H2 sensors for LPC furnaces

A joint project between Air Liquide, Insplorion, SKF

Insplorion in short

Based in Gothenburg, Sweden. 16 FTE

Public company listed on Nasdaq First North

Founded as spinoff from Chalmers University in 2010

Core is Nano Plasmonic Sensing (NPS) Technology

Research Instruments

- Research instruments for measurements in gas or liquid
- More than 125 research articles published by our users

H_2 Sensors

- Fast & specific
- Flexible platform
- Optical readout
- Commercial prototype phase

Insplorion instrument business

Credibility and Technology validation

- Over 125 research articles published by our users

Know-how and knowledge generation

- Users in fields ranging from Hydrogen Sensing, Battery Research, Life Sciences and Cosmetics
- Key in-house tools to develop current and future applications (i.e. H2 sensing)

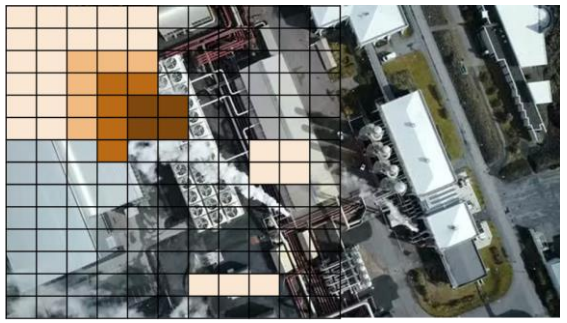
Maturing into industrial research applications

- Battery research focus
- First publication in cosmetic formulations

Insplorion Hydrogen sensing solutions

Insplorion NPS-P2

Insplorion M8



LPC furnaces

$$C_2H_{2(g)} \xrightarrow{Pyrolysis} 2C_{(s)} + H_{2(g)}$$

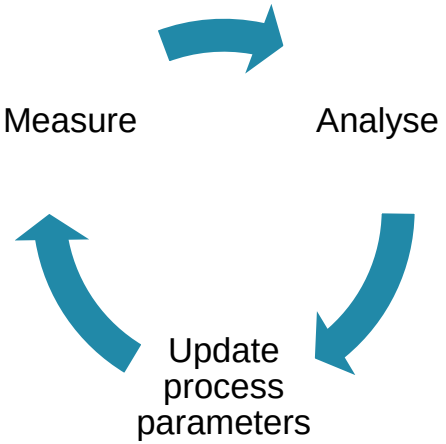
$$2NH_{3(g)} \xrightarrow{Pyrolysis} N_{2(g)} + 3H_{2(g)}$$

1000 °C, mbar pressure

Balance the amount of carbon

- Too much: soot formation
- Too little: incomplete treatment

Today each treatment is based on pre-determined recipes, limited insights of the actual status.



Established hydrogen sensor technologies

	Operation in absence of O2	High specificity H2	High sensitivity low concentrations	Operation at low pressure
Electrochemical sensor	No	No	Yes	No
Pellistor (catalytic) sensor	No	No	No	No
Thermal conductivity sensor	Yes	No	No	Yes

Present technologies are not ideal for online analysis

NPS sensor abilities

Highly specific to H_2
detects H_2, even in presence of other gases

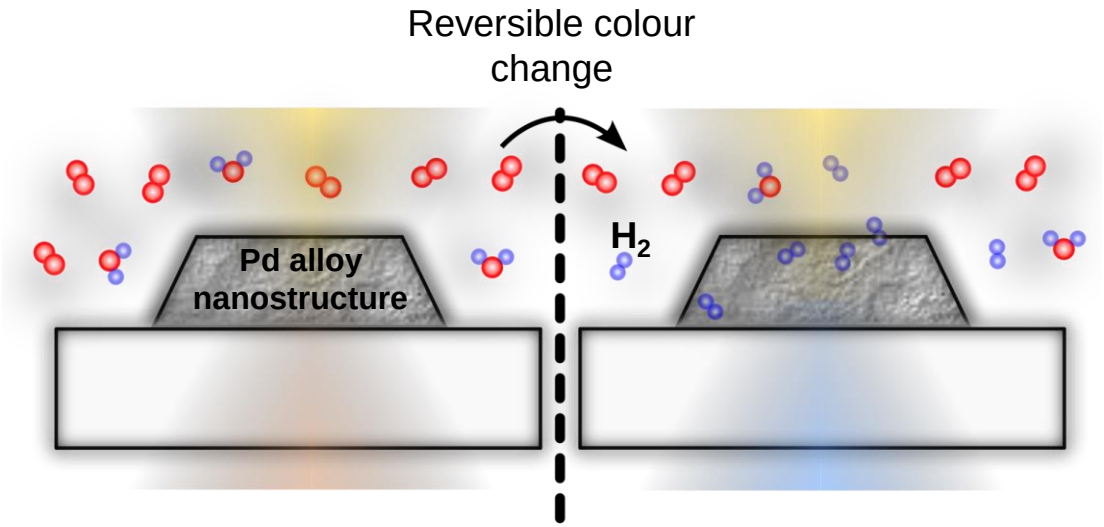
Fast response
enables quick action

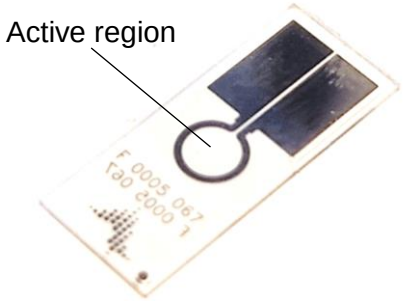
Low O_2 environments
applicable in low oxygen environments

