DENS solutions

Stream

In Situ TEM **Liquid + Biasing or Heating**

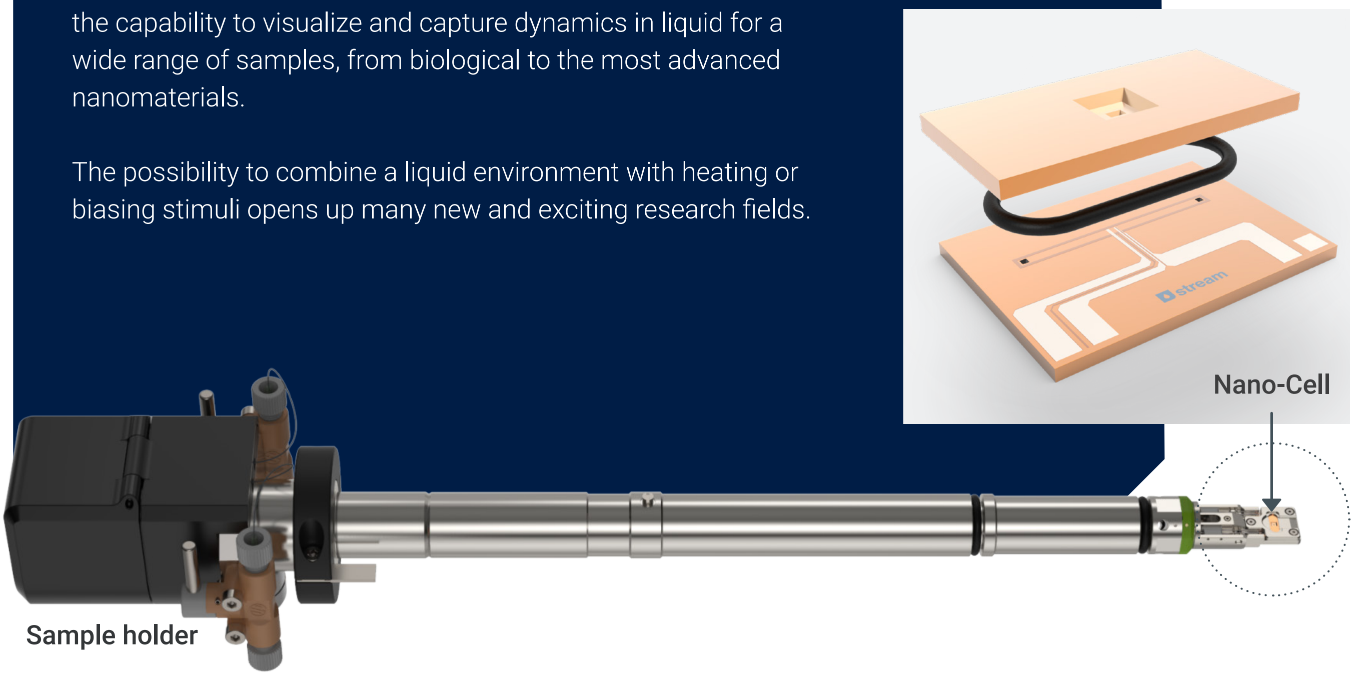
we care
we innovate
we deliver

Introduction

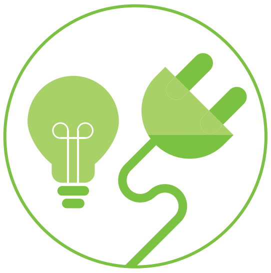
Liquid Phase Electron Microscopy (LPEM) has become increasingly popular, as it provides new insight into important processes of various research topics within materials science, chemistry and biology.

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.



