Sensors – key component for safe and efficient use of hydrogen

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Insplorion in short

Based in Gothenburg, Sweden. 13 FTE 01

Public company listed on Nasdaq First North 02

Founded as spinoff from Chalmers University in 2010 03

Core is Nano Plasmonic Sensing (NPS) Technology 04

Research Instruments

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

H_2 Sensors

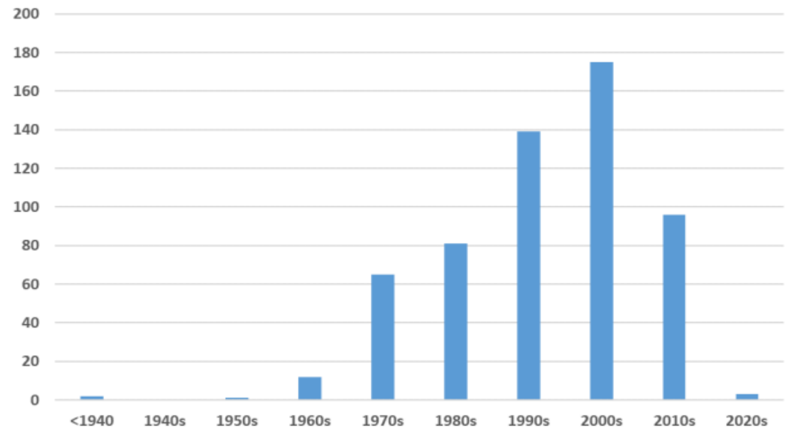
- Fast & specific
- Flexible platform
- Optical readout
- Commercial prototype phase

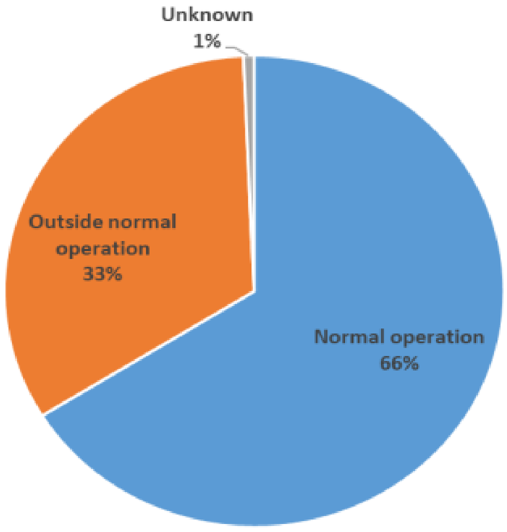
Hydrogen properties: A comparison

	Hydrogen Gas	Natural Gas	Gasoline
Toxicity	None	Some	High
Odor	Odorless	Yes (mercaptan)	Yes (benzene)
Buoyancy *Relative to **Air***	14X Lighter	2X Lighter	Vapor is 3.75X Heavier
Flammable Range by volume in air	4-75%	5-15%	1.4-7.6%
Autoignition Temperature (C)	585°	539°	232°
Minimum Ignition Energy (mJ)	0.017	0.288	0.250-0.300
Energy by Weight	2.8X > Gasoline	~1.2X > Gasoline	43 MJ/kg
Energy by Volume	4X < Gasoline	1.5X < Gasoline	120 MJ/Gallon

