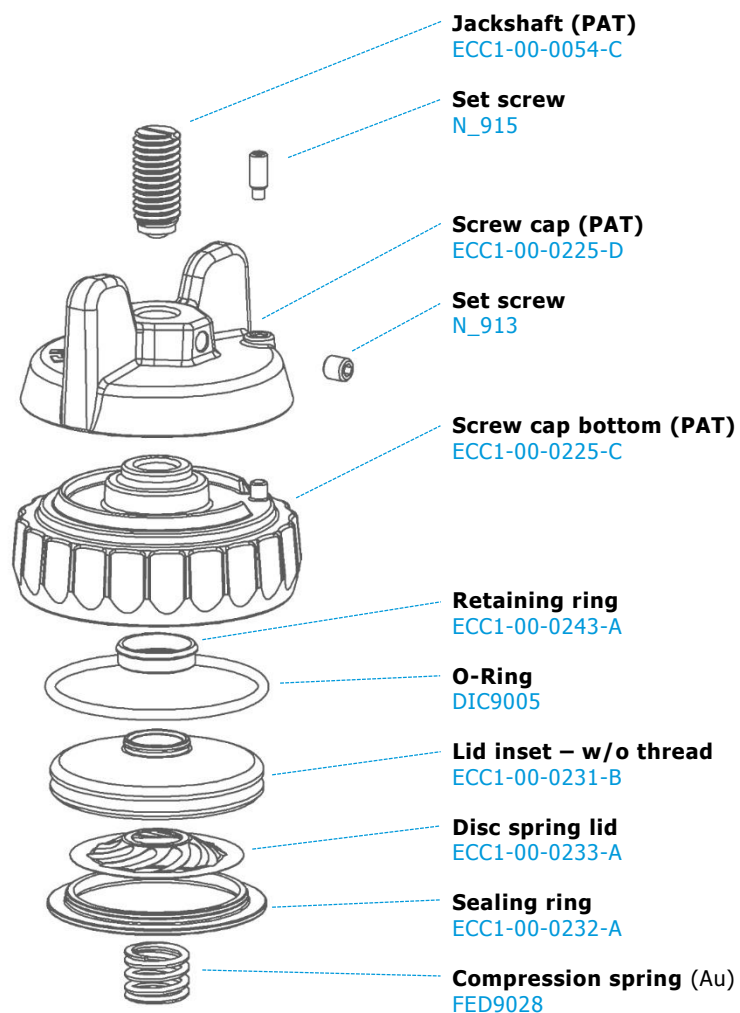
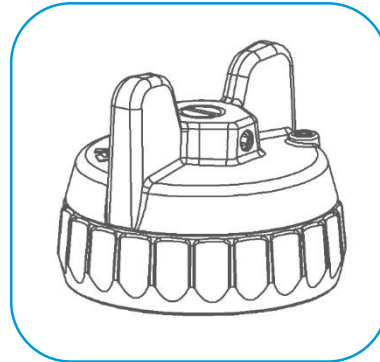
- Insulation sleeve with Li-reference ring and Viledon separator  
[ECC1-00-0210-A/x](#)
- Insulation sleeve with Viledon separator only  
[ECC1-00-0210-B/x](#)
- Insulation sleeve with Li-reference ring and glass fiber separator  
[ECC1-00-0210-O/x](#)
- Insulation sleeve with glass fiber separator only  
[ECC1-00-0210-P/x](#)

### Seals (single-use):

- Sealing ring (lid) [ECC1-00-0232-A](#)

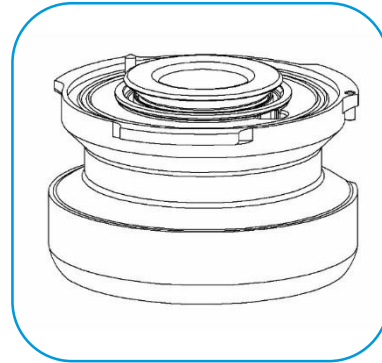
## 11 Spare Parts

Components screw cap:





## Components Cell base with PAT-Core:



**Lower plunger (SS)**  
ECC1-01-0027-C\_x  
or **Lower plunger (Al)**  
ECC1-01-0027-A\_x  
more version see chapter 7

**Upper plunger (SS)**  
ECC1-01-0026-C  
or **Upper plunger (Cu)**  
ECC1-01-0026-A  
more version see chapter 7

**Insulation sleeve with built-in GF separator and with Li-reference ring**  
ECC1-00-0210-O/x  
or **Insulation sleeve with built-in GF separator (no reference)**  
ECC1-00-0210-P/x  
more version see chapter 7

**DIN7 A1.5x4 cylindrical pin**  
NRM0013

**Cell base (PAT)**  
ECC1-00-0234-A

**Contact pin – long, assy**  
ECC1-00-0242-B

**Contact pin – short, assy**  
ECC1-00-0242-A

**Button holder**  
ECC1-00-0247-B

**Screw**  
N\_965

**Shaft ring**  
FED9029

**Button (PAT)**  
ECC1-00-0253-A

### Plunger (reusable):

- Upper plunger (SS) (to be ordered separately)  
[ECC1-01-0026-C](#)
- Lower plunger (SS), gap x = 50 to 800 (steps of 50) (to be ordered separately)  
[ECC1-01-0027-C\\_x](#)

## 12 Technical Support

Technical support for this product is exclusively provided by EL-CELL GmbH.

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## 13 Warranty

For a period of one year from the date of shipment, EL-CELL GmbH (hereinafter Seller) warrants the goods to be free from defect in material and workmanship to the original purchaser. During the warranty period, Seller agrees to repair or replace defective and/or nonconforming goods or parts without charge for material or labor, or, at the Seller's option, demand return of the goods and tender repayment of the price. Buyer's exclusive remedy is repair or replacement of defective and nonconforming goods, or, at Seller's option, the repayment of the price.

Seller excludes and disclaims any liability for lost profits, personal injury, interruption of service, or for consequential incidental or special damages arising out of, resulting from, or relating in any manner to these goods.

This Limited Warranty does not cover defects, damage, or nonconformity resulting from abuse, misuse, neglect, lack of reasonable care, modification, or the attachment of improper devices to the goods. This Limited Warranty does not cover expendable items. This warranty is void when repairs are performed by a non-authorized person or service center. At Seller's option, repairs or replacements will be made on site or at the factory. If repairs or replacements are to be made at the factory, Buyer shall return the goods prepaid and bear all the risks of loss until delivered to the factory. If Seller returns the goods, they will be delivered prepaid and Seller will bear all risks of loss until delivery to Buyer. Buyer and Seller agree that this Limited Warranty shall be governed by and construed in accordance with the laws of Germany.

The warranties contained in this agreement are in lieu of all other warranties expressed or implied, including the warranties of merchantability and fitness for a particular purpose.

This Limited Warranty supersedes all prior proposals or representations oral or written and constitutes the entire understanding regarding the warranties made by Seller to Buyer. This Limited Warranty may not be expanded or modified except in writing signed by the parties hereto.