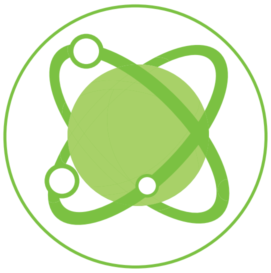
Typical applications



Batteries

Electrocatalysts

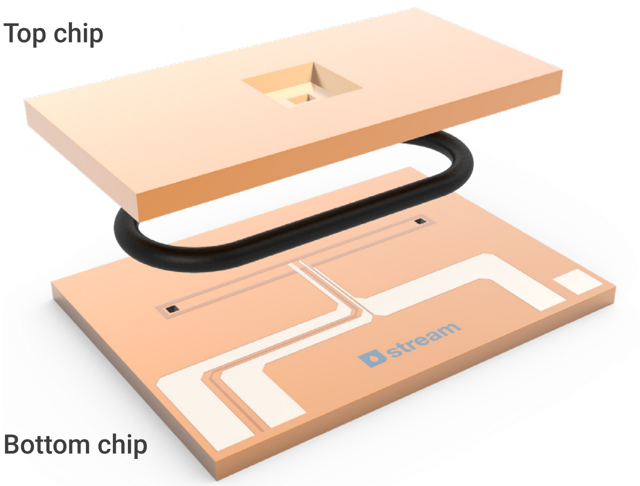
Corrosion



Materials synthesis and growth

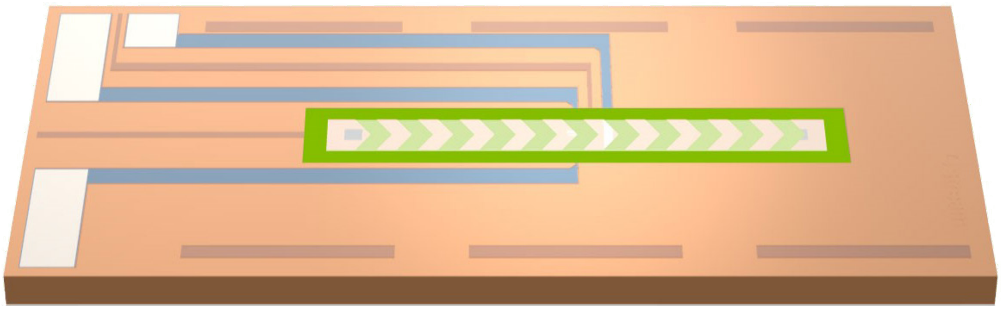
Cell biology

Life science

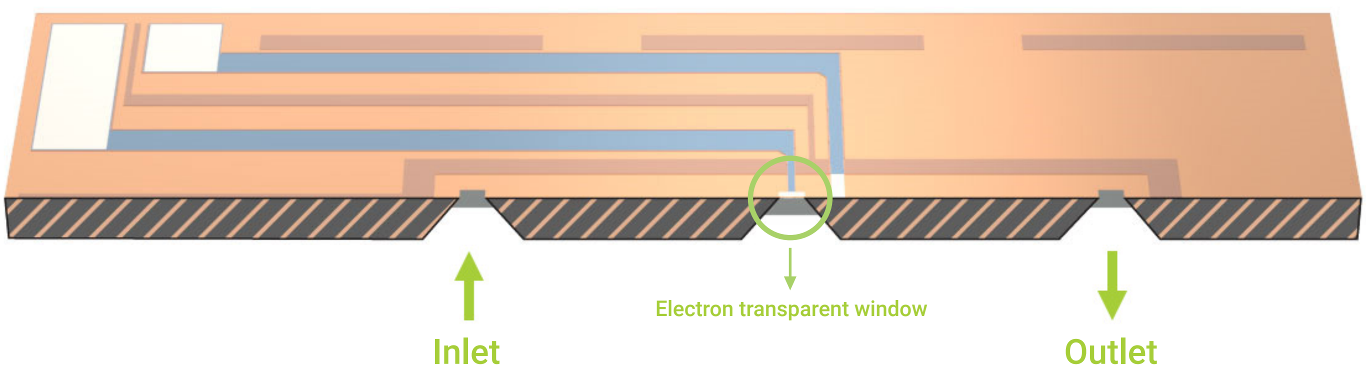


Nano-Cell

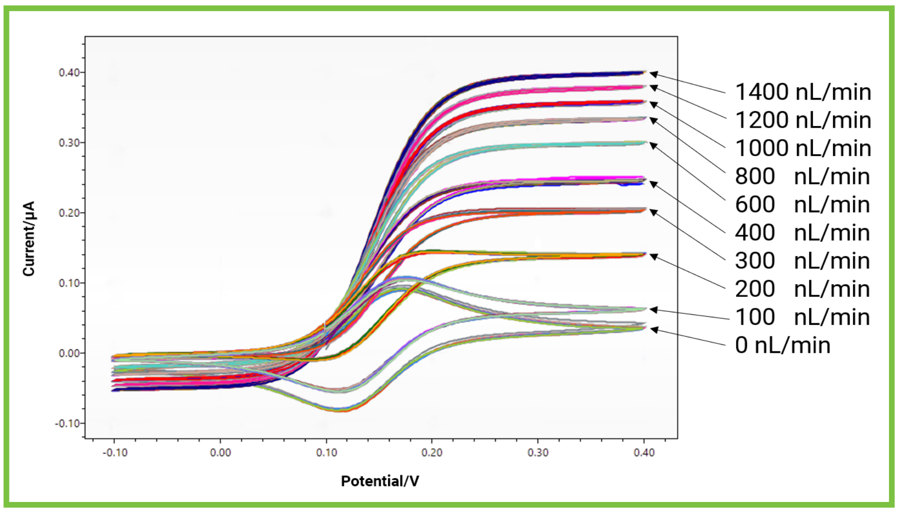
The core of the Stream system is our patented Nano-Cell, which relies on a dual-chip technology. We revolutionize the approach to liquid phase experiments by introducing the liquid inlet and the outlet directly on the bottom chip. A combination of the spacers surrounding the inlet, outlet and the top 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.



