In-Situ Measurement Technique for Data Acquisition in Fuel Cells: Enabling Accurate Energy Balance Modeling

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Specialized Measurement Techniques Required For Detailed Energy Balancing

In order to improve operation strategies of fuel cells, precise information about
- relative humidity/ water balance,
- crossover and
- nitrogen enrichment are very important.

! But:

- Available **humidity sensors struggle** with the problem of condensation at the sensor head, which leads to a slow response. High relative humidities (RH) are difficult to measure, but are often the case.
- Crossover and nitrogen enrichment cannot be measured directly, **in-situ gas diagnostic is missing.**

Measuring A Complete Energy Balance Of A Fuel Cell Stack At The Test Stand

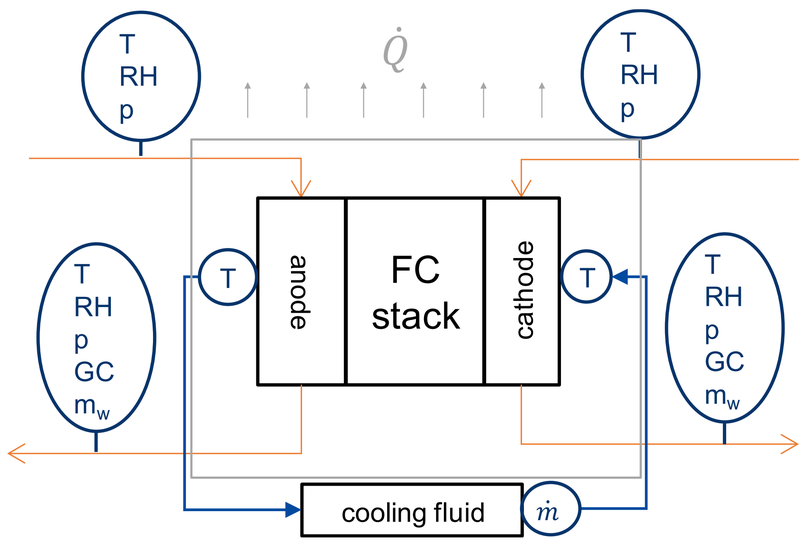


Figure 1: Measuring the energy balance of a fuel cell stack at a test bench – relevant measuring parameters (temperature (T), pressure (p), relative humidity (RH), gas composition (GC), mass of liquid water (m_w)), mass flows ($\dot{m}$), heat loss ($\dot{Q}$)

- All in- and outputs of a component can be described by **thermodynamic state variables and process parameters** e.g. temperature, pressure or heat
- Needed to form mass and energy balances and important for system understanding
- Enable calculation of system efficiencies and development of operation strategies
- **Which data do we need?**
  temperature (T), relative humidity (RH), pressure (p), gas composition (GC), mass of liquid water (m_W), mass flows ($\dot{m}$), heat loss ($\dot{Q}$)

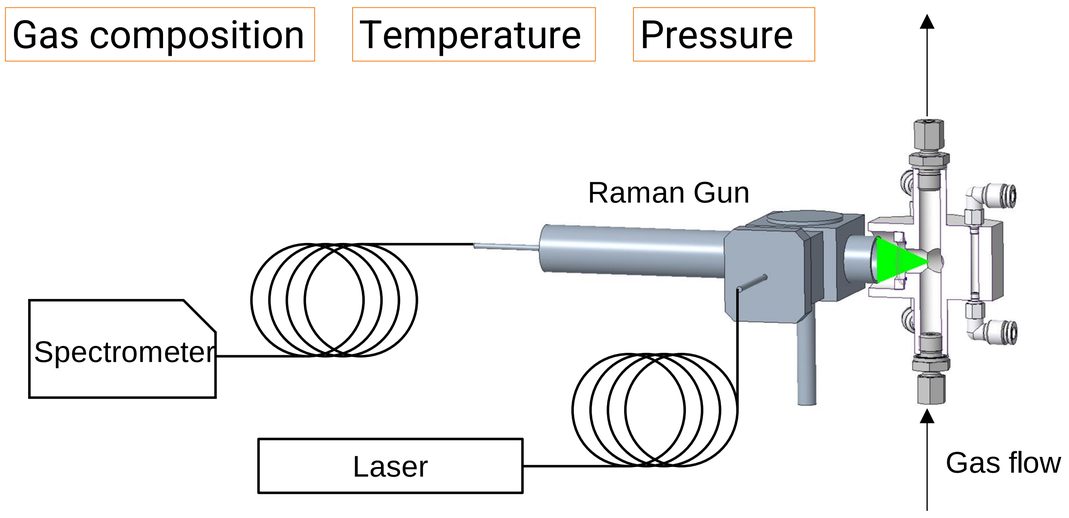
→ Gas diagnostics with Raman scattering cover a large amount of required data

Measurement Technique

Raman scattering refers to rare transitions of binding electrons that are excited by light and emit light of a different frequency. The energy change is molecule-specific.