Optical readout
sensor can be separated from electronics

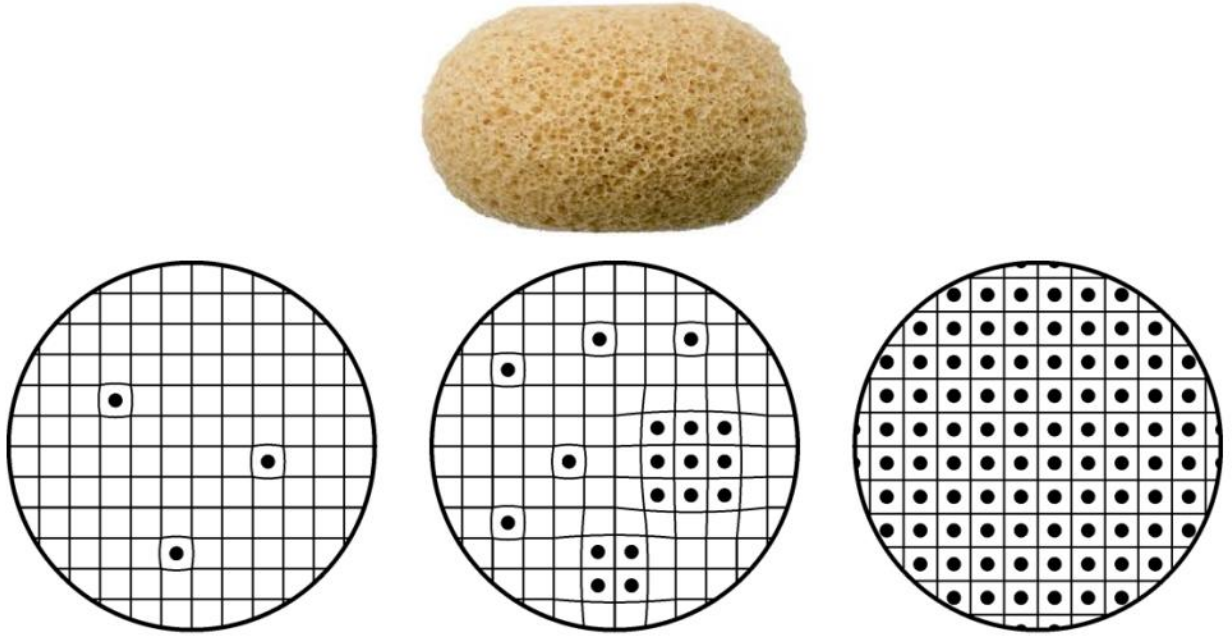
Flexible - can be adapted to different sensor needs and environments

NPS sensing technology



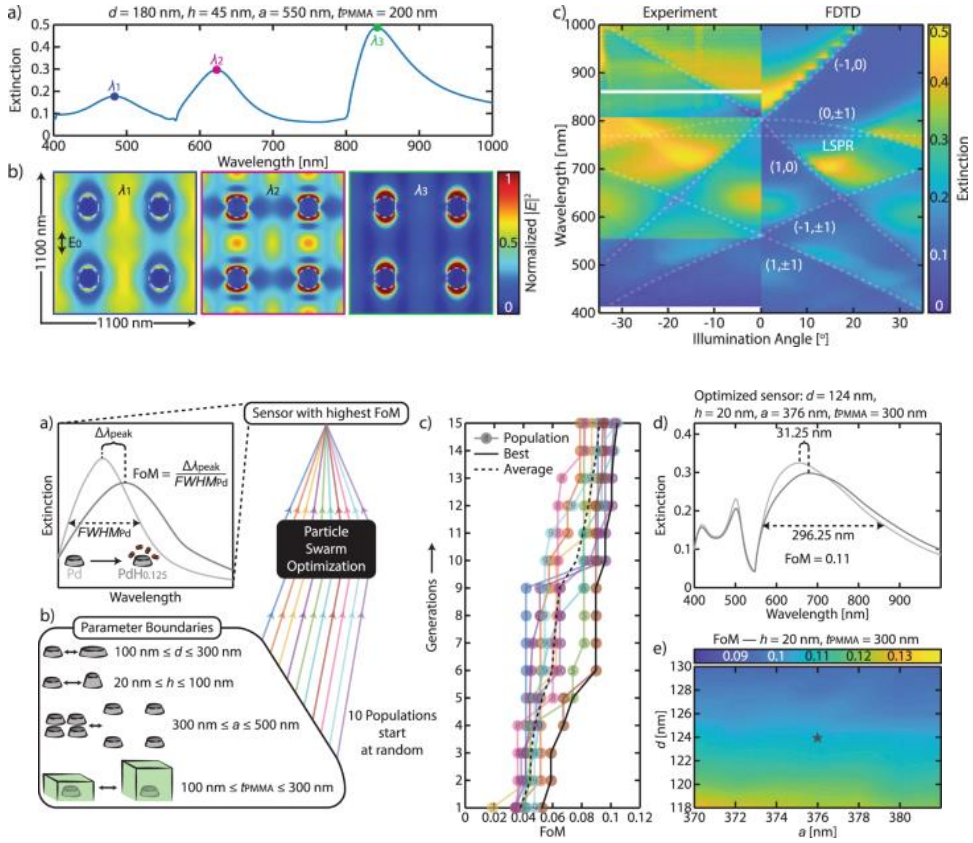


- Optical chemical transducer technology
- The sensor element consists of Pd-alloy nano discs on a transparent substrate
- Hydrogen is absorbed by the Pd nanostructures – concentration dependent colour change.



