Stream
In situ TEM liquid & biasing or heating

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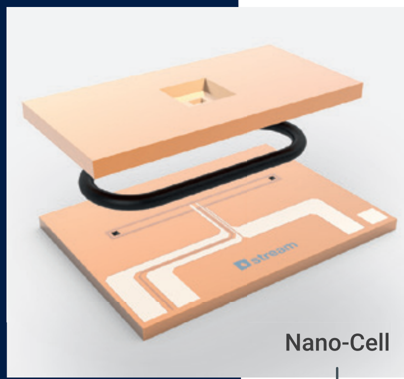
Introduction

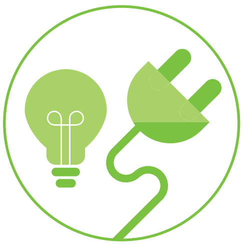
Liquid Phase Electron Microscopy (LPEM) has become increasingly popular, as it provides new insight into important processes of various research topics within materials science, chemistry and biology.

The Stream In Situ Liquid Solution provides researchers with the capability to visualize and capture dynamics in liquid for a wide range of samples, from biological to the most advanced nanomaterials.

The possibility to combine a liquid environment with heating or biasing stimuli opens up many new and exciting research fields.



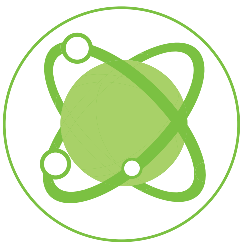
Typical applications



Batteries

Electrocatalysts

Corrosion



Materials synthesis and growth

Cell biology

Life science

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DENS solutions

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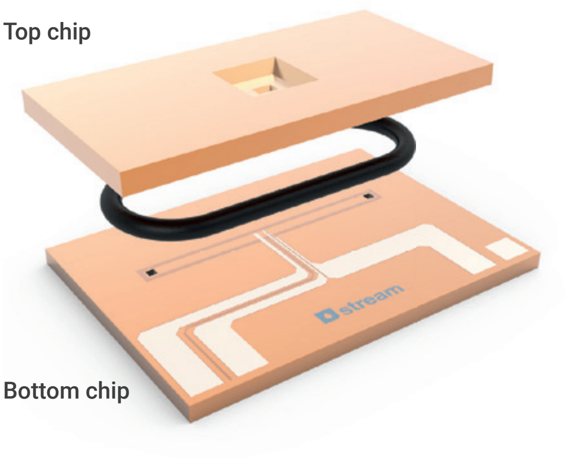
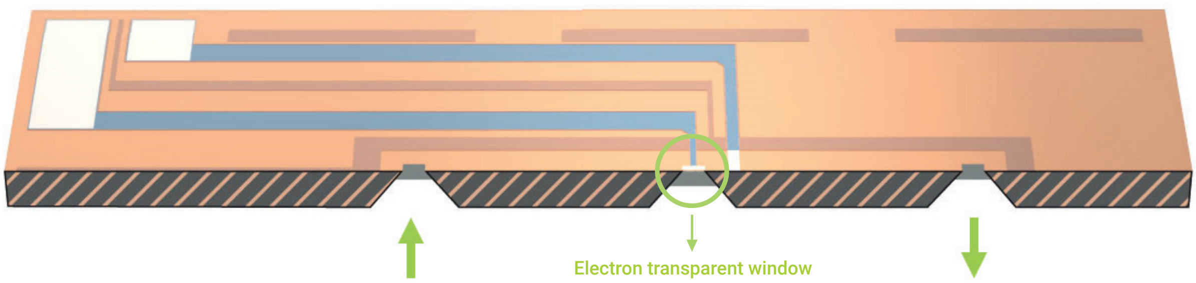


Nano-Cell

The core of the Stream system is our patented Nano-Cell, which relies on a dual-chip technology. We revolutionize the approach to liquid phase experiments by introducing the liquid inlet and the outlet directly on the bottom chip. A combination of the spacers surrounding the inlet, outlet and the top chip define a microfluidic channel, ensuring a sample-liquid interaction. As a result, the system gives you the unique ability to **independently** control flow rate and liquid thickness while heating or biasing your sample.



Schematic overview of bottom chip showing on-chip inlet and outlet.

Liquid Supply System

The Liquid Supply System (LSS) is an integrated solution designed to offer you precise fluidic control in your in situ liquid experiments.