The microfluidic channel showing liquid flow.



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

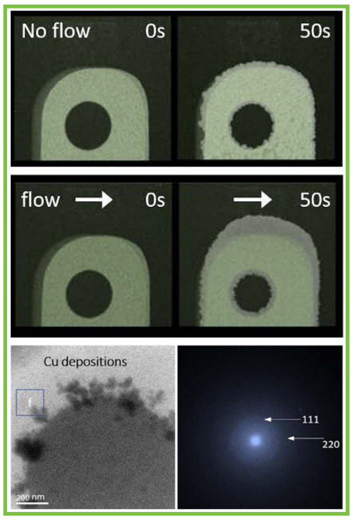


The change in cyclic voltammetry curves with different flow rates. The electrolyte is made of a mixture of 1 mM ferrocenemethanol and 0.1 M KCl.

Mass transport control

Next to the well-defined microfluidic channel of our Nano-Cell, the liquid supply system allows you to accurately control the flow rate during your experiments. This enables you to control the kinetics/ mass transport of the reaction around the sample.

Selected Publications



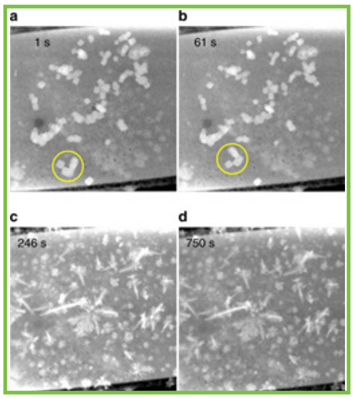
Flow rate dependent electrochemical crystallization.

Electrochemistry

Many challenges have posed considerable limitations on LPEM research, especially the lack of control over the chemical environment in a liquid cell.

In this paper, the authors present a platform for in situ electrochemical studies inside a TEM with a pressure-driven flow, with the opportunity to define mass transport and control electric potential, giving access to the full kinetics of a reaction. In order to exhibit the benefits of Stream, copper dendrites were grown and characterized in situ, showing a reliable electric potential control. The authors were able to change the morphology of the dendrites by tuning the mass transport conditions. Moreover, through controlling the liquid thickness, they demonstrate the possibility of EELS and EDS characterization of the electrodeposited copper, with an atomic resolution down to 2.15 Å.

Beker, Anne F. et al. Nanoscale 12 (2020) 22192-22201



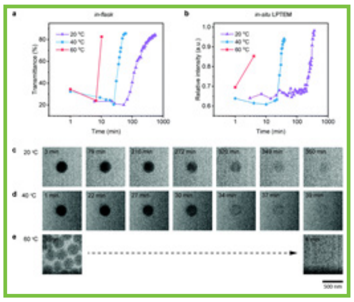
Direct observation of morphology evolution of the electrocatalysts during the working condition.

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

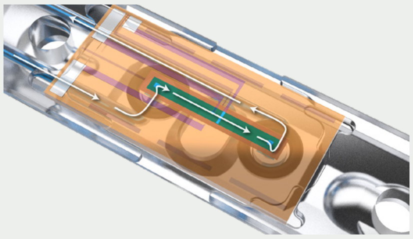
Gaining full control over the reaction environment inside the microscope, particularly the solution temperature and concentration of reactants, is a major challenge facing LPEM users.

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

Why Stream?

1



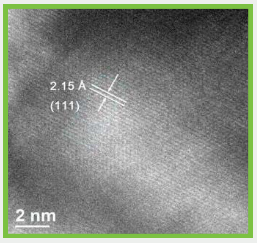
High experimental success rate

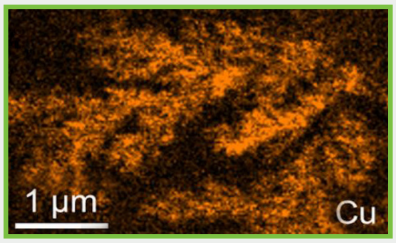
1. Ensure sample-liquid interaction
The well-defined microfluidic channel ensures that the sample of interest and liquid always interact.

