Sicherheit in Technik und Chemie

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MEASUREMENT AND TESTING METHODS FOR SENSORS IN HYDROGEN TECHNOLOGIES

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www.bam.de

Self Introduction

2000 to 2006	Studying Chemistry, Focus: Analytic
2006 to 2010	PhD Thesis, BAM and TU Ilmenau (Dep. Chemistry)
2010 to 2016	Post Doc at BAM
2016	Certification for Quality Management and Auditor
2017	Scientist at BAM and Test Laboratory for Gas and Humidity Sensors
2020	Member of Competence Center H2Safety@BAM for safe hydrogen technologies

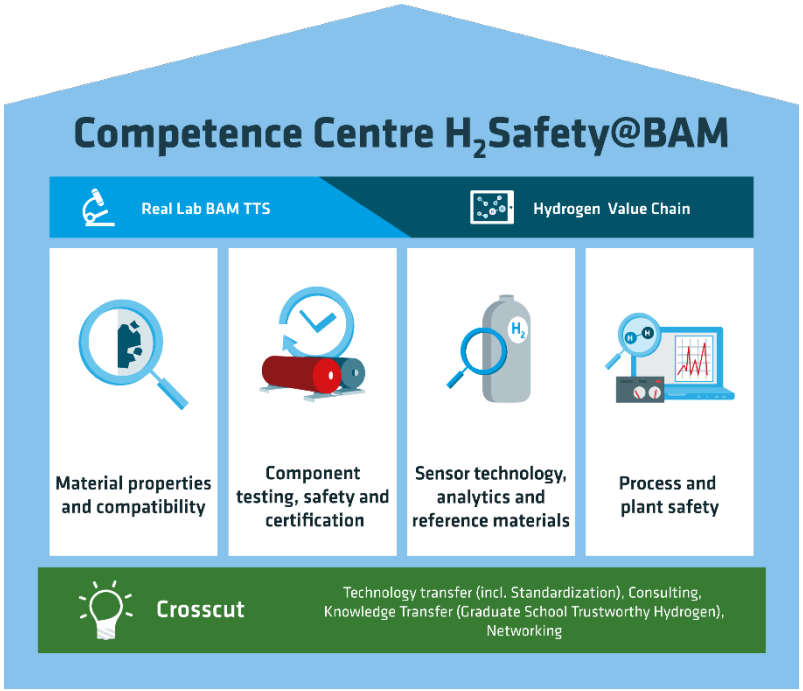
Hydrogen – our contribution to safety

Competence Center
H_2Safety@BAM

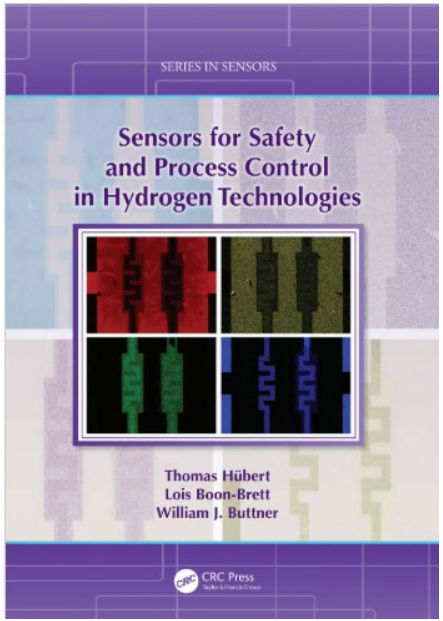
URL

https://www.bam.de/Content/EN/Standard-Articles/Topics/Energy/Hydrogen/hydrogen.html

Building trust in the energy carriers of the future!



Hydrogen – our contribution to safety (SensRef)

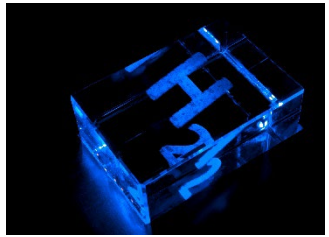


T. Hübert (BAM), L. Boon-Brett (JRC), W. J. Buttner (NREL) Sensors for Safety and Process Control in Hydrogen Technologies, **2016**, 1st Edition, CRC Press, https://doi.org/10.1201/b19141.

