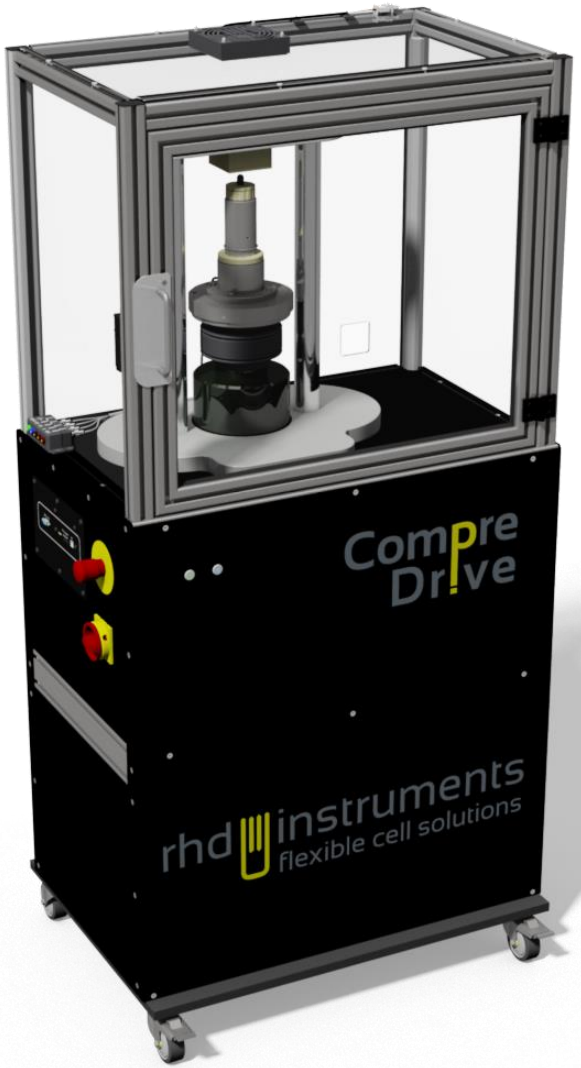
rhd instruments
flexible cell solutions



Do you work well under pressure?

Introducing the

CompreDrive

rhd instruments – flexible cell solutions

Marcel Drüschler

CEO
Sales and Marketing

Benedikt Huber

CEO
Research & Development

Jens Wallauer

Head of Product Management
Software Development

Christoffer Karlsson

Senior R&D Scientist

Michael Schöll

Mechanical Design
Engineer

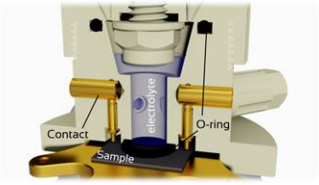
Sebastian Kranz

International Sales
Manager

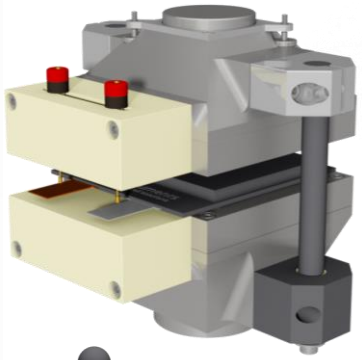
Electrochemistry experts and engineers with a passion
to develop innovative testing solutions for you

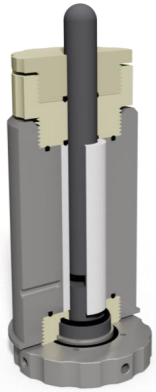
rhd instruments – flexible cell solutions

Microcell product line



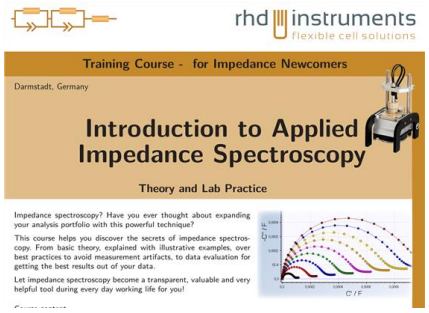
CompreDrive product line





Software and Services

RelaxIS 3
Impedance Spectrum Analysis



rhd instruments – flexible cell solutions

2020
The CompreDrive press system is released

2018
On-site seminars on the topic of 'Impedance Spectroscopy'

2017
Move to our new headquarters in Darmstadt

2015
Coupling of electrochemistry with spectroscopy with the TSC Spectro

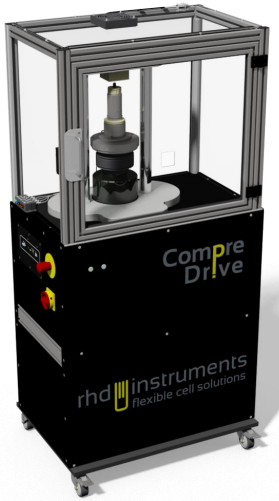
2014
RelaxIS: Impedance Spectrum Analysis joins the software portfolio

2014
Inception of the cooperation with Metrohm Autolab and Deutsche Metrohn

2013
Official formation of rhd instruments GmbH & Co. KG

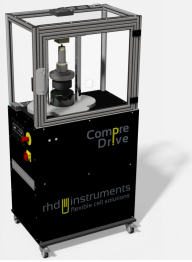
2012
Expansion of cell portfolio with the TSC Battery and TSC Surface

2011
Commercial launch of the Microcell HC system



RelaxIS 3
Impedance Spectrum Analysis

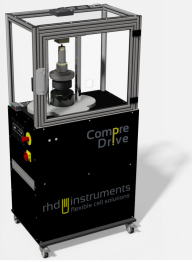
Motivation for CompreDrive development



State-of-the-art measuring systems: Needs in cutting-edge research

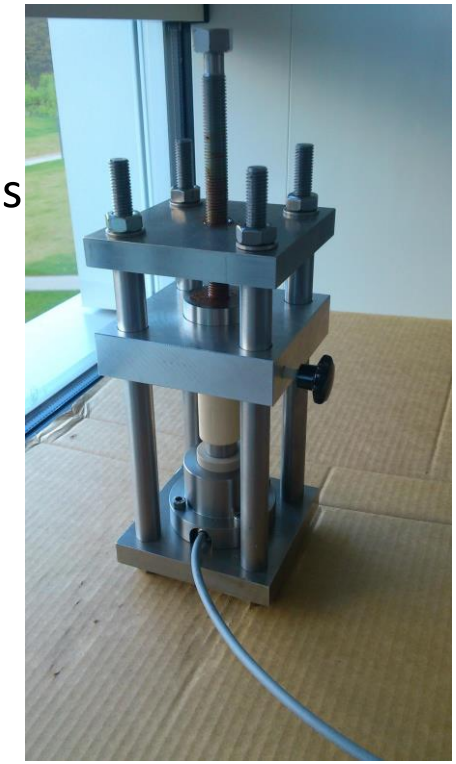
- ❑ Reproducible results
- ❑ Robust and easy to handle equipment
- ❑ Active force control and logging
- ❑ Active temperature control and logging
- ❑ Automation
- ❑ Fixed, standardized procedures
- ❑ Data management
- ❑ Safety of operation