Research breakthroughs of NPS based H2 sensing

- ”Worlds fastest H2 sensor” (2019)
- H2 detection over 7 order of magnitudes in pressure (2021)
- Sub ppm H2 detection limit (2022)
- 3D printed plastic H2 sensor (2023)
- AI to enable operation in complex gas environments (2024)



Nugroho, Ferry AA, et al. "Metal–polymer hybrid nanomaterials for plasmonic ultrafast hydrogen detection." *Nature materials* 18.5 (2019): 489-495
Bannenberg, Lars, Herman Schreuders, and Bernard Dam. "Tantalum-palladium: hysteresis-free optical hydrogen sensor over 7 orders of magnitude in pressure with sub-second response." *Advanced Functional Materials* 31.16 (2021): 2010483
Nugroho, Ferry Anggoro Ardy, et al. "Inverse designed plasmonic metasurface with parts per billion optical hydrogen detection." *Nature Communications* 13.1 (2022): 5737
Darmadi, Iwan, et al. "Bulk-processed plasmonic plastic nanocomposite materials for optical hydrogen detection." *Accounts of chemical research* 56.13 (2023): 1850-1861.
Tomeček, David, et al. "Neural network enabled nanoplasmonic hydrogen sensors with 100 ppm limit of detection in humid air." *Nature Communications* 15.1 (2024): 1208.

Project scope

Audit/control tool for LPC (Low Pressure Carburizing) furnaces

Validate Insplorion NPS H2 sensor technology for LPC furnace application

- Custom prototype detector system
- Laboratory test at Insplorion
- Field tests at SKF

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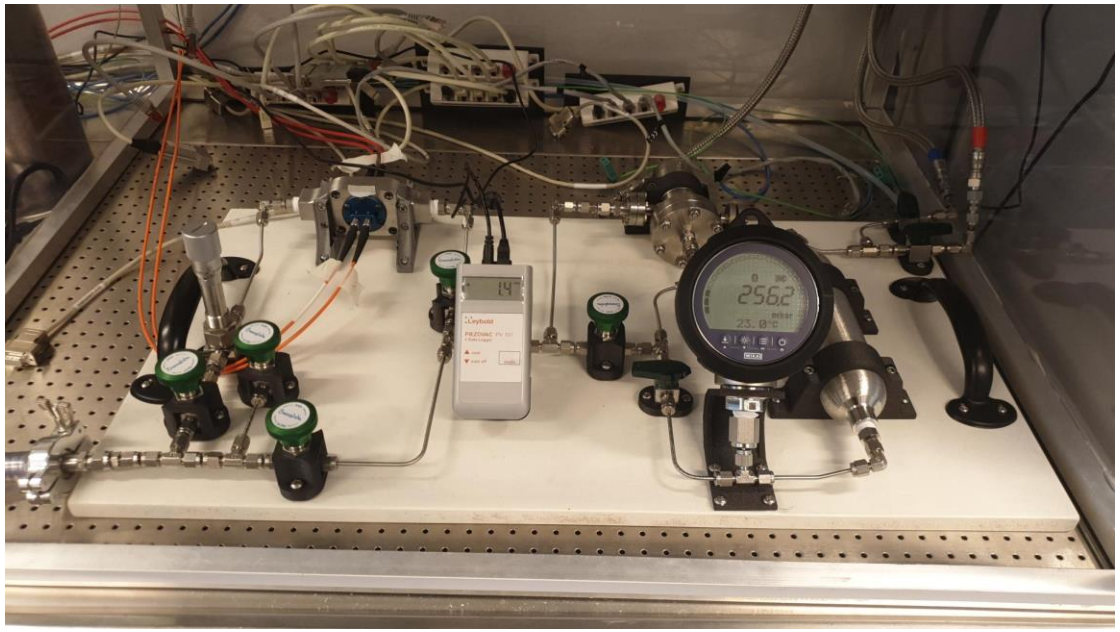
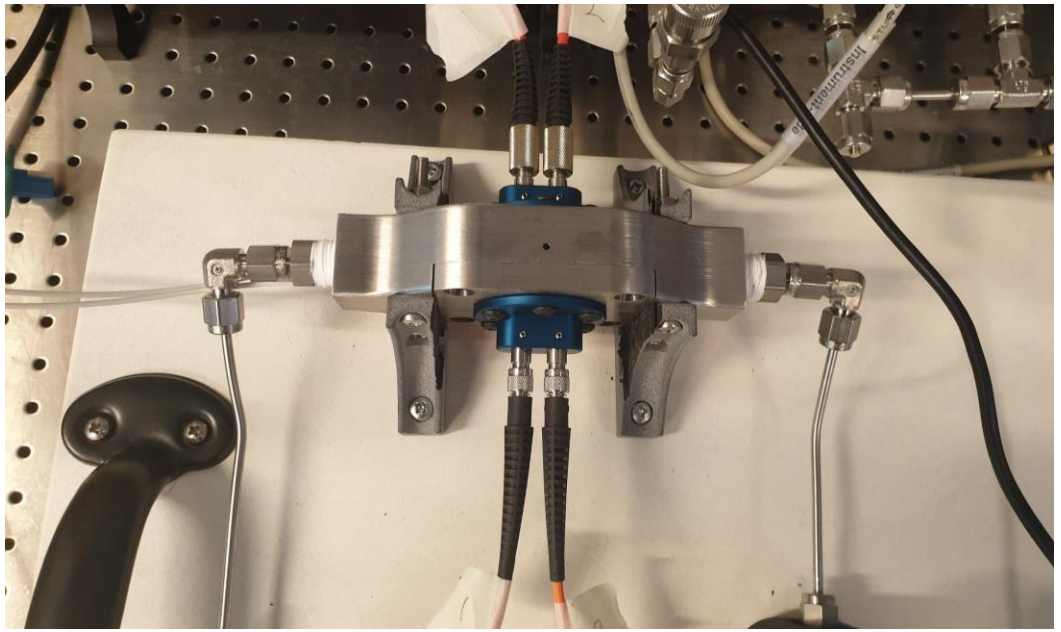
Measurement setup