- Sensors provide information on gas composition, which is essential for safety and process control
- Authors: T. Hübert (BAM), L. Boon-Brett (JRC), W. J. Buttner (NREL) with contributions of E. Weidner (JRC), V. Palmisano (JRC), U. Schmidtchen (BAM), B. Fellmuth (PTB)
- H2Safety@BAM https://www.bam.de/Navigation/EN/Topics/Energy/Hydrogen/hydrogen.html

Hydrogen

Attribute	Specific information
Hydrogen	H_2
CAS No.	1333-74-0 EU: REACH | DE: GefStoffV
Substance group	inorganic gas
Properties	colourless, odourless (compressed) gas, liquid at specific conditions
Chemical characterisation	



BAM Medienteam, 13D4-13.jpg

Tasks for Sensors in Hydrogen Technologies

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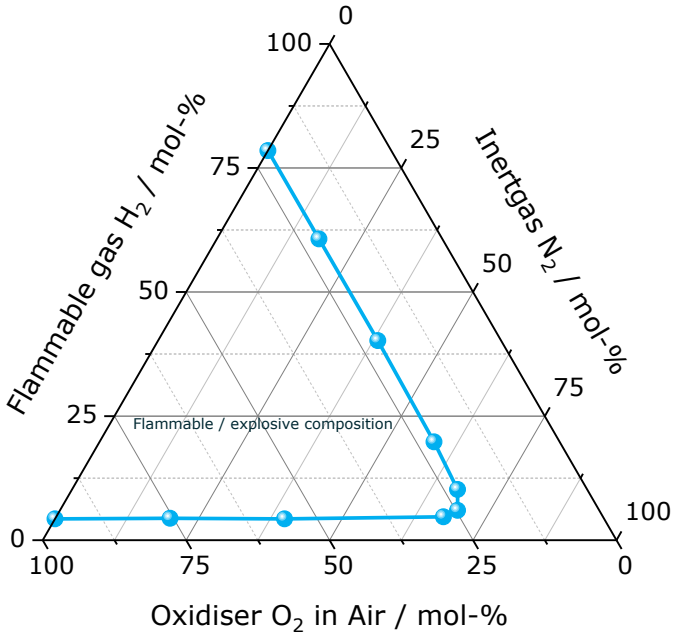
Safe use of Hydrogen

Specific safety issues in air

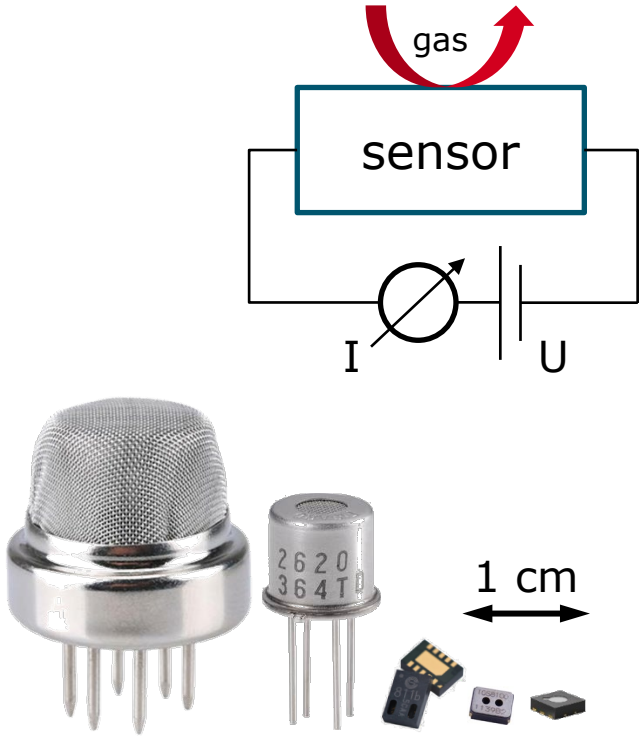
- Dependency of pressure on lower (**LEL**) and upper explosion limit (**UEL**)



M. Molnárné, T. Schendler, V. Schröder, in Sicherheitstechnische Kenngrößen, Vol. 2, Wirtschaftsverlag NW, Bremerhaven, 2008, pp. 1-539.
Data available on: https://www.chemsafe.ptb.de/home

What is a gas sensor?

A **gas sensor** is a technical component that can record certain physical or chemical properties (temperature, pressure, material properties qualitatively or quantitatively as a measured variable). These quantities are measured by means of physical or chemical effects and converted into quantities that can be processed further (usually electrical signals).