Motivation for CompreDrive development



Issues in solid state electrochemistry:

- Home-built setups
- “Measuring Cells” with insufficient manufacturing tolerances
- Manual force regulation via hydraulic cylinder or screw
- Force direction inaccurate due to manufacturing tolerances



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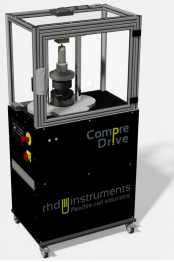

State-of-the-art

Issues in solid state electrochemistry:

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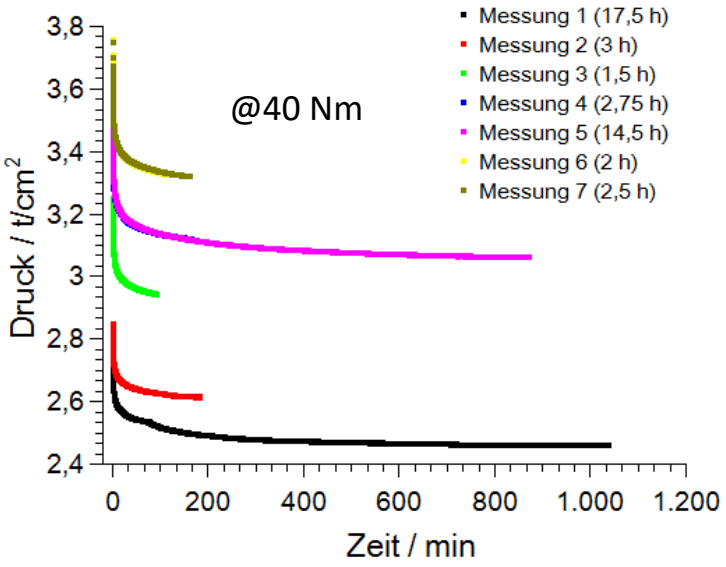
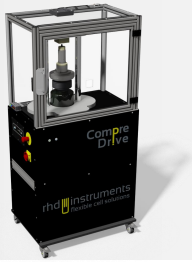
- Often no force monitoring at all



Motivation



State-of-the-art

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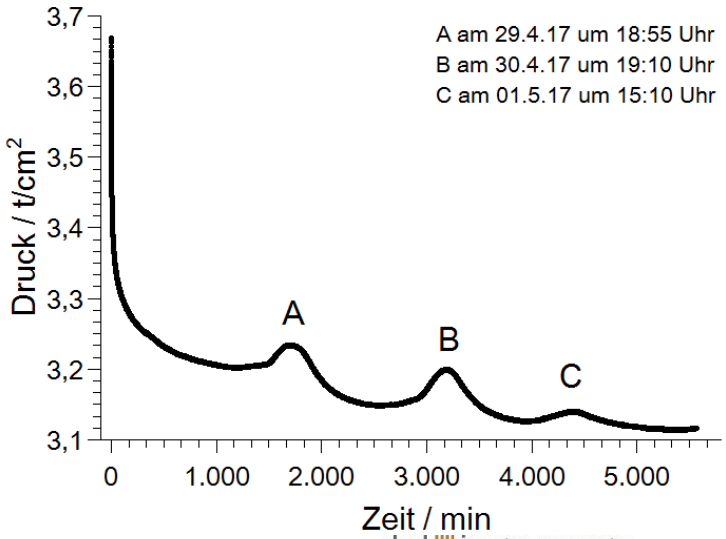
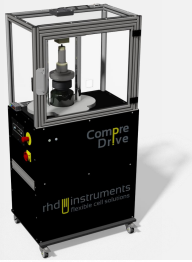


rhd instruments flexible cell solutions

Motivation



State-of-the-art

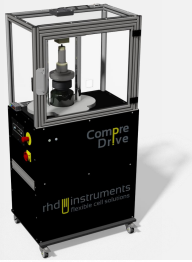
Issues in solid state electrochemistry:

- Home-built setups
- “Measuring Cells” with insufficient manufacturing tolerances
- Manual force regulation via hydraulic cylinder or screw
- Force direction inaccurate due to manufacturing tolerances
- Often no force monitoring at all
- No active force regulation
- No or insufficient temperature regulation

→ **Inaccurate conditions**

- Highly limited force range
- Limited flexibility
- No automation

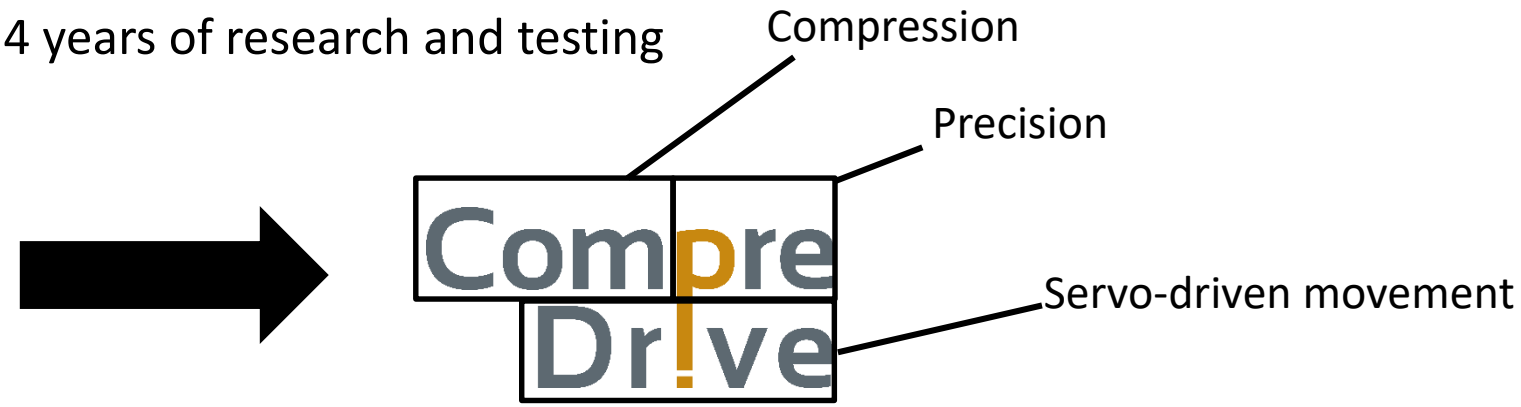
Motivation



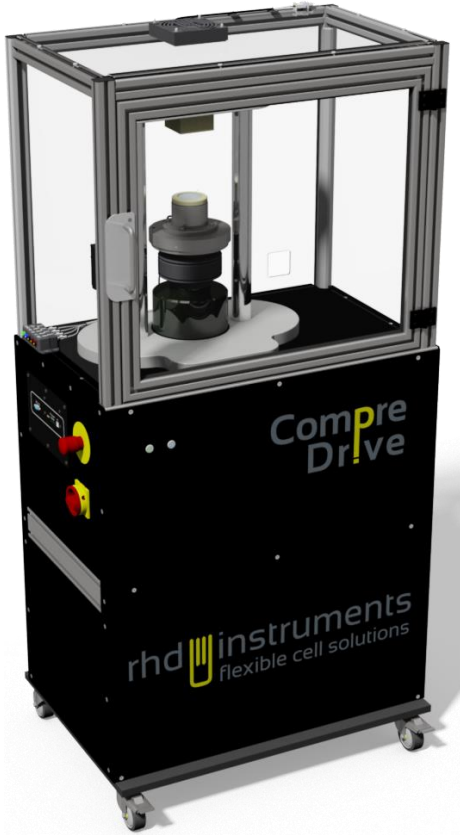
rhd´s approach:

- Design of highly specific measuring set-up for solid state research
- Eliminate common drawbacks
- Enable (semi-)automated solid state measurements

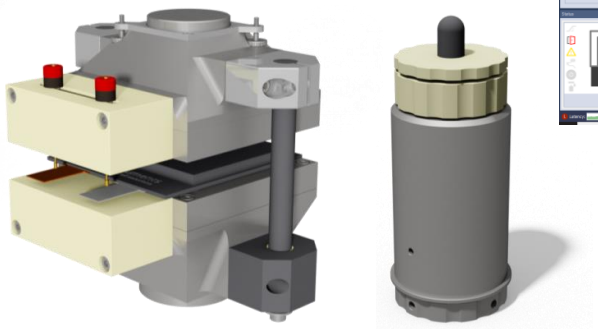
→ Over 4 years of research and testing



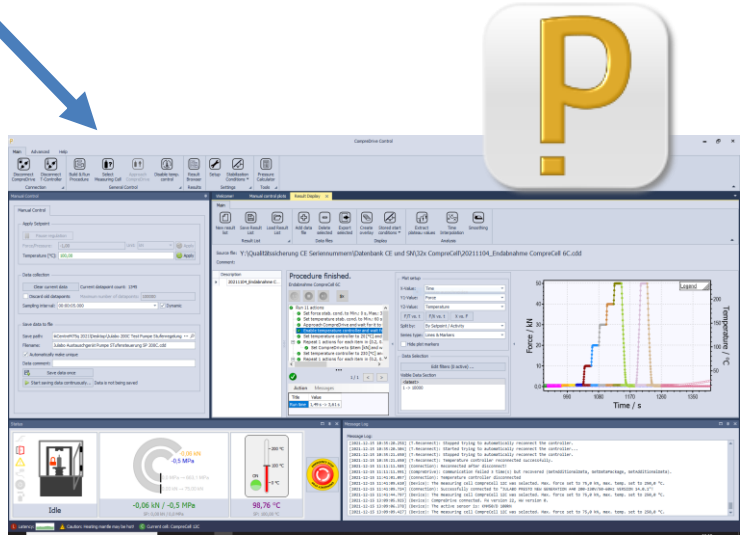
Compre Drive



1. CompreDrive

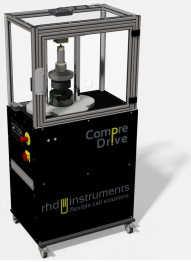


2. CompreCell



3. CompreDriveControl

1. CompreDrive



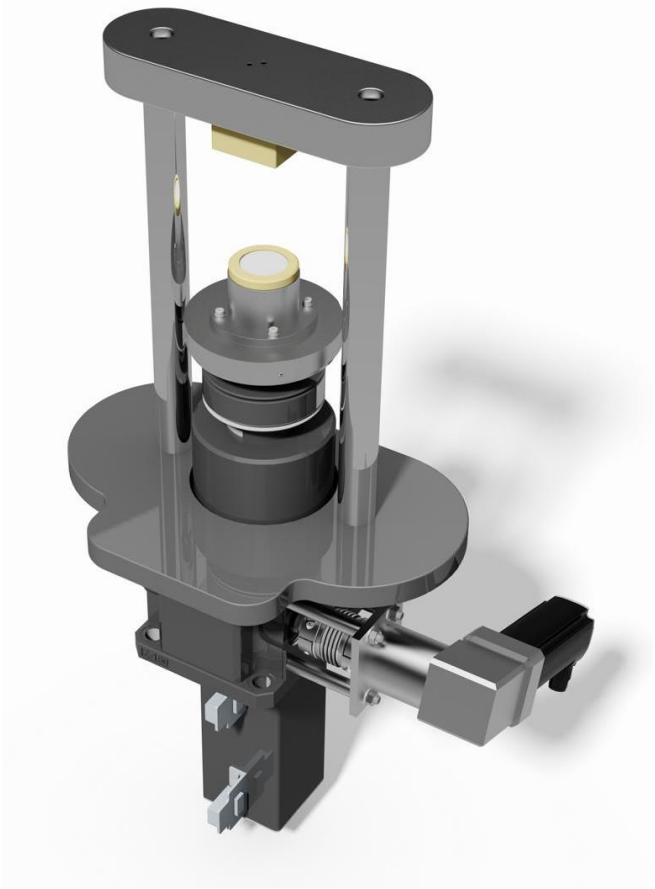
- Modular platform -> Different measuring cells available
- Main part: Force control unit
- High precision servo drive

  → minimum step width <10 nm
- 75 kN maximum force

  → 663 MPa @ 12 mm sample diameter

  → 1.7 GPa @ 6 mm sample diameter

  → Different force sensors available



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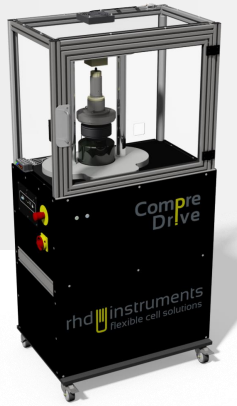


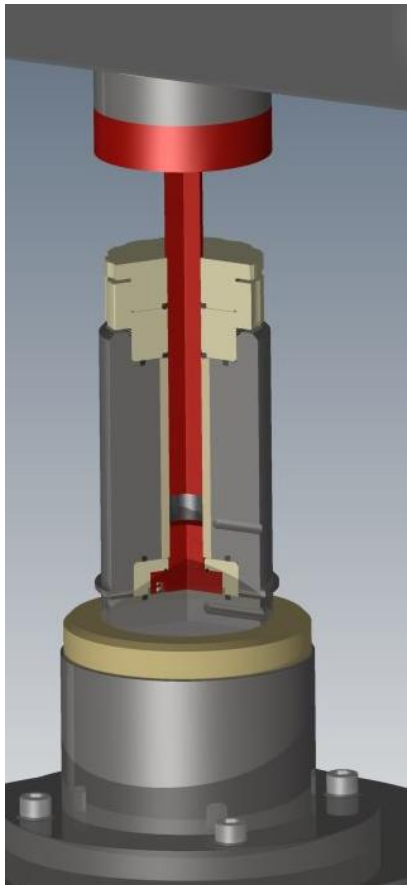
- Application of force via spherical collet