https://eec.ky.gov/Energy/Documents/Slides-Nick%20Barilo.pdf

Hydrogen incidents





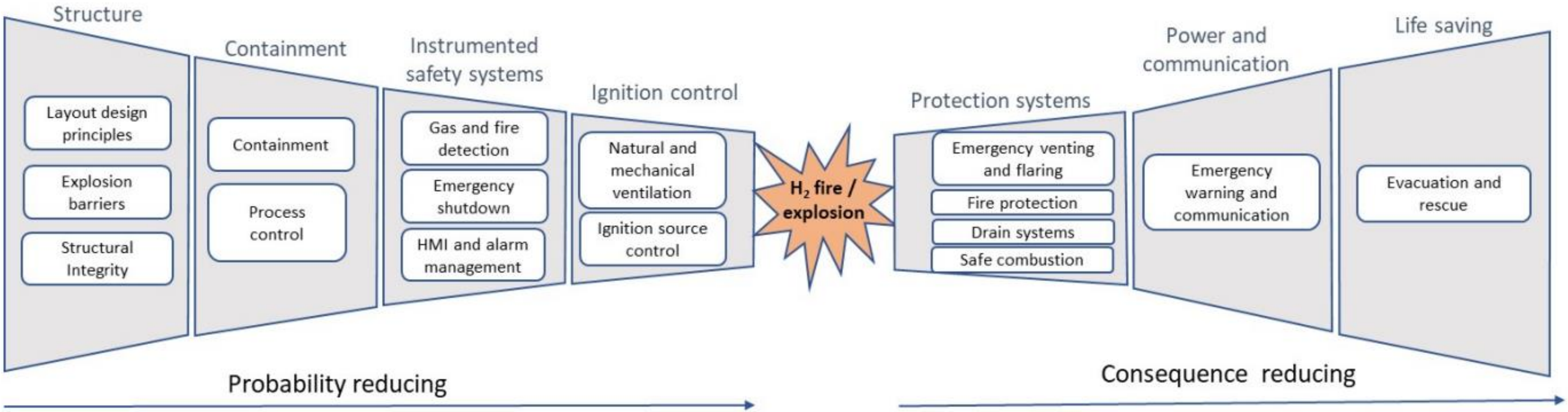
Lessons learned from previous incidents

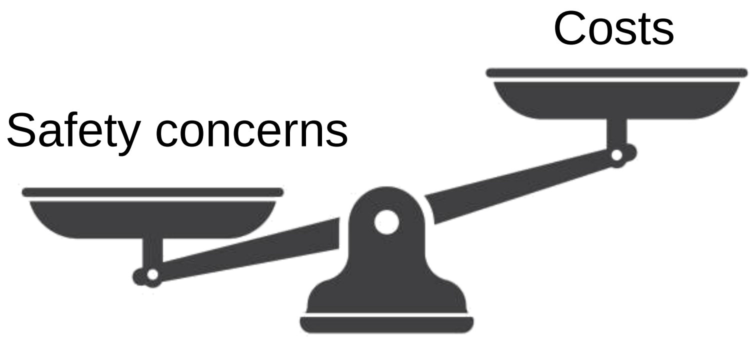
- Leakages the major cause for hydrogen related incidents
- The amount of gas leakage is underestimated by 60 % [1, 2]
- Aging of components will increase leakage

Source: Center of Hydrogen Safety 2019 Conference, NASA, WSTF | Data source: Factory Mutual

Statistics, lessons learnt and recommendations from the analysis of HIAD 2.0 database (2022)
Alvarez, Ramón A., et al. "Assessment of methane emissions from the US oil and gas supply chain." *Science* 361.6398 (2018): 186-188.
Lauvaux, Thomas, et al. "Global assessment of oil and gas methane ultra-emitters." *Science* 375.6580 (2022): 557-561.

Hydrogen specific requirements to safety barriers





Ref: Samdal, U. N., et al. "Hydrogen Safety Strategies and Risk Management in Equinor." (2021).

Need for H_2 Sensors

Safety
Accidents mean physical damage, to property and potentially human lives, financial damage, and setbacks in public perception.

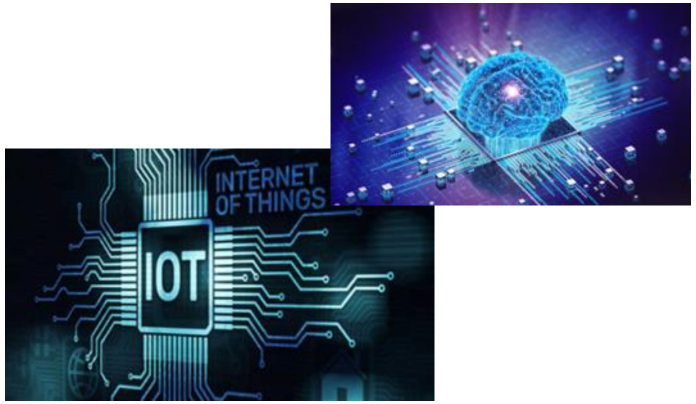
Efficiency
Downtime and yield has direct effect on profitability.