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.

2





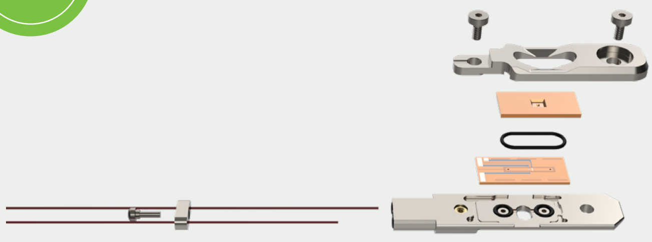
Full experimental control

1. Liquid thickness control
Perform high resolution imaging, meaningful elemental analysis and electron diffraction.

2. Liquid flow control
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.

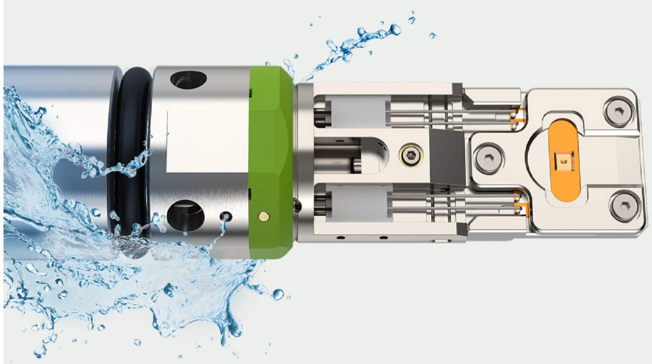
2. Avoid clogging
Easily clean the tubings during your experiments without having to remove the holder from the microscope.

System Specifications

<table>
<tr><th>Nano-Cell</th><th>Liquid Heating</th><th>Liquid Biasing</th></tr>
<tr><td>Liquid thickness</td><td colspan="2">< 500 nm</td></tr>
<tr><td>Resolution</td><td colspan="2">≤ 3 Å</td></tr>
<tr><td>Liquid pressure range (accuracy)</td><td colspan="2">200 mbar - 4000 mbar (± 2 mbar)</td></tr>
<tr><td>Liquid modes</td><td colspan="2">Static, flow (infusion, withdrawal)</td></tr>
<tr><td>Liquid flow range</td><td colspan="2">0 to 8 ul/min</td></tr>
<tr><td>Flow control: Direct closed loop feedback control</td><td colspan="2">< 10 s</td></tr>
<tr><td>Liquid pressure safety limit</td><td colspan="2">Yes</td></tr>
<tr><td>Temperature range</td><td>RT to > 100 °C</td><td>NA</td></tr>
<tr><td>Temperature stability</td><td>±0.01 °C</td><td>NA</td></tr>
<tr><td>Electrodes</td><td>NA</td><td>3</td></tr>
<tr><td>Voltage range</td><td>NA</td><td>- 10 V to +10 V</td></tr>
<tr><td>Current range</td><td>NA</td><td>From pA to mA</td></tr>
<tr><td>AC impedance frequency range</td><td>NA</td><td>10 uHz - 1 M Hz</td></tr>
</table>

<table>
<tr><th>System</th><th>JEOL</th><th>Thermo Fisher Scientific</th></tr>
<tr><td>Fluidic control</td><td colspan="2">Pressure-based pump</td></tr>
<tr><td>Modular holder design</td><td colspan="2">Yes</td></tr>
<tr><td>Modes</td><td colspan="2">TEM, STEM, EDS, EELS, diffraction</td></tr>
<tr><td>Alpha tilt range*</td><td>UHR, FHP = limited
HRP = ±15 deg, WGP = ±21 deg</td><td>Bio-TWIN, C-TWIN, TWIN = ± 35 deg
X-TWIN, S-TWIN = ± 25 deg</td></tr>
</table>

** Listed specifications are dependent on microscope configuration*



Microscopy TODAY
2021 Innovation Award

Complete 'plug & play' package

1. Stream Liquid Biasing / Liquid Heating TEM specimen holder
2. Nano-Cells starter pack
3. Pressure-based liquid pump
4. Laptop with dedicated software
5. Chip alignment setup
6. Holder leak test system (optional)
7. Heating control unit
8. Potentiostat

Including:
Supporting tools

Service and Support

Product warranty	24 months with optional extension
Regulatory compliance	CE, RoHS, FCC
Radiation safety	According to TEM manufacturers compliance regulations

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Wildfire
Heating

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Climate
Gas + Heating

Stream
Liquid + Biasing or Heating

Version 3.0