  → Only uniaxial forces

- Electrical insulation by Al_2O_3/ZrO_2 ceramic

- Highly stressed parts made from hard-metal

  → Robust and durable



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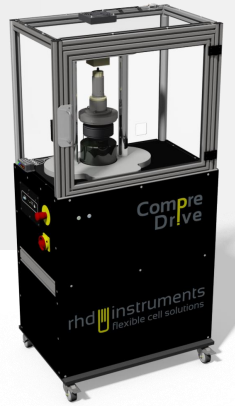

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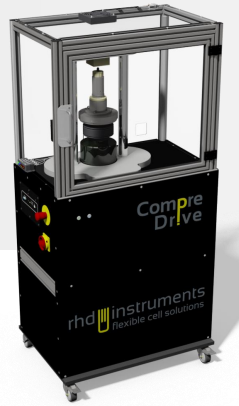
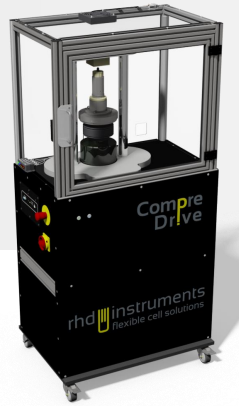
- Universal connection capabilities for all potentiostat/galvanostat models

1. CompreDrive



- Application of force via spherical collet
  - → Only uniaxial forces
- Electrical insulation by Al_2O_3/ZrO_2 ceramic
- Highly stressed parts made from hard-metal
  - → Robust and durable
- Universal connection capabilities for all potentiostat/galvanostat models
- Safety first!
  - Safety glass housing with open door detection
  - Electromechanical door lock
  - Self checks, SW based limits, User input checks, ….

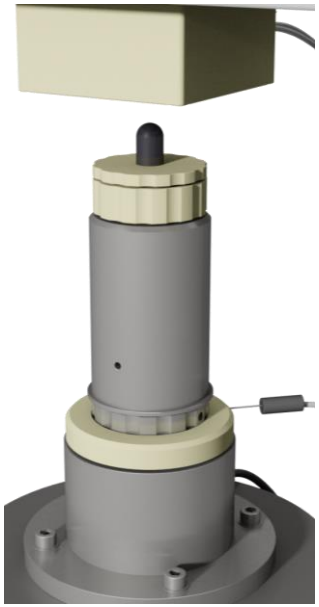
1. CompreDrive



Temperature regulation add-ons

- High precision Pt100 temperature sensor
- 3 different configurations:

No active heating



CompreDrive

Electrical heating
RT → +250°C

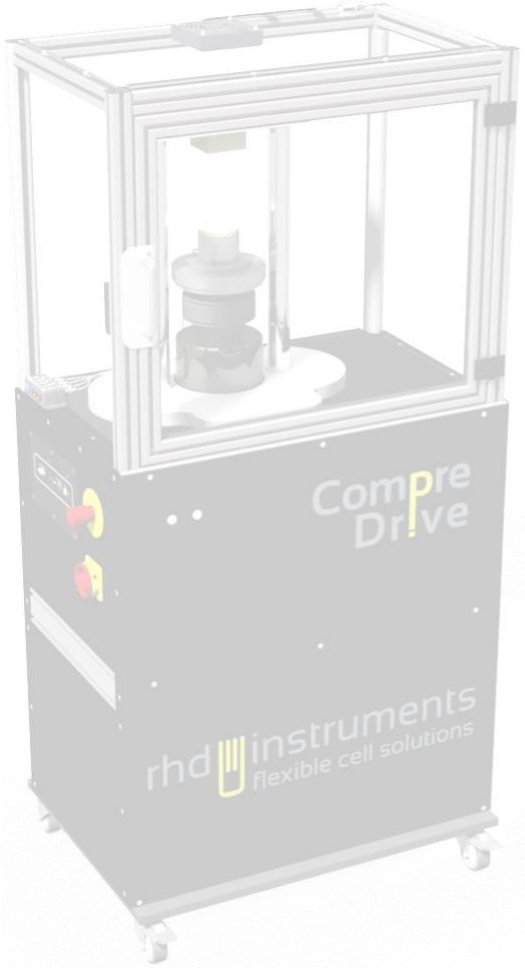
CompreDrive H

Fluid heating and cooling*
-40°C → +250°C

*lab scale refrigerated circulator required

CompreDrive HC

Compre Drive



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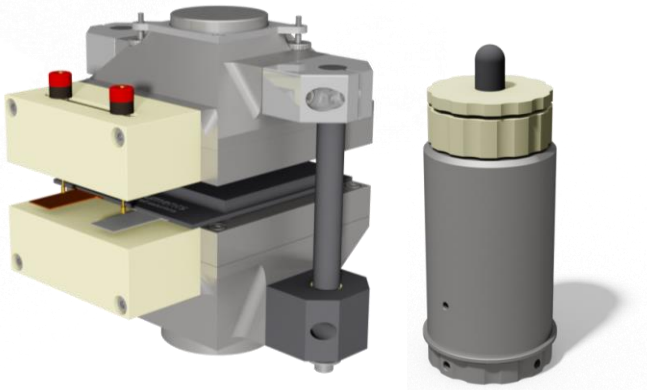


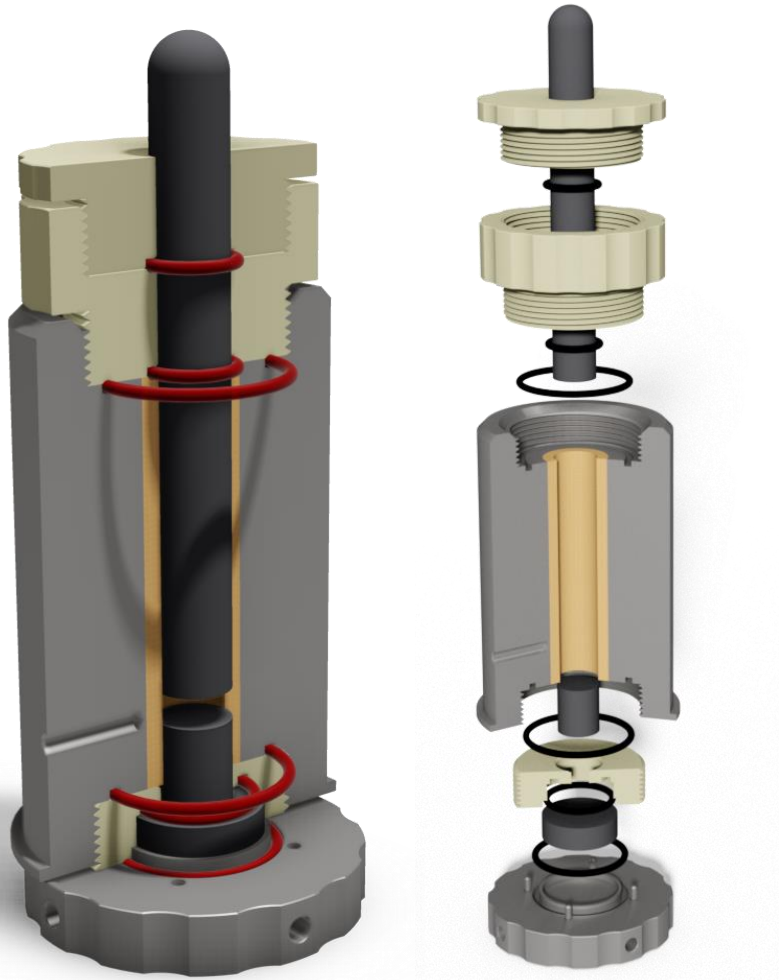
2. CompreCell

3. CompreDriveControl

2. CompreCell

Example 1: CompreCell 12C

- Designed for powders and disc-like samples
- Airtight (He leakage rate < 10^{-7} mbar·l·s^{-1})
- Stainless steel body
- Insulation sleeve: Al_2O_3
- Sample diameter: 12 mm
- Maximum sample height: 10 mm
- Maximum Force: 75 kN (=663 MPa)
- Temperature Range: -40 → +250°C
- Plate-plate geometry (2 electrodes)