Gas detection development

Catalytic

Electrochemical

TCD



1900 ~ 1950 2000 2020

Detection solutions

Leak detection tapes (passive)

Point detectors

Portable devices

Ultrasonic detectors

Flame detectors

New gas detection needs in the H2 industry




New industries are demanding:

- Increased safety concern
- Maximization operation efficiency
- Low weight
- Limited space
- Minimize impact on operating costs

New sensing needs

- Actual **real-time** data
- Limit any **false responses**
- Detection in **confined spaces**
- Operation in **complex gas environments**
- Autonomous operation, minimize **calibration**

State of the art H2 sensors

	Traditional sensors		
Sensor technologies / Technical performance	Electro-chemical	Catalytic	TCD
Response time, t_{90}	20 s	10-30 s	5 s
O_2 requirements	> 10 vol%	> 10 vol%	None
H_2 limit range	2 vol%	5 vol%	100 vol%
Specificity H2	Low	Low	Low
Recalibration routines	6-12 months	6-12 months	12-24 months
Lifetime	1-3 years	2-5 years	2-5 years

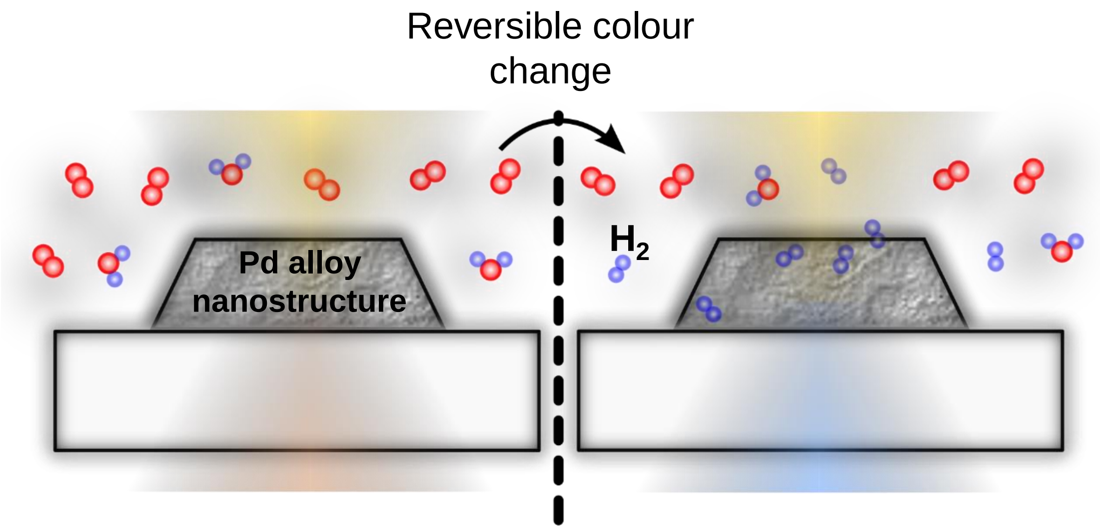
State of the art H2 sensors

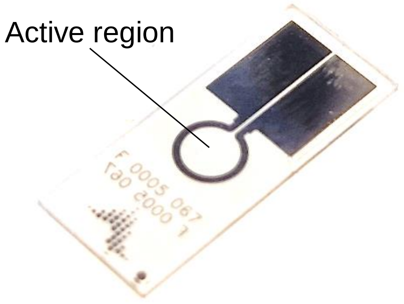
	Traditional sensors			Emerging solutions	
Sensor technologies / Technical performance	Electro-chemical	Catalytic	TCD	MPS	Pd thin film
Response time, t_{90}	20 s	10-30 s	5 s	20 s	30 s
O_2 requirements	> 10 vol%	> 10 vol%	None	> 15 vol%	None
H_2 limit range	2 vol%	5 vol%	100 vol%	4 vol%	100 vol%
Specificity H2	Low	Low	Low	Low	High
Recalibration routines	6-12 months	6-12 months	12-24 months	None	None
Lifetime	1-3 years	2-5 years	2-5 years	> 5 years	> 5 years