Raman spectroscopy measures the intensities of spectral components of scattered light depending on the Raman shift. The spectrum of a gaseous sample gives information about

Gas composition | Temperature | Pressure



Advantages:
- Contact-free optical measurement of flow → no condensation at the sensor
- In-Situ-measurement
- High sampling rate of 1/s, small focus → interesting for dynamic operation
- Small, portable, robust → flexible usage

Data Analysis

Measurement point:

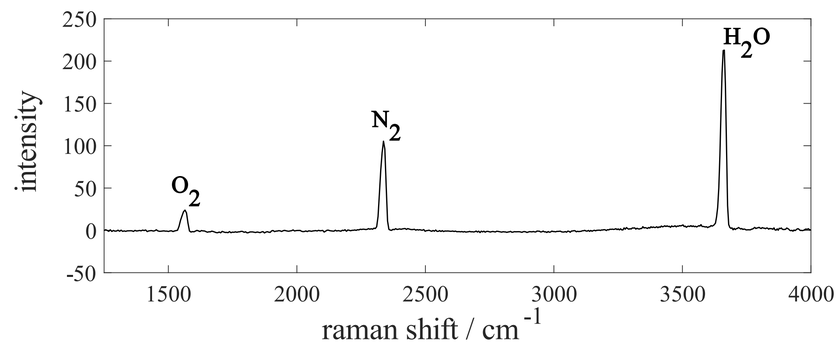


Figure 2: Example of Raman spectrum of humidified air with detected gas signals

Temporal resolution:

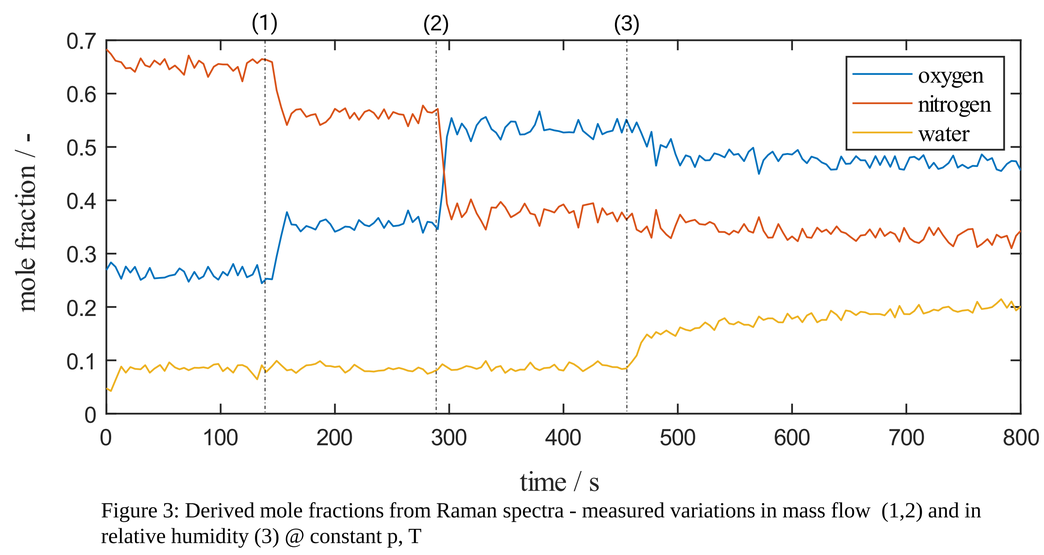


Figure 3: Derived mole fractions from Raman spectra - measured variations in mass flow (1,2) and in relative humidity (3) @ constant p, T

→ Calculation of relative humidity (RH) out of mole fraction

Conclusion & Outlook

- Gas diagnostic with Raman scattering is a powerful measurement tool providing relevant fuel cell data
- Gas composition + thermodynamic parameters => characterization of fuel cells and system components like humidifiers, ejectors etc.

→ Integration in our self-designed fuel cell test bench => detailed energy balancing

Literature

A. Braeuer, In situ spectroscopic techniques at high pressure. Amsterdam, Netherlands: Elsevier, 2015. [Online]. Verfügbar unter: https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=4188017

Acknowledgements

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