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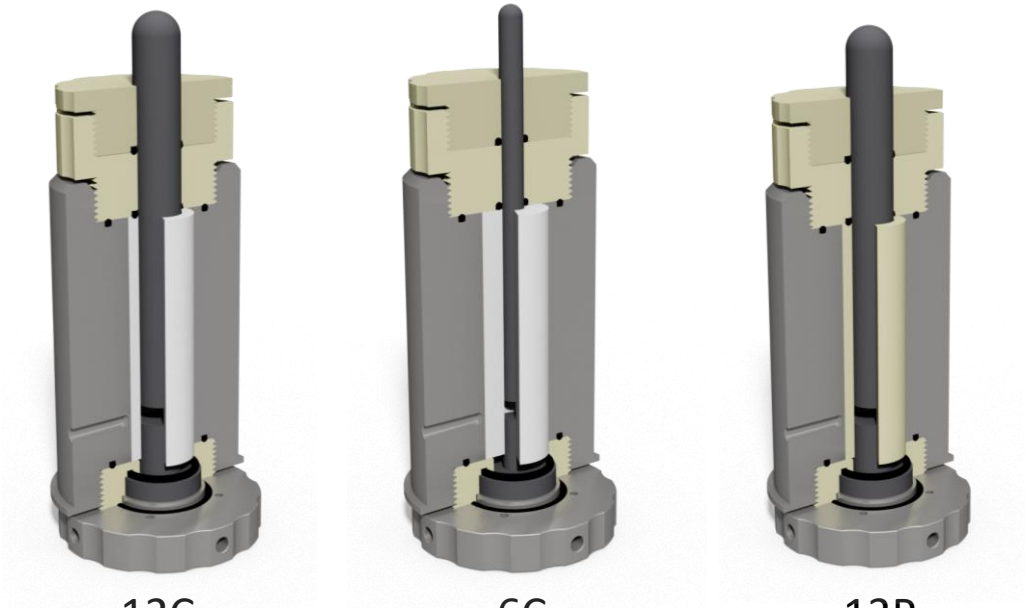
flexible cell solutions

2. CompreCell

Different Labs – different needs

Max. pressure: 1,7 GPa



CompreCell:	12C	6C	12P
Diameter:	12 mm	6 mm	12 mm
Insulation:	Al_2O_3	Al_2O_3	PEEK*/PEI**

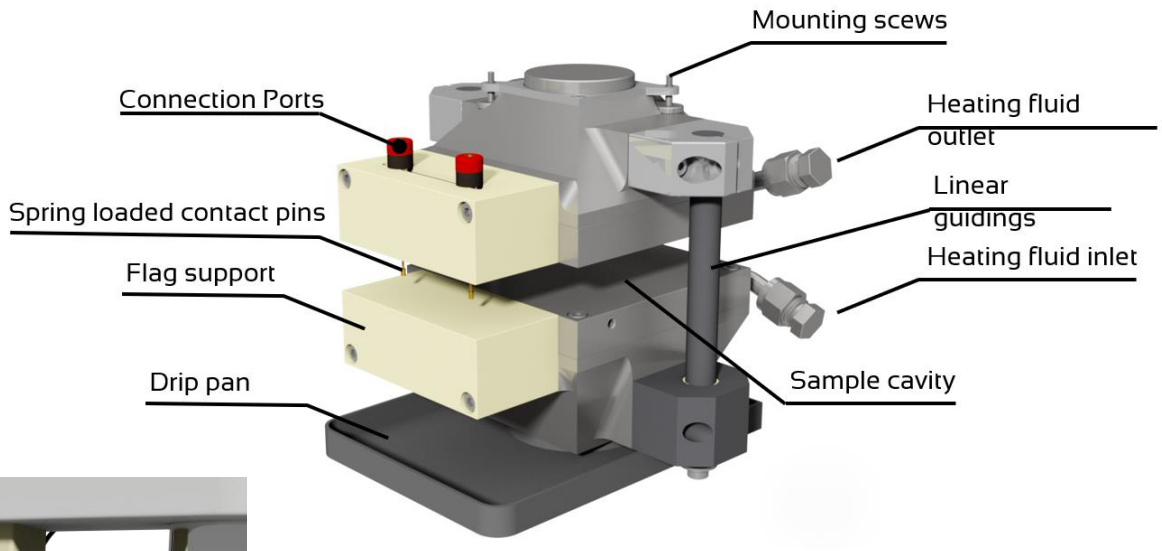
* up to 150 °C
** up to 200 °C

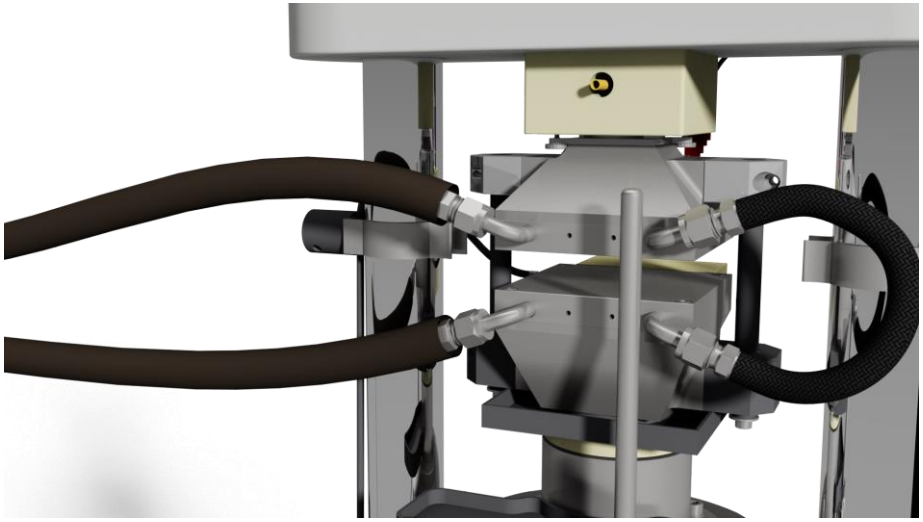
→ Custom cells available! ←

Recent developments for CompreDrive

CompreCell Pouch 10S HC

- Designed for pouch-bag samples
- 10cm x 10cm sample cavity
- Solid stainless steel body
- Temperature range: 0-100 °C
- Both plates with fluid channels