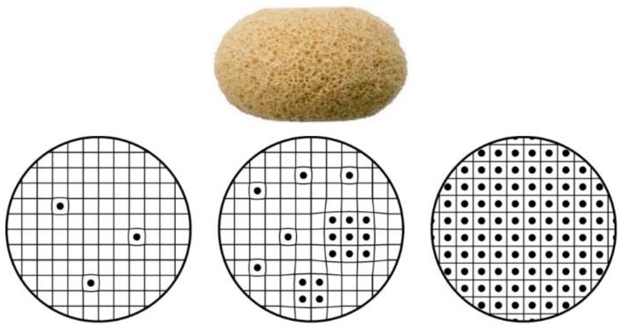
State of the art H2 sensors

	Traditional sensors			Emerging solutions		
Sensor technologies / Technical performance	Electro-chemical	Catalytic	TCD	MPS	Pd thin film	Insplorion NPS
Response time, t_{90}	20 s	10-30 s	5 s	20 s	30 s	1 s
O_2 requirements	> 10 vol%	> 10 vol%	None	> 15 vol%	None	None
H_2 limit range	2 vol%	5 vol%	100 vol%	4 vol%	100 vol%	100 vol%
Specificity H2	Low	Low	Low	Low	High	High
Recalibration routines	6-12 months	6-12 months	12-24 months	None	None	None (target)
Lifetime	1-3 years	2-5 years	2-5 years	> 5 years	> 5 years	10 years (target)