1. Ease of use

The flexible design of the LSS, particularly the moveable base, enables you to easily relocate, store and set it up in various locations.

2. HR imaging & meaningful analytical analysis

The LSS introduces the capability of controllable and repeatable inert gas purging. Via purging, you can swiftly get rid of excess liquid in your sample, enabling high resolution imaging, meaningful elemental analysis and electron diffraction.

3. Reliable and reproducible results

Via the liquid flow meter, you can actively measure the liquid flow, making it possible for you to compare results from different experiments. The combination of our LSS and unique Nano-Cell design enables the liquid delivery to be both reliable and reproducible with a success rate of more than 95%.

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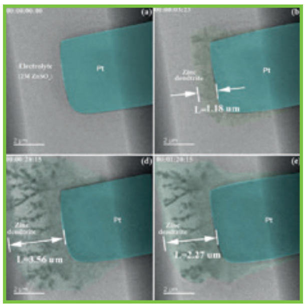
Selected Publications



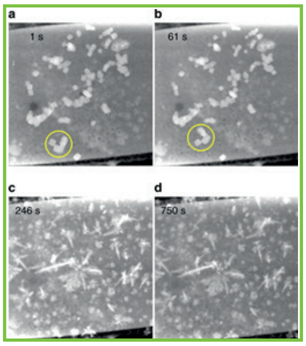
Zinc plating and stripping process at different times in 2 M $ZnSO_4$.

Zinc ion batteries

Metallic zinc is a widely used electrode material for aqueous rechargeable zinc-ion batteries (ZIBs) due to its high theoretical capacity, low redox potential, natural abundance and low cost. Despite these valuable benefits, little is known about the underlying reasons for the failure of zinc anodes on a deeper level.

In this paper, the authors were able to obtain a deep understanding of the stripping/plating behaviors of zinc in various aqueous electrolytes using Stream. Specifically, the researchers investigated the effects of adding Mn^{2+} and $CF_3SO_3^-$ in zinc-salt aqueous electrolytes on the zinc plating/stripping behavior. This work provides effective strategies to achieve long-term stable rechargeable ZIBs, beneficial for several critical applications, including large-scale energy storage and portable electronic applications.

Huang, Yongfeng et al. Energy Storage Materials 46 (2022) 243-251



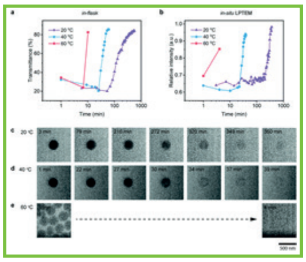
Direct observation of morphology evolution of the electrocatalysts during the working condition.

Electrocatalysis

Copper-based alloys or oxides with defined exposed facets show high activity and selectivity toward C2 products formation during electrochemical CO_2 reduction. However, the stability of such tailored nanostructures under reaction conditions remains poorly understood.

Using Stream, the authors show the formation of cubic copper oxide particles from copper sulfate solutions during direct electrochemical synthesis and their subsequent morphological evolution under a reductive potential. They were able to achieve the shape-selected synthesis of copper oxide cubes, effectively providing new insights into the electrodeposition parameters required to custom-tune the synthesis of size- and shape-selected nanoparticles.

Arán-Ais, Rosa M. et al. Nature Communications 11 (2020) 3489



The temperature-dependent etching kinetics of silica nanoparticles, in-flask vs. in situ LPTEM.

Nanomaterials and corrosion

Gaining full control over the reaction environment inside the microscope, particularly the solution temperature and concentration of reactants, is a major challenge facing LPEM users.

In this paper, the authors demonstrate the capabilities of the system by studying the liquid flow dynamics and comparing the temperature-dependent etching kinetics of silica nanoparticles by in situ LPEM to in-flask experiments. They find that the combination of the on-chip microfluidic channel and the microheater enables the nanoscale observation of temperature-dependent chemical dynamics.

Van Omme, Tijn et al. Journal of Materials Chemistry 8 (2020) 10781-10790

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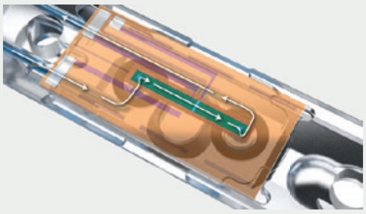
Why Stream?