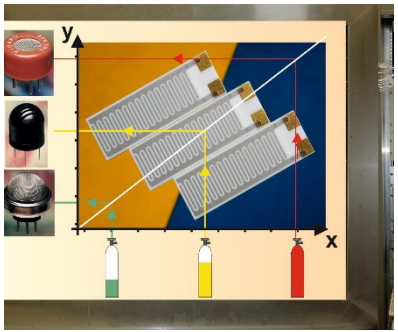


Different gas and humidity sensors compiled by M. Hofmann, 2019.

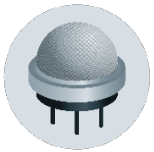
Tasks for Sensors in Hydrogen Technologies

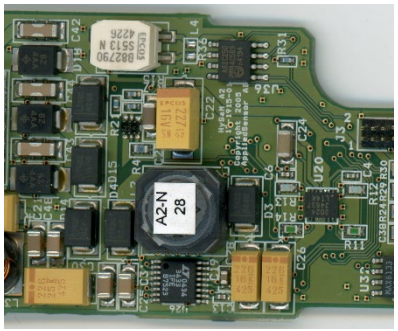
What?
- Safety protection
- Leak detection
- Process control

Why?
- Indicate a hazardous condition
- Provide warnings or alarms for out-of-limits conditions
- Monitor and control operation
- Provide performance data



Where?
- Hydrogen production
- Transport and disposal of hydrogen
- Infrastructure
- Energetic use of hydrogen
- Hydrogen used for non energetic reasons





Cost-effective and reliable hydrogen sensors for facilitating the safe use of hydrogen, https://cordis.europa.eu/project/id/325326/reporting.

Performance of gas sensors

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Definition

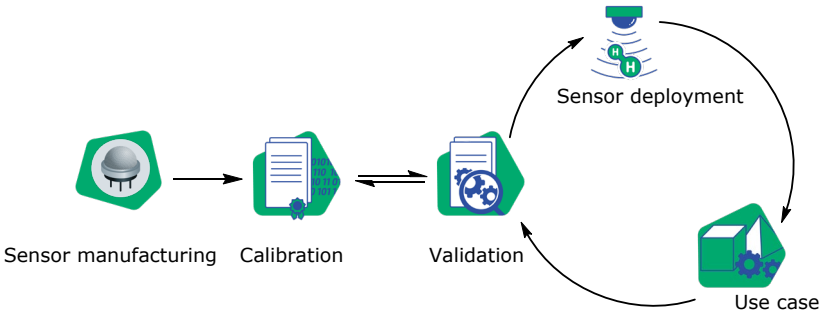
Definition [ISO 26142]	Description
Sensing element	performs the basic sensing operation and provides a meaurable, continously changing physical quanity in correlation to the stimulus, e. g. hydrogen concentration
Sensor	combination of one or more sensing elements together with electronic circuits
Detection Apparatus	higher-level system as a stand-alone instrument system, handheld device or a fixed site device

[ISO 26142:2010, Hydrogen detection apparatus — Stationary applications, https://www.iso.org/standard/52319.html]

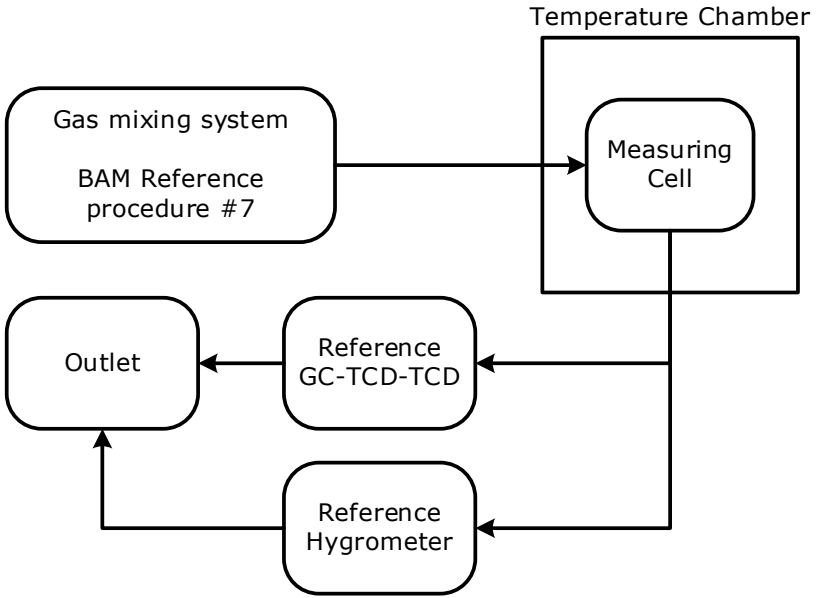
Quality Infrastructure for Sensor Testing

To ensure accurate results, it is advisable to conduct sensor testing under controlled conditions, focusing on identifying specific properties and quantifying performance criteria.