Measurement setup

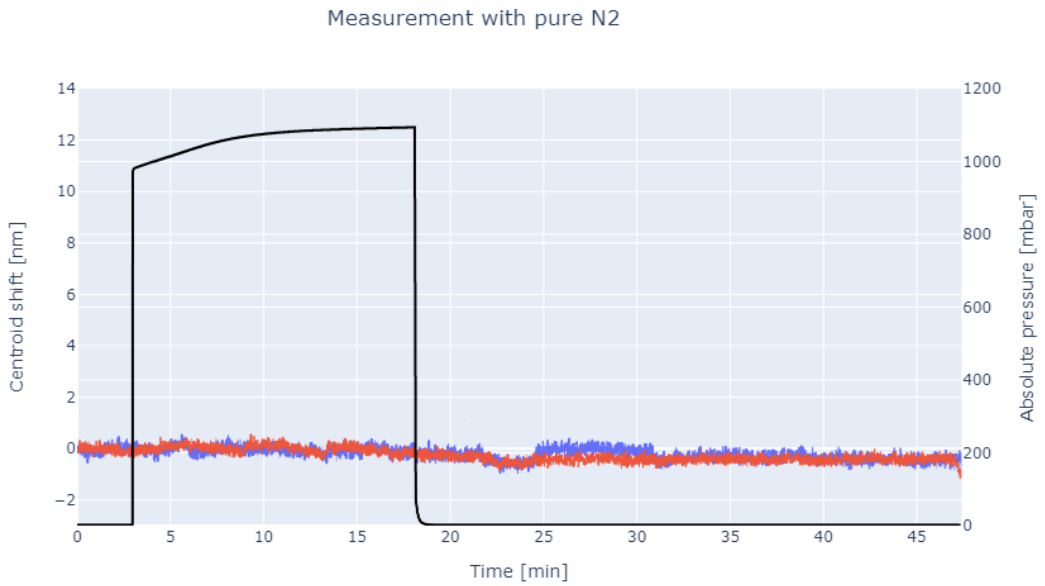


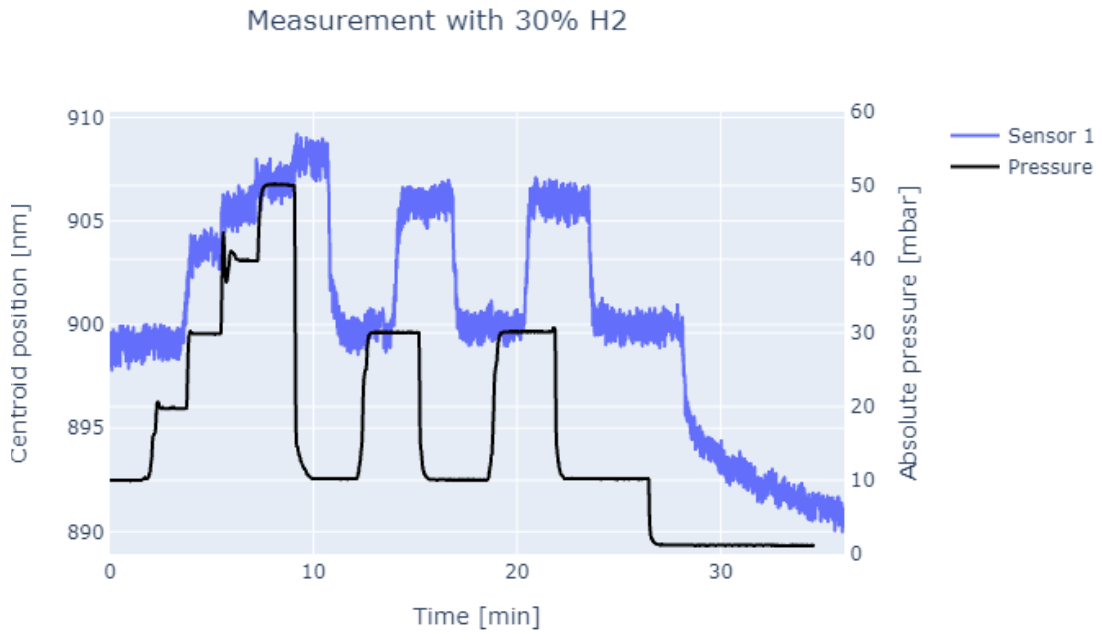
Insplorion H2 measurement cell

- Absolute pressure: 5 – 40 mbar
- Hydrogen concentration: 40 – 60 %
- Carrier gas: Nitrogen