1



High experimental success rate

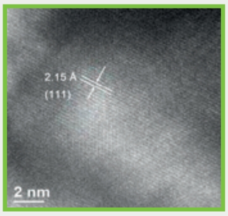
1. Ensure sample-liquid interaction
The well-defined microfluidic channel ensures that the sample of interest and liquid always interact.

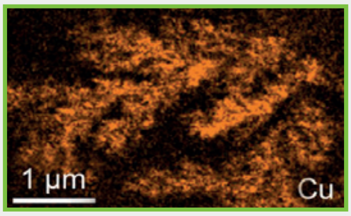
2. Dissolve unwanted bubbles
Bubbles can be flushed away from the imaging area or dissolved, enabling a greater control over experimental conditions.

3. Introduce fresh solution
The controlled flow in the imaging area allows to maintain a constant and directional flow, enabling a continuous fresh solution.

4. Ease of use
The integrated Liquid Supply System greatly simplifies the operation of the system and improves user friendliness.

2





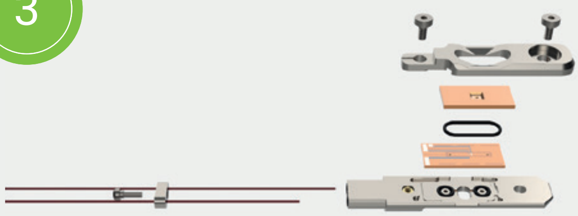
Full experimental control

1. Liquid purging and thickness control
Perform high resolution imaging, meaningful elemental analysis and electron diffraction by minimizing the liquid thickness or by purging the Nano-Cell.

2. Liquid flow measurement
Gain full control over the dynamics of your liquid experiment via flow control.

3. Mass transport control
Explore the effect of flow kinetics on the morphological and electrochemical changes of your sample

3



Clean experiments

1. Avoid cross-contamination
The modularity of the holder allows for each component to be either cleaned or replaced in a user-friendly manner.

2. Avoid clogging
Easily clean the tubings during your experiments without having to remove the holder from the microscope.

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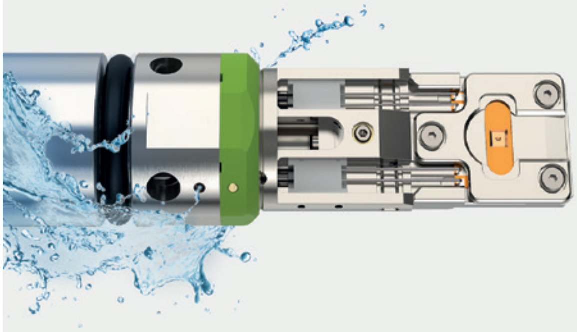
System Specifications

Nano-Cell	Liquid Heating	Liquid Biasing
Resolution	≤ 3 Å	
Liquid thickness control	Yes, via inlet and outlet liquid pressure control	
Liquid modes	Static, flow (infusion, withdrawal)	
Liquid flow measurement	Yes, via inlet liquid flow meter	
Liquid pressure safety limit	Yes	
Temperature range	RT to ≤ 100 °C	NA
Electrodes	4-point probe based microheater	3
Voltage range	NA	- 10 V to +10 V
Current range	NA	From pA to mA
AC impedance frequency range	NA	10 uHz - 1 MHz

System	JEOL	Thermo Fisher Scientific
Fluidic control	Integrated pressure-based pumps (Liquid Supply System)	
Modular holder design	Yes	
Modes	TEM, STEM, EDS, EELS, electron diffraction	
Alpha tilt range*	UHR, FHP = limited HRP = ±15 deg, WGP = ±21 deg	Bio-TWIN, C-TWIN, TWIN = ± 35 deg X-TWIN, S-TWIN = ± 25 deg

