

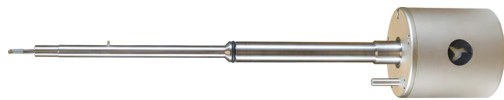


# HUMMINGBIRD SCIENTIFIC



## TEM Gas Flow

### Technical Specs



	1500 Series - Single Channel	1500 Series - Multi-Channel
<b>Pressure Range at Sample</b>	1 atm up to 1.5 atm	10 <sup>-6</sup> mbar up to 1.5 atm
<b>Experimental Gas Inlets</b>	1	2 - 8*
<b>Purge Capability</b>	Yes	Yes
<b>Gas Analysis Capability</b>	No	Yes
<b>Tubing System</b>	All Metal	All Metal
<b>Biasing Contacts</b>	3 or 4 contact (depending on model)	3 or 4 contact (depending on model)
<b>Heating Temperature</b>	Up to 800°C	Up to 800°C
<b>Holder Cleaning</b>	Bakeable to 160° C	Bakeable to 160° C
<b>TEM Compatibility</b>	FEI, JEOL, Hitachi, Zeiss	FEI, JEOL, Hitachi, Zeiss

\* Contact us for Custom Configurations

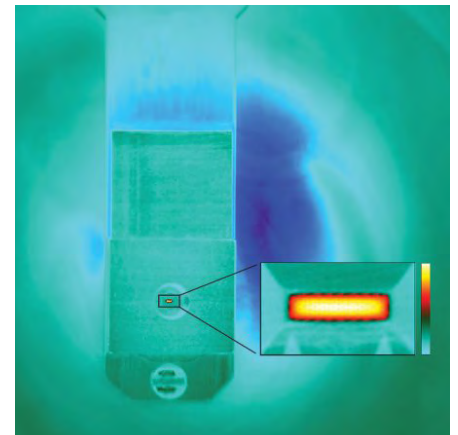
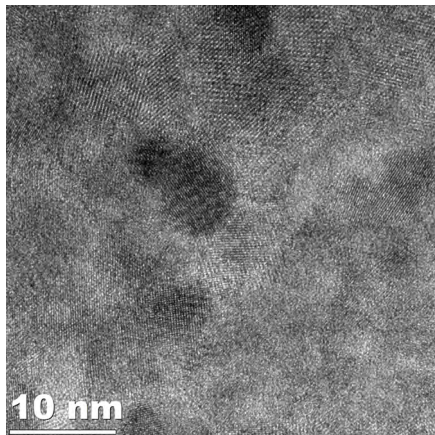
### Features

#### Heating

Our thin-film heating system for the gas holder discretely heats samples up to 800°C. Heating is controlled via a custom-designed control box featuring closed-loop temperature control and software that interfaces with a calibrated sensor on the chip.

**Right:** IR image of Gas Flow Tip during high-temperature heating cycle.

**Left:** TiN film on SiN substrate at 700C in ~1 atm nitrogen inside the Gas Cell TEM holder.



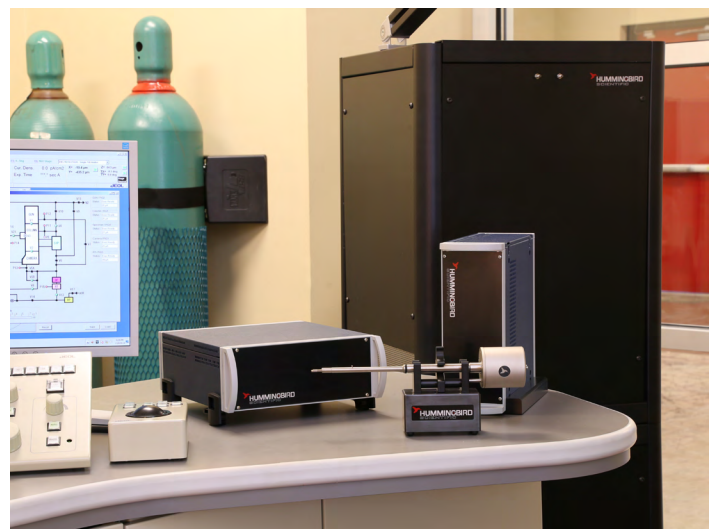
## Features

### Single-channel gas delivery system

Hummingbird's single-channel atmospheric gas delivery system delivers a single pressure-controlled experimental gas to the sample holder. This system, which comes with a built-in purging line for safe cleaning, operates at or just above atmospheric pressure inside the gas cell. The gas-control software allows users to operate in a pressure-controlled, closed-loop feedback mode, and it gives the user full electronic control of the system. The software is also capable of logging gas delivery parameters.