Replication of measurement conditions

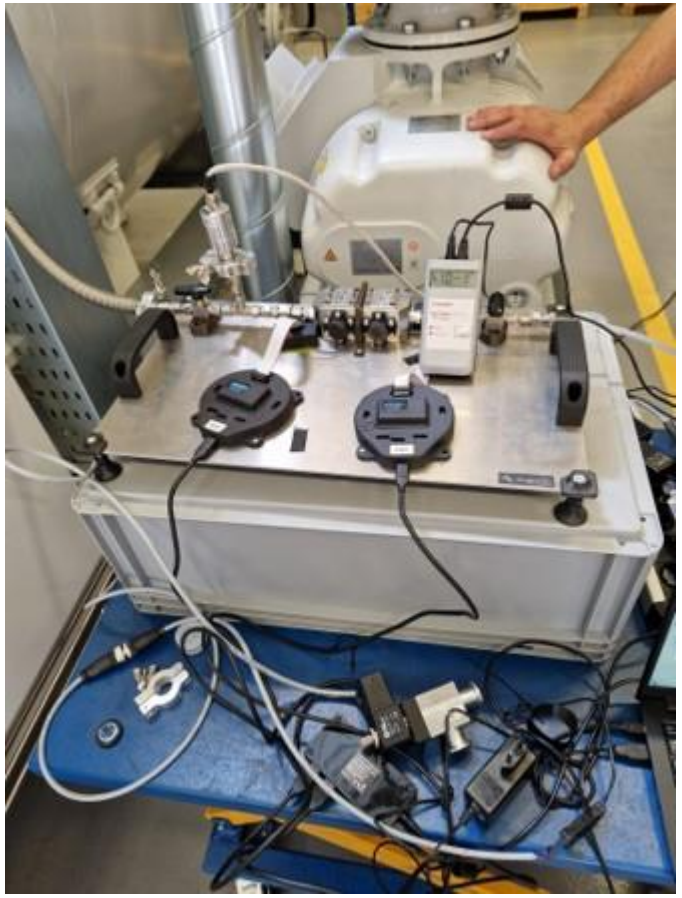
- ✓ No sensor influence from N2
- ✓ Fast detection, 5 s response time
- ✓ Partial pressure H2 directly proportional to the sensor output