Produced devices undergo calibration with at the factory calibration or according to ISO/IEC 17025, followed by testing/validation prior to intended use. Subsequent inspections shall be repeated in appropriate intervals.



Volumetric preparation of gas mixtures for determining the characteristics of gas sensors



Dynamic preparation of gas mixtures

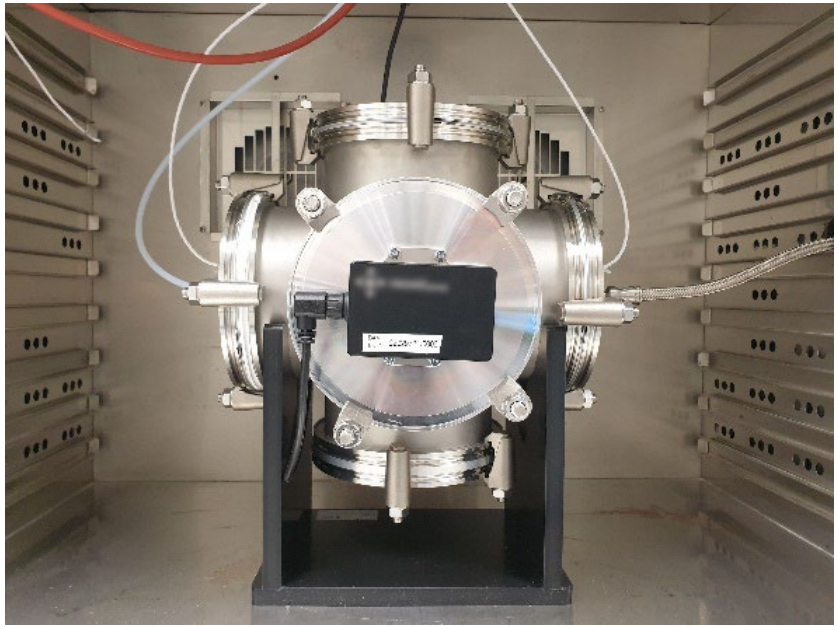
- For sensor testing for the determination of non-explosive gas mixture composition (in particular hydrogen-, ammonia-, methane-, sulfur dioxide and ethanol mixtures), response time and characteristic curves of gas sensors, gas measuring devices.
- Volumetric preparation of gas mixtures with defined humidification for determining the characteristics of gas sensors, LINK

Metrological Traceability of Quantification with Certified Reference Materials (CRM)

Production of CRM

Calibration Gas Example and Storage of Primary Gas Standards
https://webshop.bam.de/webshop_de/katalog-1.html

Test set up: Measuring Cell in Temperature Chamber equipped with Device under Test (DUT)