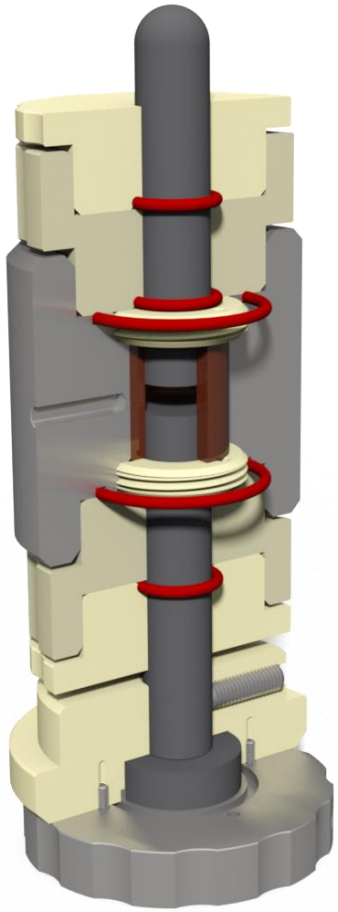


- Adjustable gold-plated contacts
- Maximum sample height: 20 mm
- Maximum Force: 75 kN
- Fixed to CompreDrive main unit

Recent developments for CompreDrive

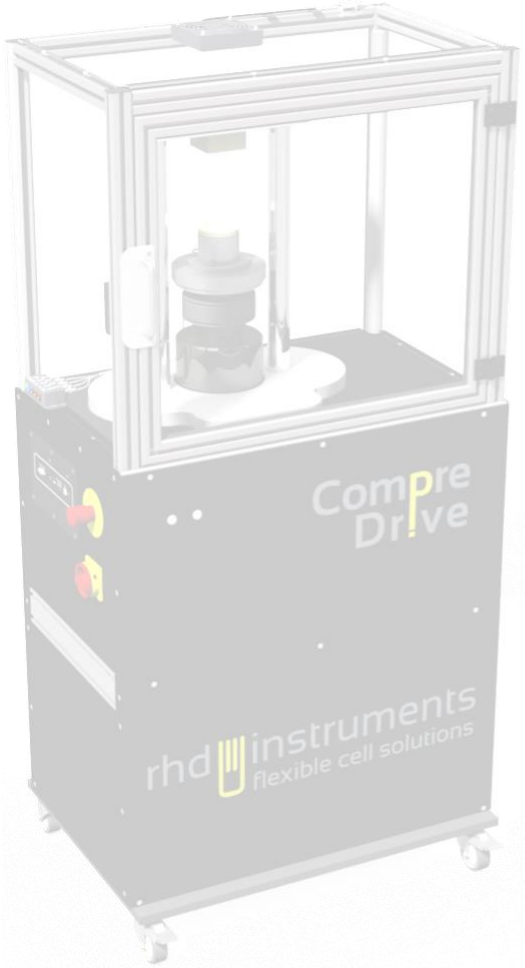
Double-Piston CompreCell

- Optimized for ASSB preparation
- Moveable cell body
- Air tight
- Compatible with H/HC add-on
- Variable insulation sleeves available
- Same temperature and pressure ratings like standard CompreCells



rhd instruments
flexible cell solutions

CompreDrive



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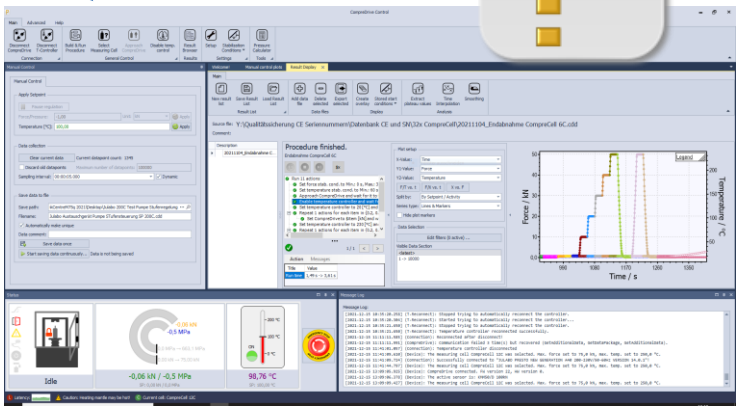


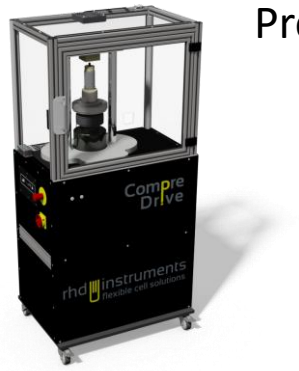
3. CompreDriveControl

3. CompreDriveControl

Potentiostat / Galvanostat

Temperature control

Pressure control



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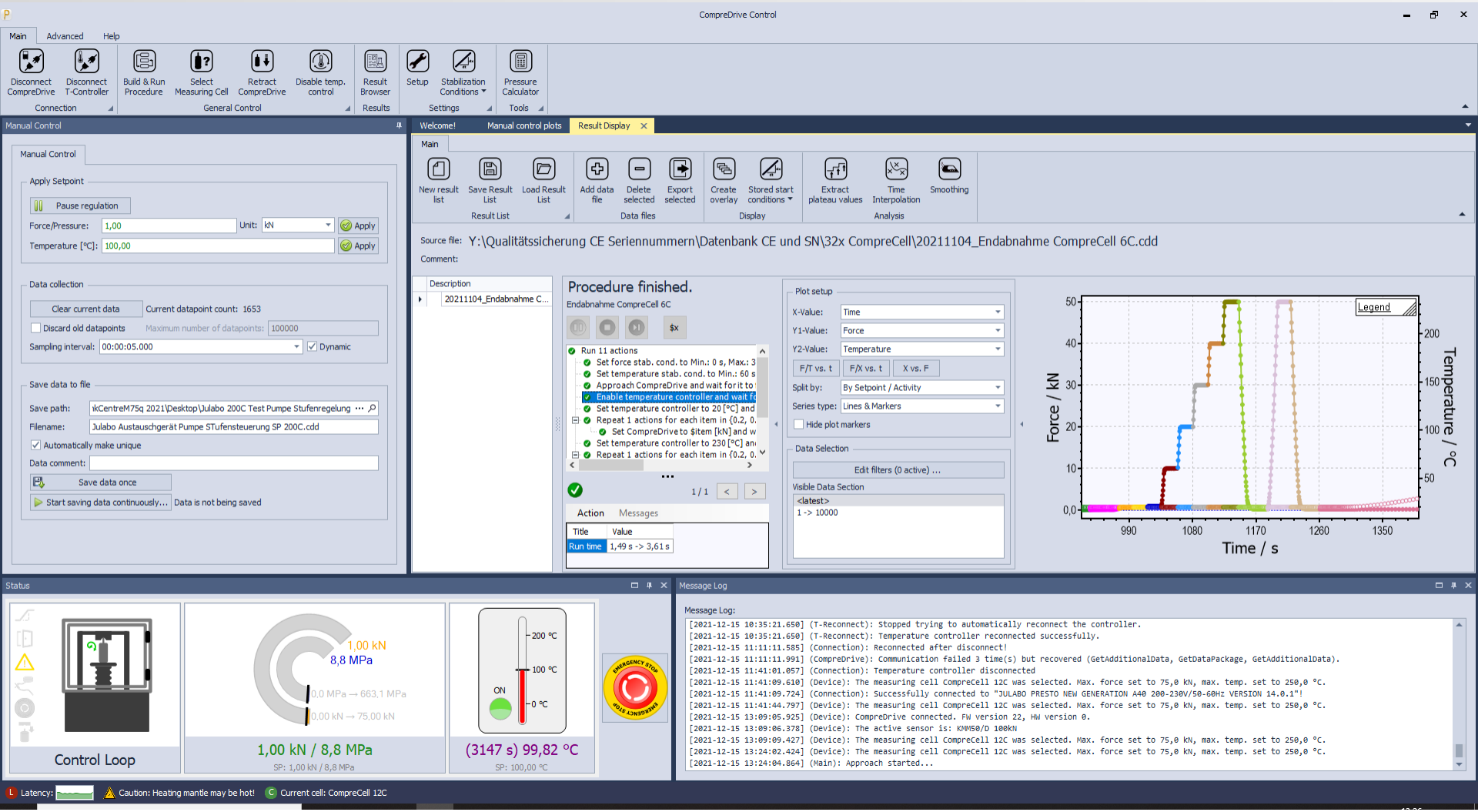