### Multi-channel gas delivery system

Hummingbird Scientific's multi-channel option is a fully configurable and scalable gas-delivery system designed to deliver multiple pressure-controlled gases to an environmental cell. It features up to eight gas channels that can be run independently or simultaneously in user-defined ratios. Like the single-channel delivery system, the multi-channel system has a built-in purging line for safe cleaning of the gas-flow path. It operates at a full range of sample pressures, from high vacuum ( $\approx 10^{-7}$  Torr) to above atmospheric pressure. In addition to the mixing capability, the system includes gas-control software & a built-in gas analyzer for post reaction analysis. When used in combination with Hummingbird Scientific's optional heating system and heating chips, the system also supports real-time observation of catalysis reactions in the TEM.



Hummingbird Scientific's gas-flow TEM holder comes with either a single-channel or multi-channel delivery systems.



### TEM Safety

Careful preparation of your samples and system are essential for effective use of environmental holders. A critical component of any holder system is a high-vacuum leak check station.

Our high-vacuum pumping station is a compact, all-in-one vacuum storage and seal-checking mechanism for TEM specimen holders. The station features short pumping and venting times, a low base pressure (10<sup>-6</sup>mbar), and a glass viewing port for the holder tip. The integrated stereo-microscope allows researchers to inspect and test the seal of a liquid or gas cell assembly before loading it into the TEM, crucial for protecting vacuum quality. A convenient, easy-to-use control-panel and a compact design make the check station a worthwhile addition to your electron microscopy laboratory.

### Available For

 TECNAI/TITAN/CMX00 SUPER TWIN, X-TWIN, ULTRA-TWIN

 HITACHI

 JEOL 2010/2100/ARM, HR/ARP POLE, URP/UHR POLE, GRAND ARM

 ZEISS

### Accessories

Accessories available for your gas-flow holder:

- Specialized Sample Substrate Chips
- Vacuum Tip Cover





## Product Summary



Our in-situ TEM gas cell specimen holder allows researchers to study material behavior in gases and at elevated temperatures, obtaining atomic resolution images of gas-solid interactions at real-world reaction temperatures and pressures. Gases are introduced to the microfabricated environmental cell via one of our optional dedicated gas delivery systems. Cell pressure is fully user-controlled and can be adjusted from high vacuum to above atmospheric pressure. Local specimen heating is provided via an integrated thin film heater with a temperature sensor calibrated for accurate readings. To ensure clean gas delivery, the entire holder can be baked at up to 160°C.

### Sample Applications:

- Gas catalysis
- Growth of nano-structures
- Fuel-cell research
- Atomic layer deposition

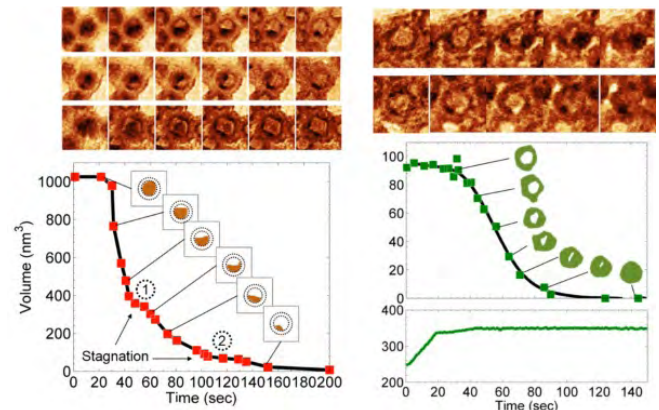
## Application Example

### Kirkendahl effect in Co nanoparticles

Researchers at the Lawrence Berkeley National Laboratory and Hummingbird Scientific have directly imaged the process of Co nanoparticle oxidation and reformation as Co is heated to 250°C and 350°C. The study shows the specific morphological changes that occur during these processes, shedding light on their governing mechanisms.

**Right:** Formation of hollow core oxide shells when Co nanoparticles are heated from 150°C to 250°C in 1 bar of flowing oxygen.

**Far Right:** Coalescence of the oxide shells when particles are heated from 250°C to 350°C.



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Reference: H.L. Xin, K. Niu, D.H. Alsem and H. Zheng. **"In-Situ TEM Study of Catalytic Nanoparticle Reactions in Atmospheric Pressure Gas Environment,"** Microscopy & Microanalysis 19 (2013) pp. 1558.

## Selected Publications

R Colby, DH Alsem, A Liyu, B Kabius **"A method for measuring the local gas pressure within a gas-flow stage in situ in the transmission electron microscope "** Ultramicroscopy, in review, 2015

D.H. Alsem, N.J. Salmon, R.R. Unocic, G.M. Veith, and K.L. More. **"In-situ liquid and gas transmission electron microscopy of nano-scale materials,"** Microscopy and Microanalysis 18:S2 (2012) pp. 1158-1159.

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