Measuring Cell
ISO-K Cross piece DN160
Volume V = 5.8 L

Gas Inlet: 6 mm stainless steel tube plus temperature sensor

DUT: Schottky Diode Sensor

Gas Outlet: 6 mm PTFE-tube plus temperature sensor

Results and discussion

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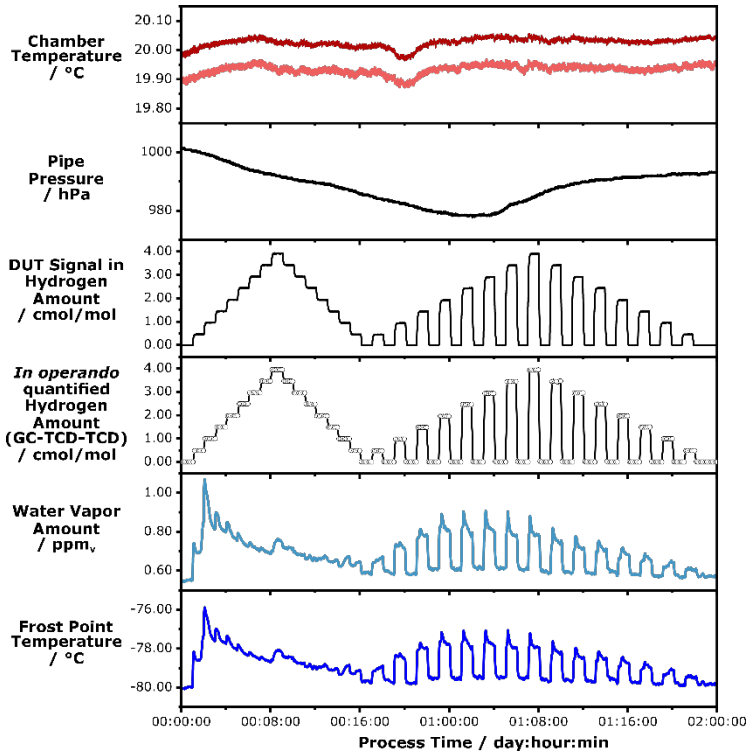
Time series of observed test data



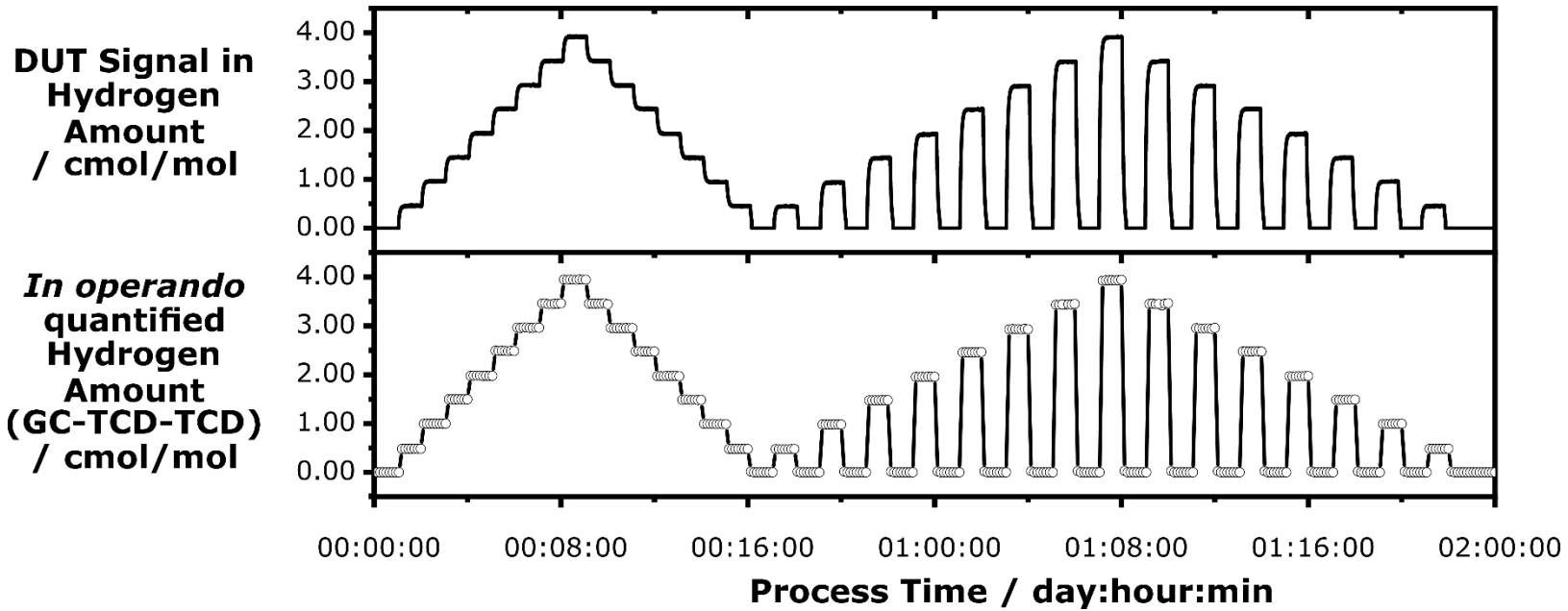
Test Temperature is in the range of 19.9 °C to 20.1 °C.