** Listed specifications are dependent on microscope configuration*



Microscopy TODAY
2021 Innovation Award

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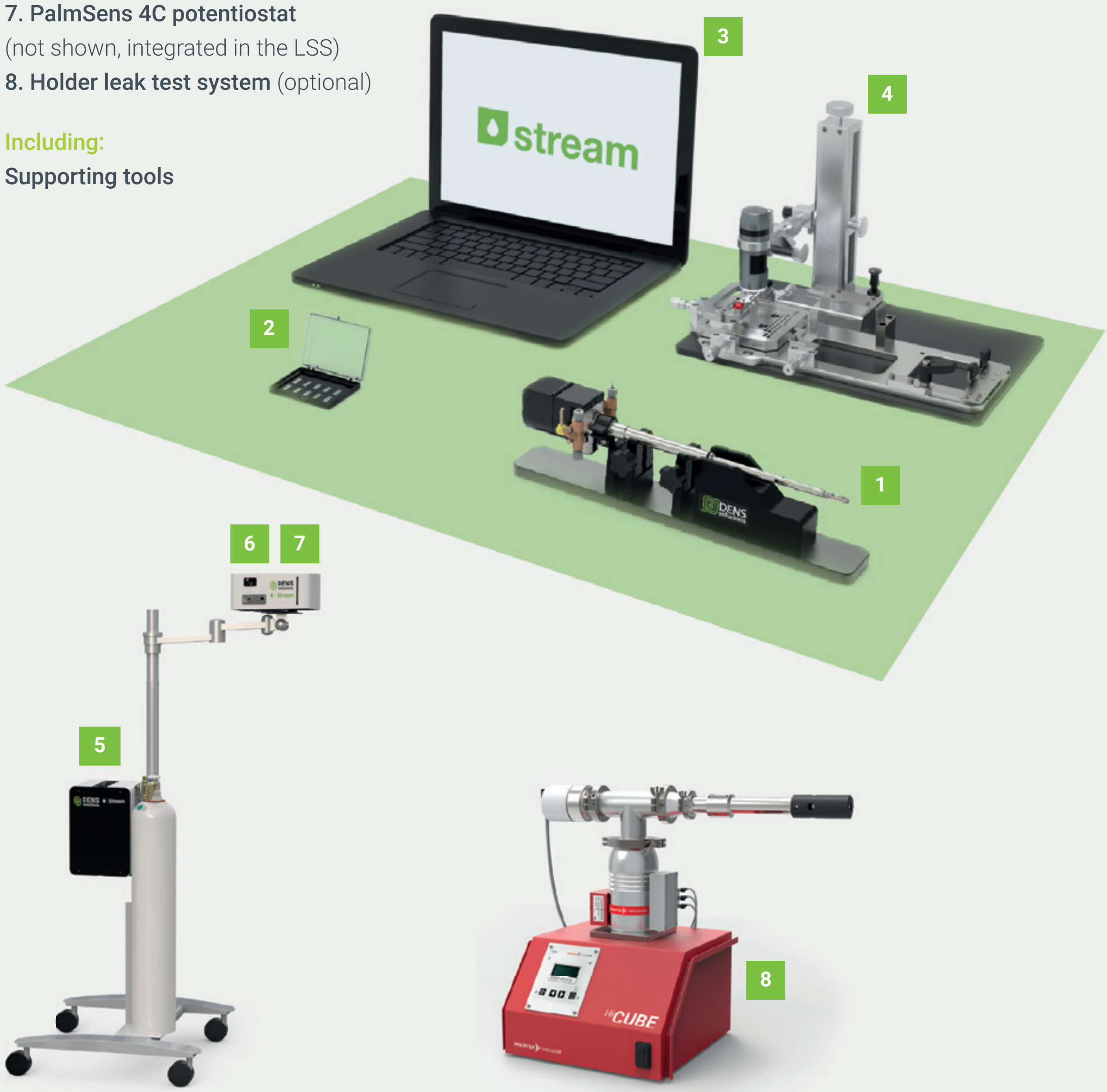
DENS solutions

Complete 'plug & play' package

1. **Stream Liquid Biasing / Liquid Heating TEM specimen holder**
2. **Nano-Cells starter pack**
3. **Laptop with dedicated software**
4. **Nano-Cell alignment setup**
5. **Liquid Supply System** (including pressure-based pumps and potentiostat or heating control unit)
6. **Heating control unit** (not shown, integrated in the LSS)
7. **PalmSens 4C potentiostat** (not shown, integrated in the LSS)
8. **Holder leak test system** (optional)

Including:
Supporting tools



Service and Support

Product warranty	24 months with optional extension
Regulatory compliance	CE, RoHS, FCC

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DENS solutions

Stream
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Wildfire
Heating

Lightning
Heating + Biasing

Climate
Gas + Heating

Stream
Liquid + Biasing or Heating

Version 3.1

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