Insplorion NPS sensor technology







Highly specific to H_2 - detects H_2 in presence of other gases

Fast response - enables quick action

Low oxygen environments

Able to measure in reduced oxygen environments

Optical readout - sensor can be separated from electronics

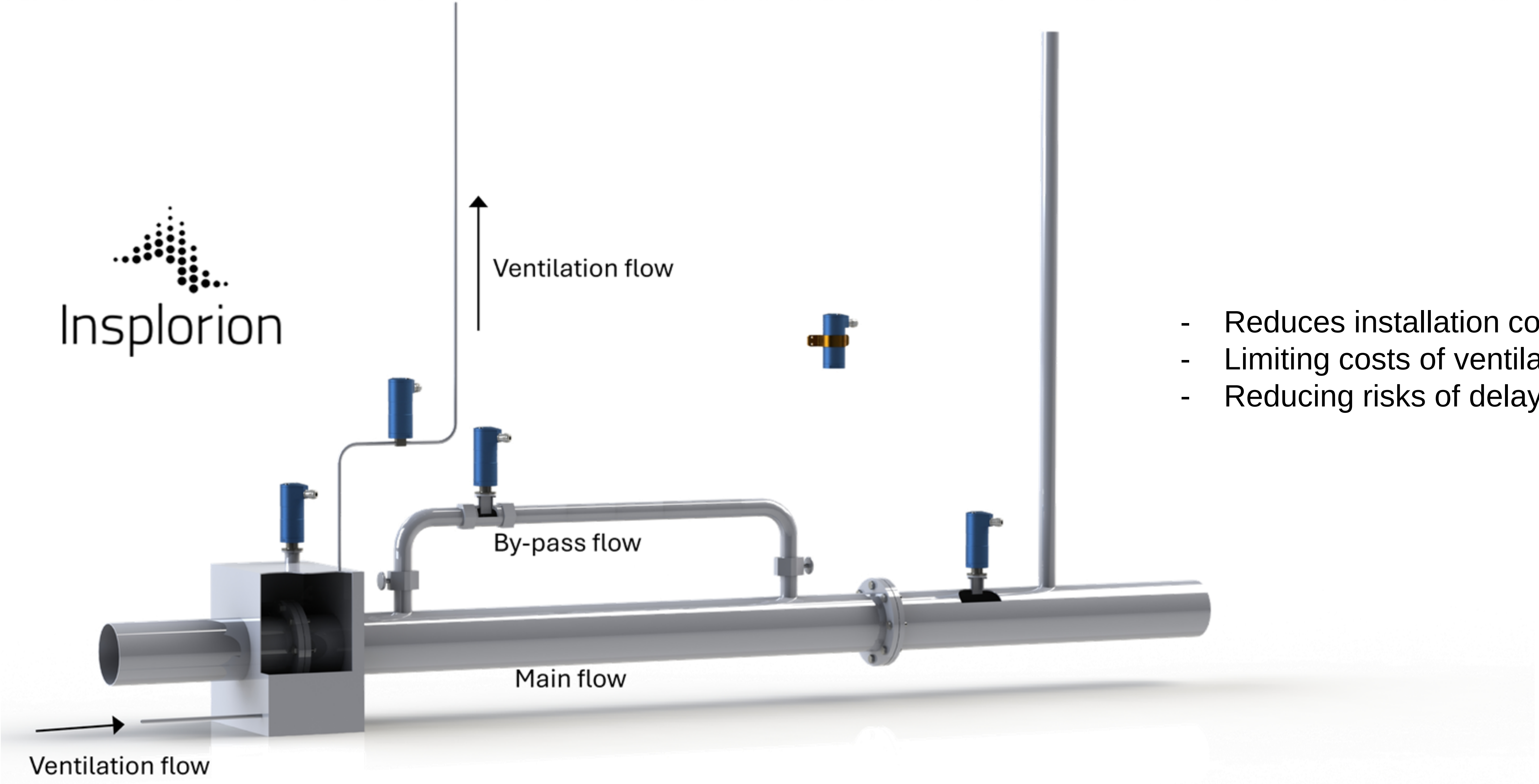
Sensor manufacture

Insplorion NPS-P2 hydrogen detector

Primary applications:
- Confined spaces
- Inerted systems
- Ambient air

Offering:
- Fixed detection by diffusion/in-line sampling
- Ultrafast detection of leakages
- Small form factor

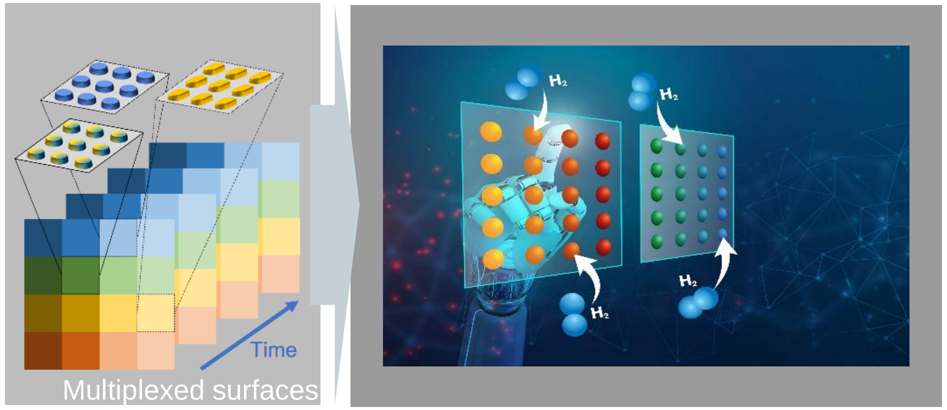
Enable safe and efficient usage of hydrogen



- Reduces installation complexity
- Limiting costs of ventilation
- Reducing risks of delayed actions

Research in 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)
- Accelerated H2 sensing by 40 times (2024)
- AI to enable operation in complex gas environments (2024)



Tech4H2

CHALMERS

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.
Martvall, Viktor, et al. "Accelerating Plasmonic Hydrogen Sensors for Inert Gas Environments by Transformer-Based Deep Learning." *arXiv preprint arXiv:2312.15372* (2023).
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.

Co-development projects

Hydra Specma

<u>H2 detection for processes</u>
- In-line detection

SAAB

<u>H2 detection of aircrafts</u>
- Remote and multiple detection
- Minimizing weight
- Integration in confined areas

Insplorion strategy – commercial roll-out

Provides prototype detectors for system design, validation and pilot projects

- Leak detection/safety
- Process monitoring

Launch ATEX certified leak detector (NPS-P2) in 2025

Partnerships for

- Commercial rollout of NPS-P2
- Co-development for specific segments/applications

Insplorion

Thank you for your attention

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