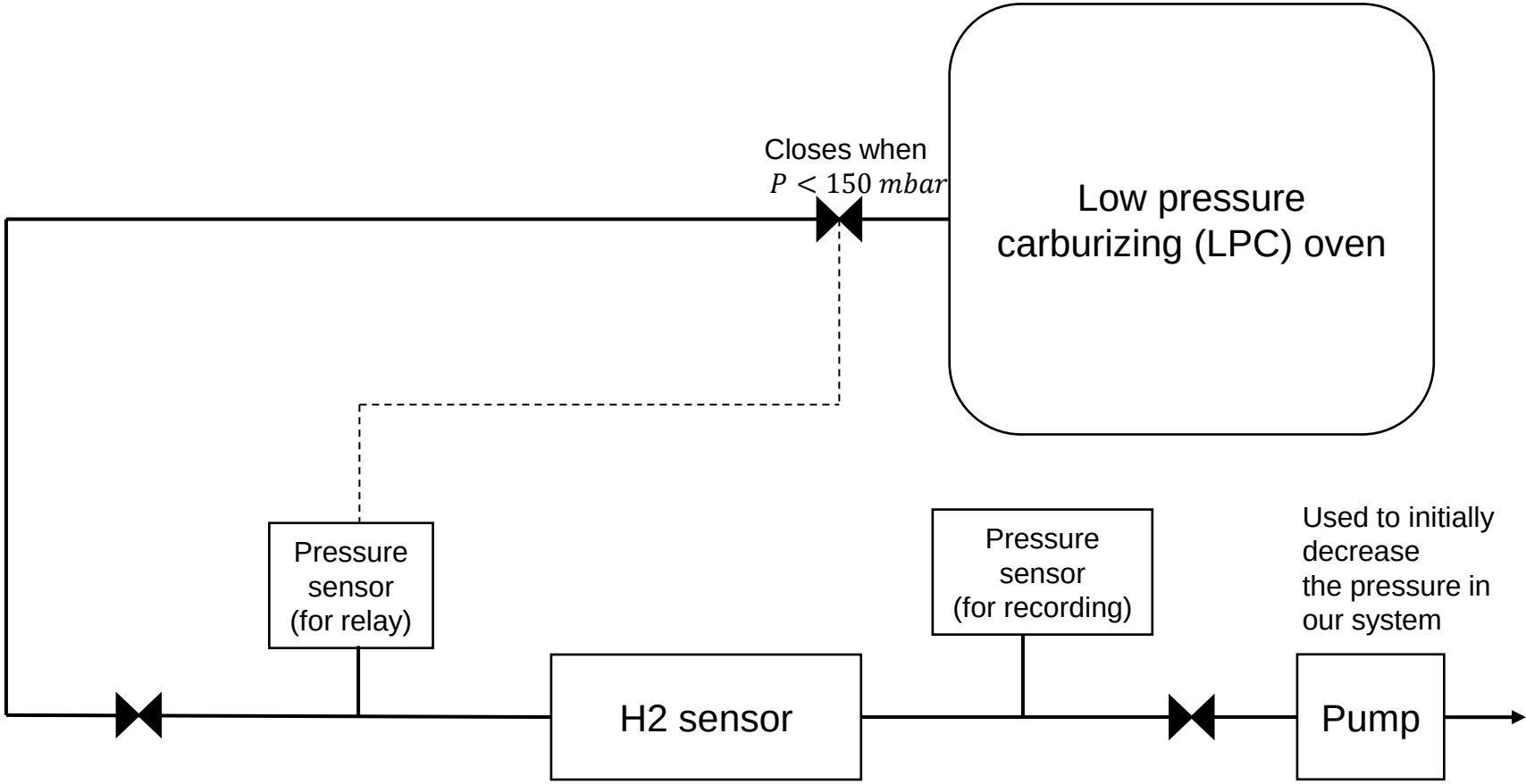




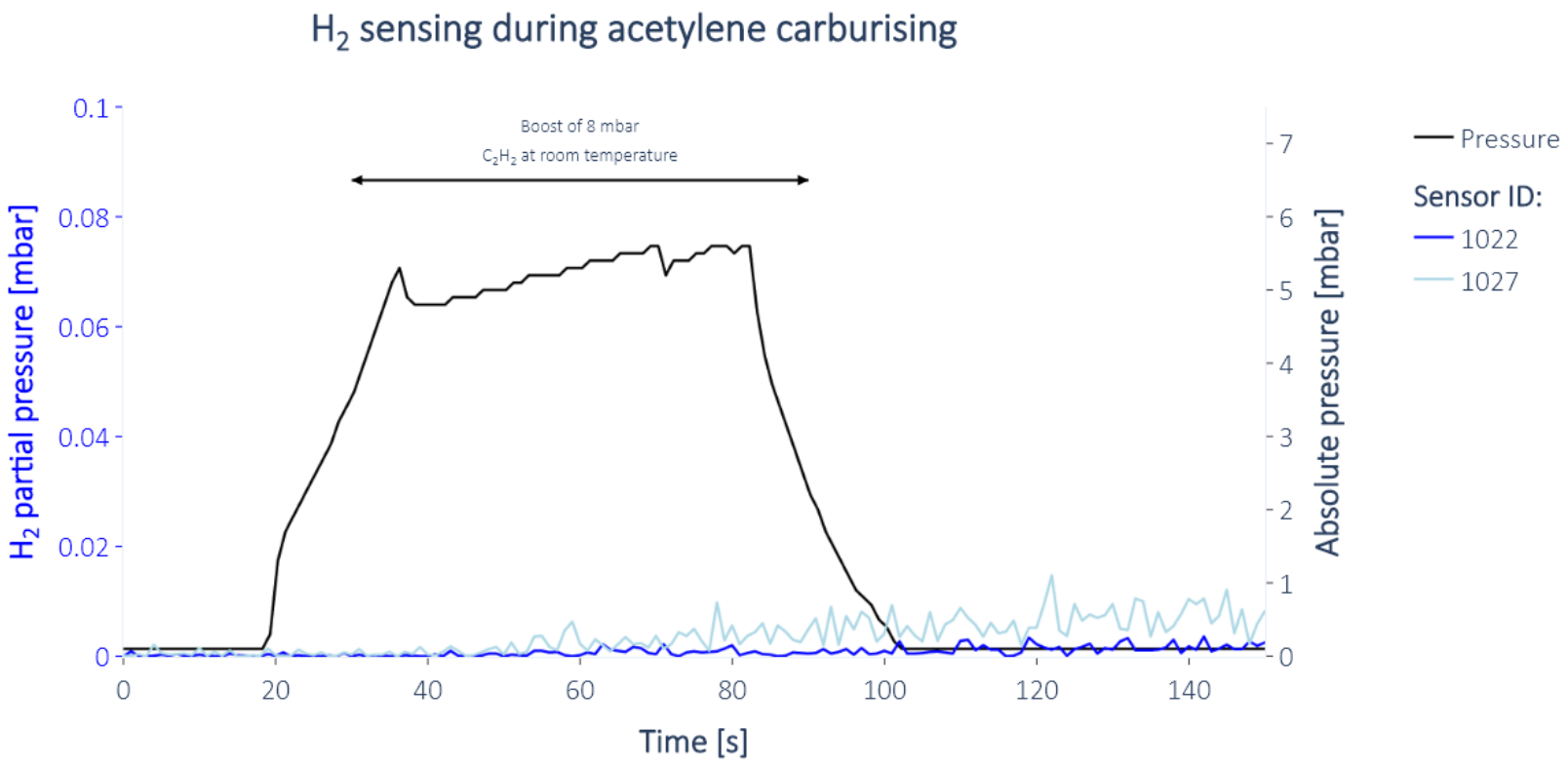
30 % H2 in varying absolute pressure 0-50 mbar