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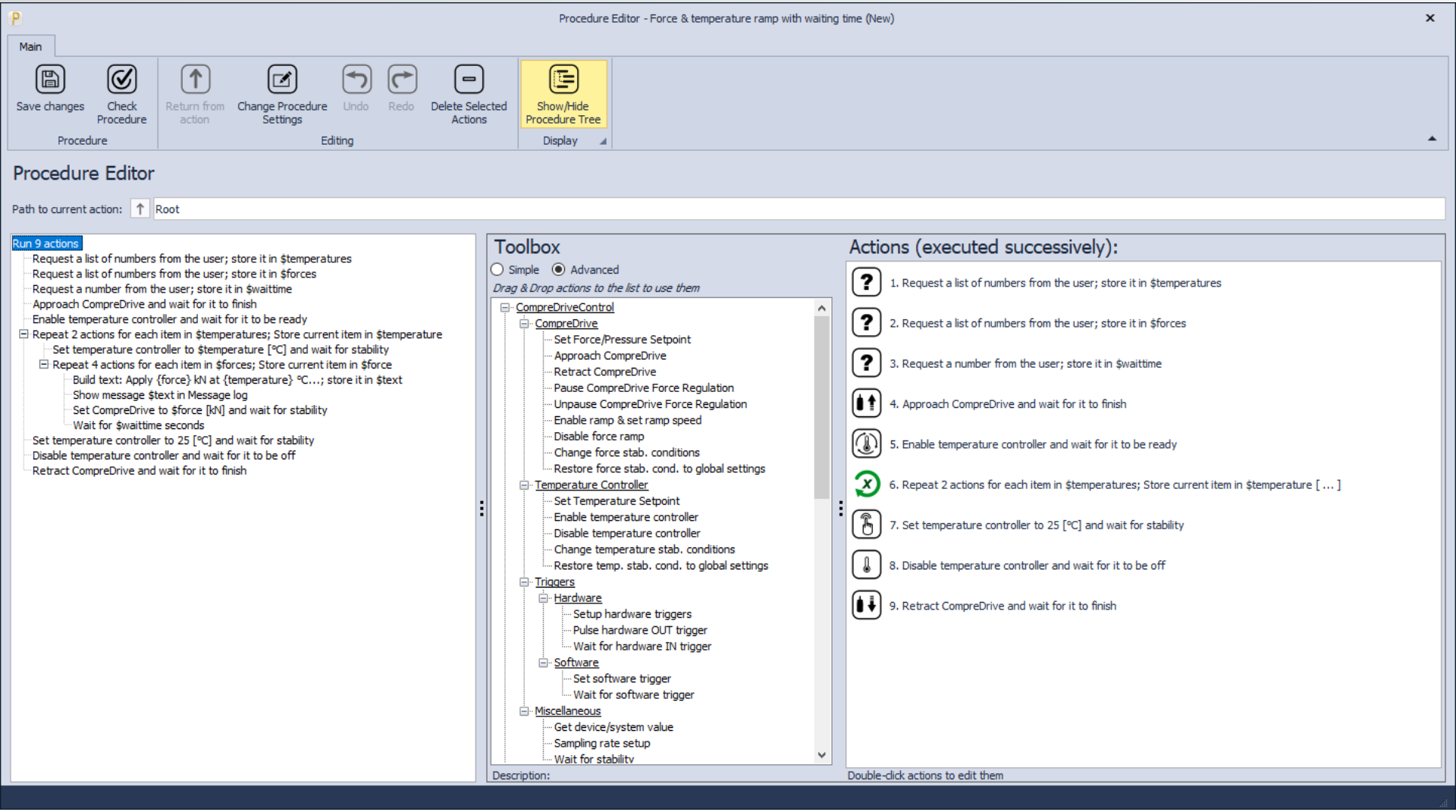
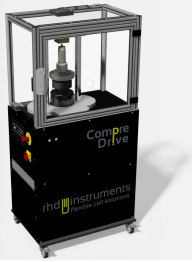


3. CompreDriveControl

CompreDriveControl main features

- Full control of forces/pressures, temperatures, electrochemistry (optional)
- Manual control and fully automated procedures
- Logging, visualization and analysis of all available data
- Results browser, export functions (graph, text)
- Read and set external setpoints: Synchronization with other programs via a simple http interface or hardware triggers

Motivation for CompreDrive development



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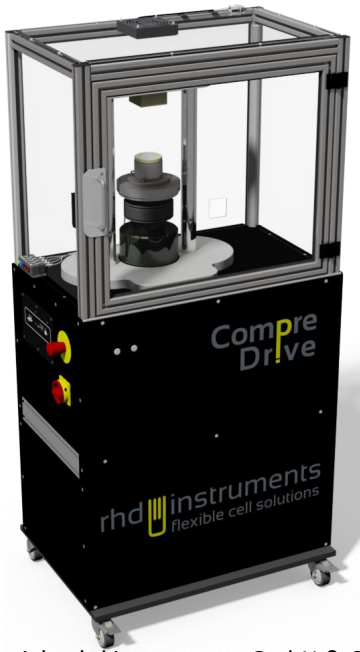
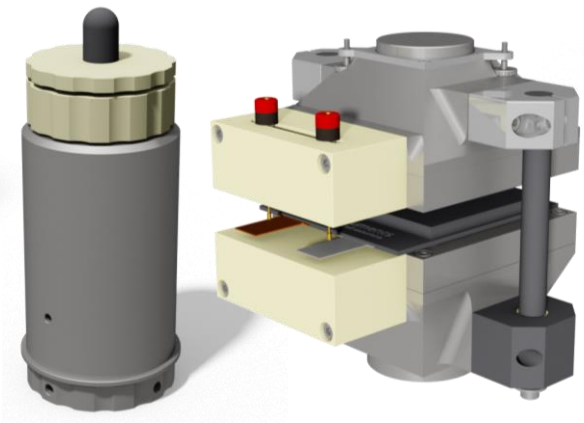
- ✓ Data management
- ✓ Safety of operation