The test gas pressure is 0.98 bar to 1 bar.

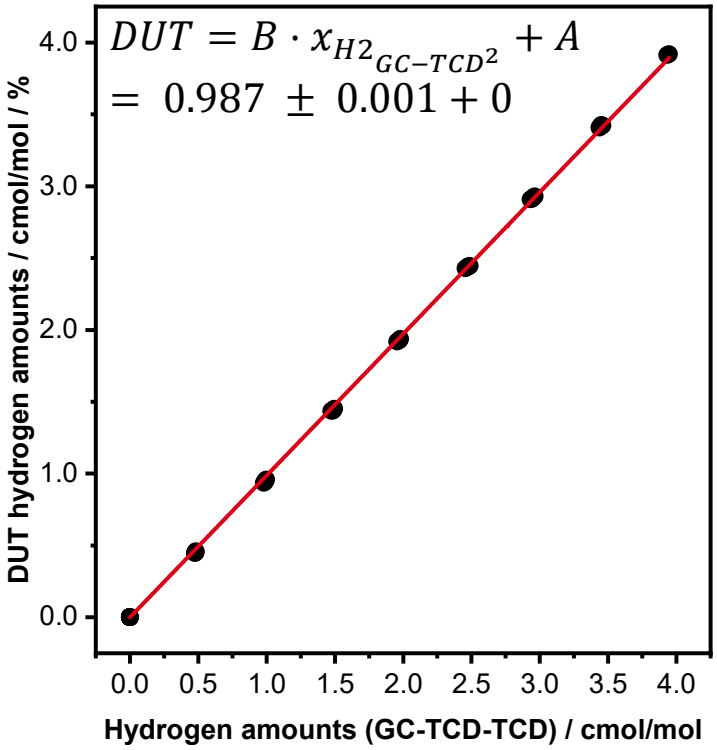
The DUT and *in operando* GC-TCD-TCD data shows the cyclic exposure with respect to different hydrogen amounts.

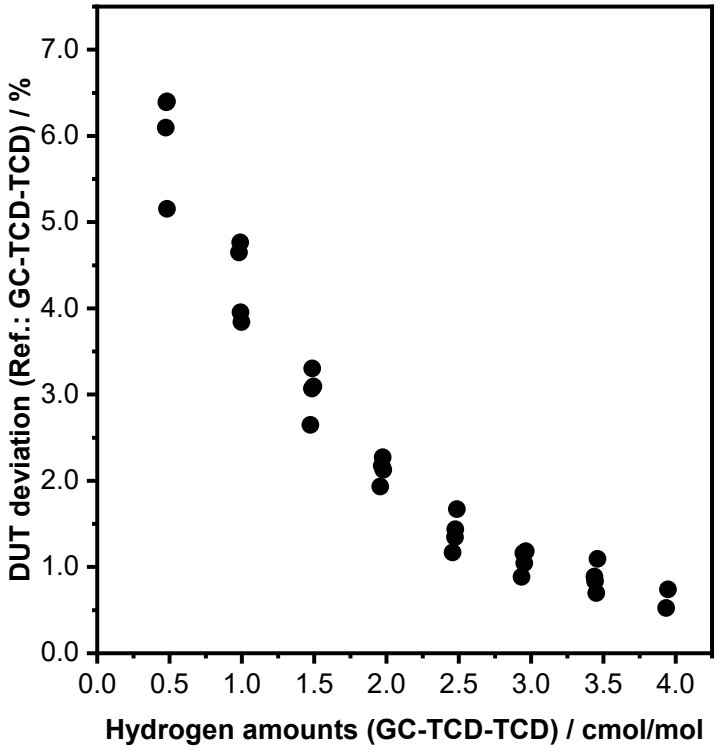
The humidity level is in the range of 0.55 µmol/mol to 1 µmol/mol.

Zoomed: Time series of observed test data Hydrogen Sensor and GC-TCD-TCD



Calibration curve and deviation with respect to reference GC-TCD-TCD





Conclusion

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Conclusion

The test results prove the effectiveness of the gas sensor in detecting hydrogen.

It reacts to different amounts of hydrogen in the air and reliably returns to zero.

The reference procedure uses GC-TCD-TCD and dew point hygrometer as transfer standards for validation and quantification of the generated gas mixtures.

A fundamental basis for modern and efficient quality assurance of gas sensors.

Acknowledgement

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