Installation in LPC furnace at SKF



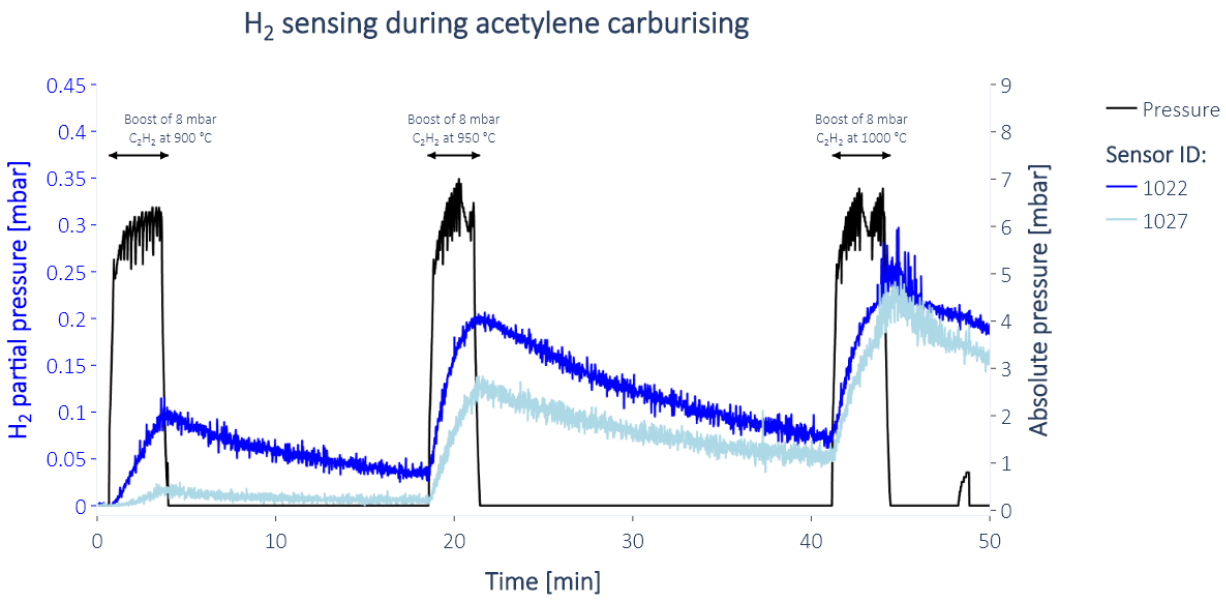


Cold run with acetylene

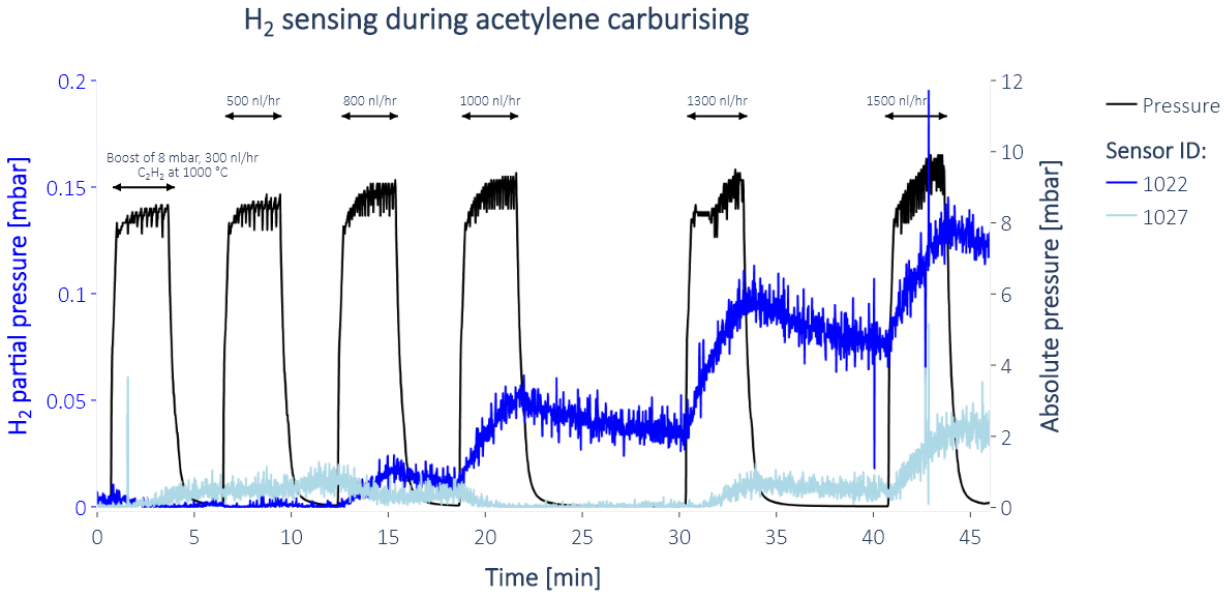


✓ No influence on sensor from acetylene

Acetylene boosts



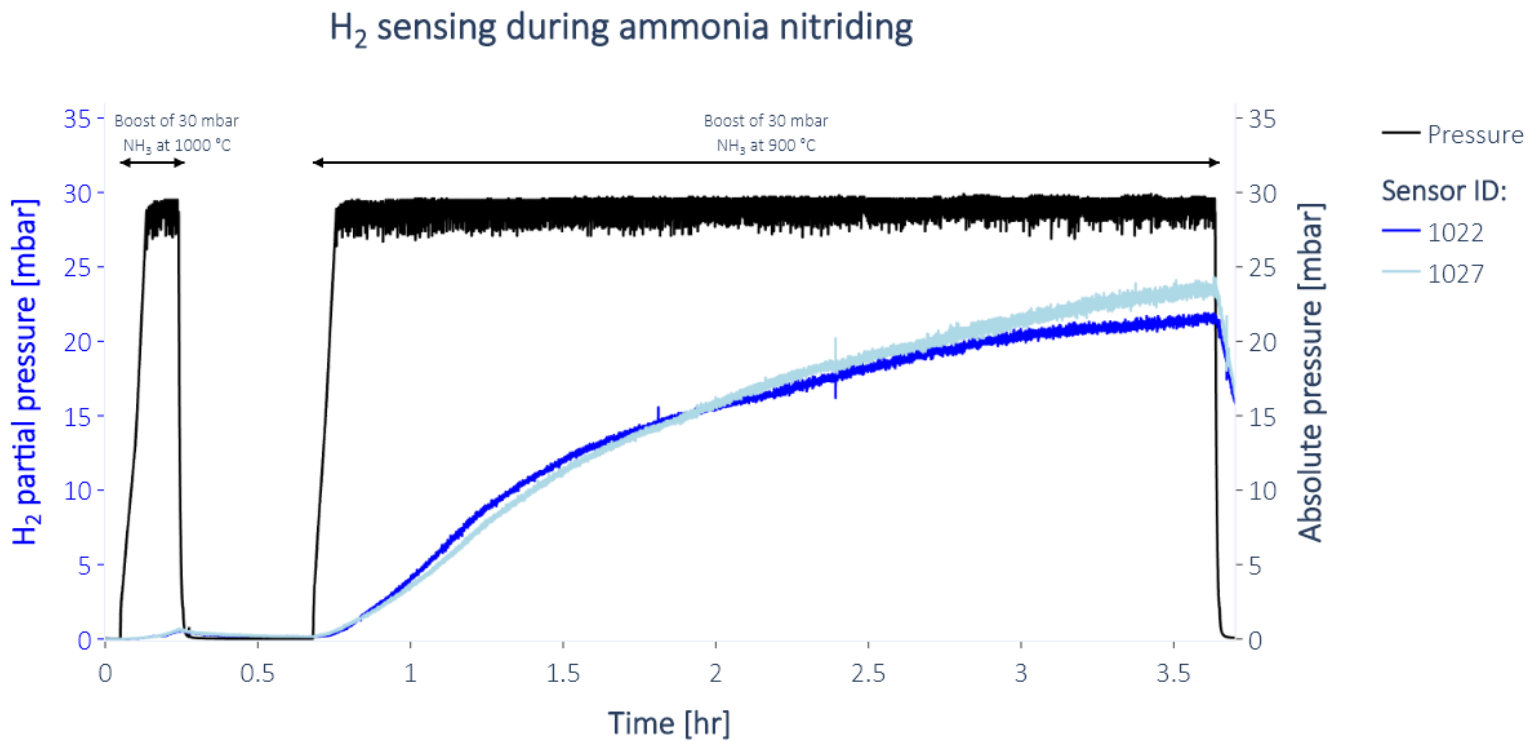
Varying oven temperatures



Varying injection rates

✓Specific monitoring of H2

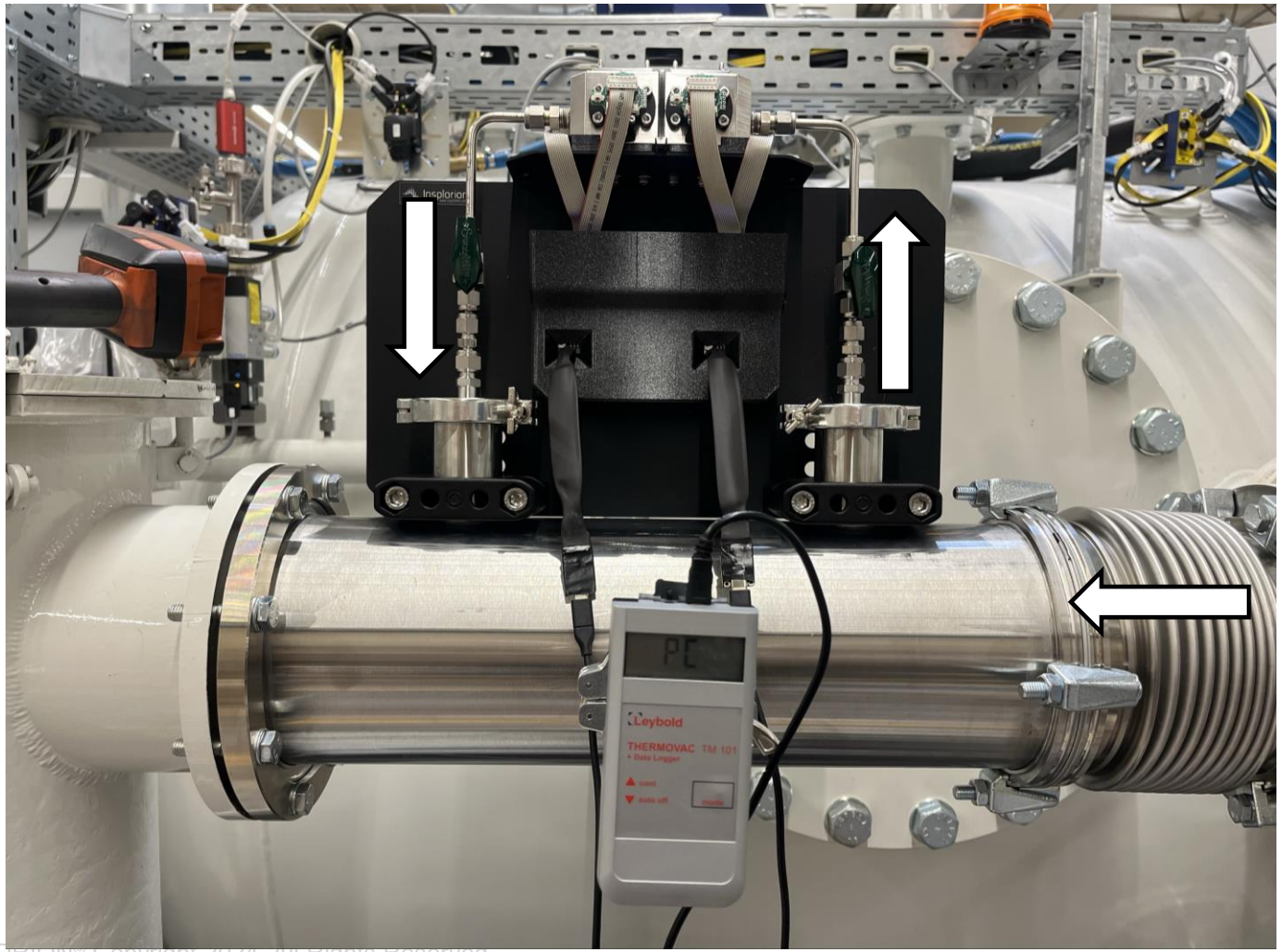
Ammonia boosts



✓ Very low influence from ammonia (< 0.2 %)
✓ Indication of 20-25 mbar H2 (theoretical value 22.5 mbar)

Sensor installation of exhaust

H2 sensor



Exhaust

Summary/Outlook

NPS applicability in LPC furnace environments:
- Low pressure
- Inert environments
- Low H2 concentrations
- Fast H2 detection

Other carburizing applications in progress

Further miniaturisation of sensor system

Applications in mind:
- Audit control system
- On-line detection fixed

Insplorion

Thank you for your attention

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