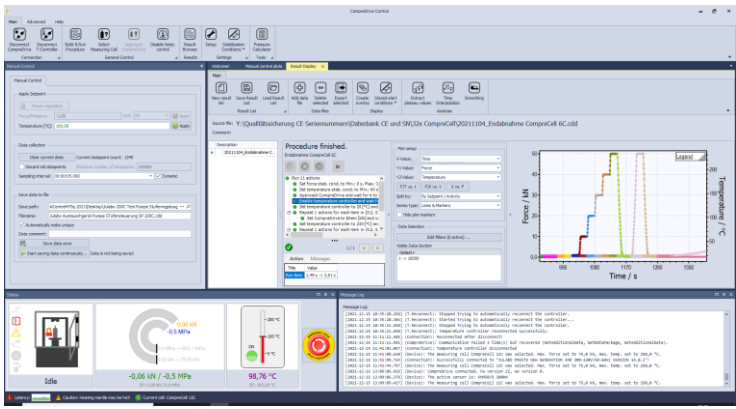
CompreDrive

- New experimental horizons in solid state electrochemistry -

Keep the pressure up!





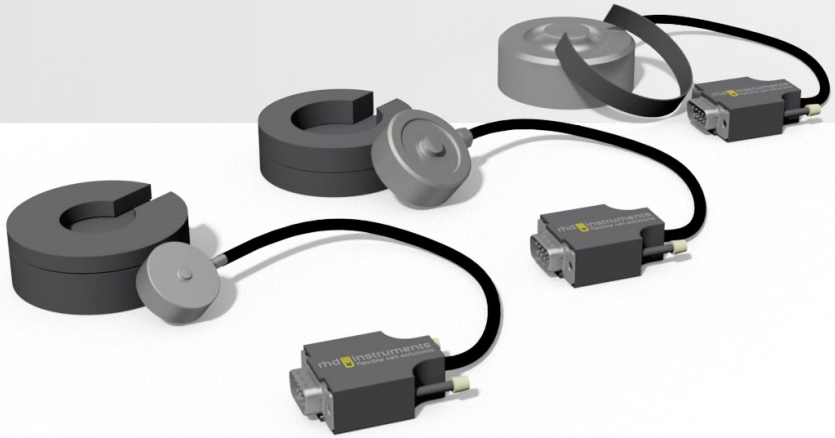


Summary

CompreDrive

- **Mechanical force up to 75 kN (1.7 GPa @ 6mm sample diameter)**
- **Temperature range -40°C <-> +250°C**
- **Active(!) force and temperature control**
- **Modular system allows for extension and customization**
- **Airtight measuring cells**
- **Extensive control software**
- **Fully automated electrochemical measurements of solid samples**

Available sensors



100 kN sensor: accuracy of the whole system is within +- 0.1 kN.

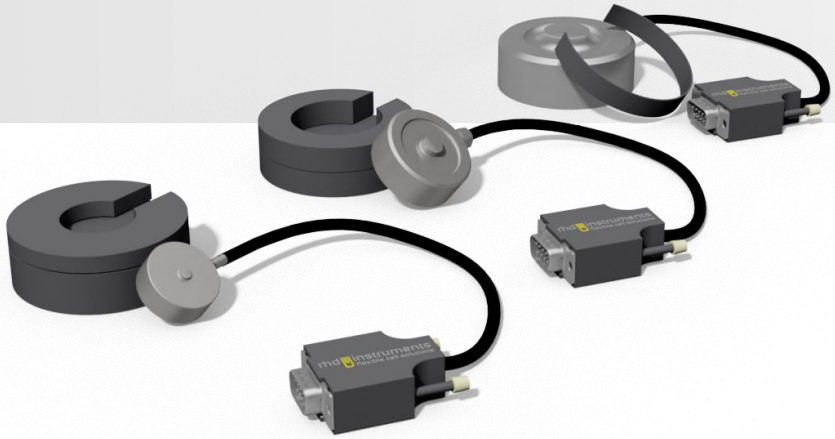
10 kN sensor: linearity error is <0.5 % full scale according to the sensor data sheet (0.05 kN)

2 kN sensor: linearity error is <0.2 % full scale according to the sensor data sheet (0.004 kN)

For the 100 kN sensor, you would get 0.1 % error.
The difference here is, that this is the standard sensor, and we check every single unit with a second calibration sensor in the system instead of a measuring cell.
The sensors are typically much better than the limit given in the datasheet.
In case of the 100 kN sensor, we do not use full scale.

Measured value amplifier has 24 bit resolution

Available sensors



Minimum force available

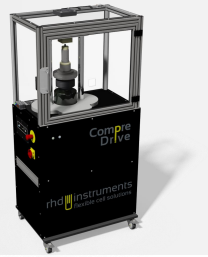
In general: 0.15 % of full scale, absolute minimum 30 N.

100 kN sensor: minimum force 150 N

10 kN sensor: minimum force 30 N

2 kN sensor: minimum force 30 N

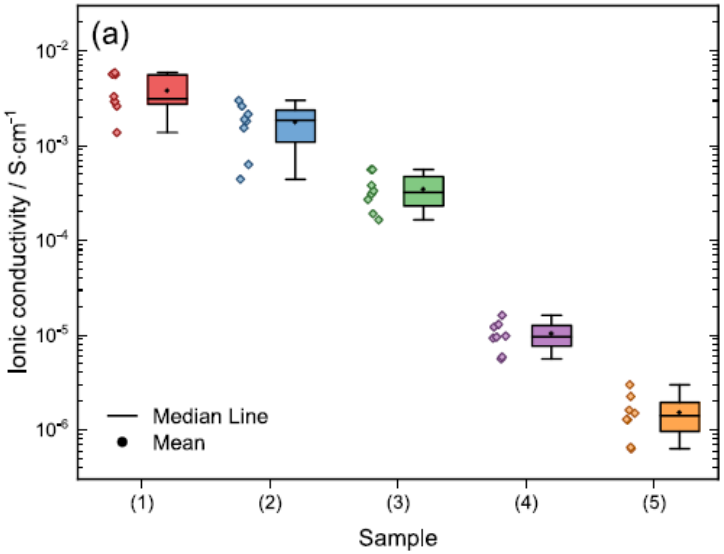
The CompreDrive by rhd instruments



The importance of pressure and temperature control

Round-robin study by S. Ohno et al.

- 5 different solid electrolytes
- 8 labs around the world
- Determining ionic conductivity σ



S. Ohno et al., *ACS Energy Lett.* 2020, 5, 3, 910–915

Results:

- σ deviation: One order of magnitude
- Results highly dependent on local sample processing

→ **Precise pressure and temperature control during sample preparation crucial**