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RECENDT RESEARCH CENTER NON DESTRUCTIVE TESTING

Modern NIR spectrometer technology for real-time state-of-charge estimation of heat storage materials

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SORPTION HEAT STORAGE

- Well-suited to store solar and geothermal energy, both for seasonal and daily demands
- Shows high energy densities, robustness, low heat losses, and good cycling stability as compared to sensible and latent heat storages
- Water is a commonly used sorbate.
- Important characteristics are adsorption capacity, cyclability, state-of-health (SOH), and state-of-charge (SOC). A suitable technology to control these parameters in real time is required.
- Only a few concepts of a suitable real-time SOC sensor exist.

Studied sorption heat storage materials: a) A-type zeolite; b) A-type zeolite, binder-free; c) NaY-type zeolite, binder-free; d) microporous silica gel; e) salt-hydrate composite, 20 wt% salt; f) salt-hydrate composite, 40 wt% salt

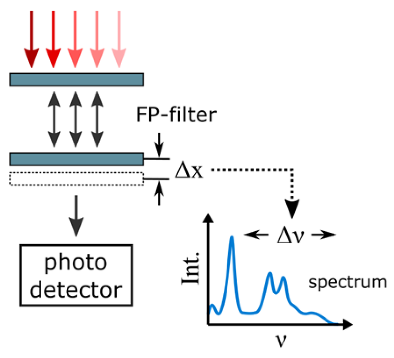
MOEMS-BASED NIR SPECTROMETER TECHNOLOGY

Benefits:

- miniature
- low-cost
- robust (therefore, low maintenance costs)
- flexible spectral range and step

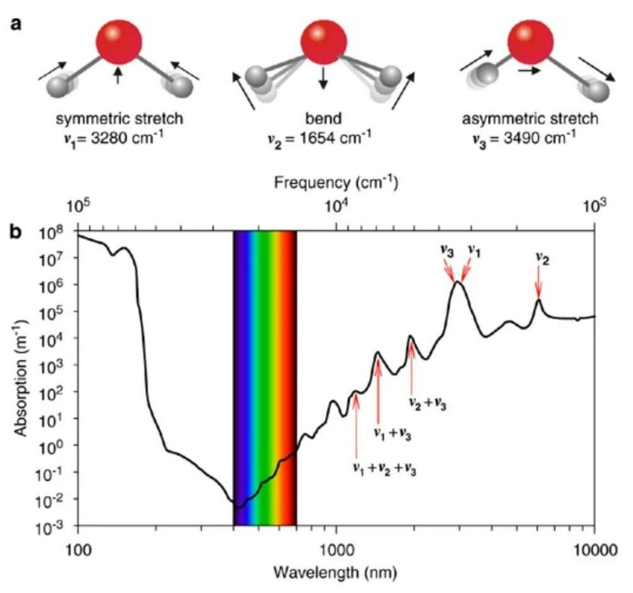
Drawbacks:

- low spectral resolution
- narrow spectral range



Tunable Fabry–Pérot filter

CONCEPT



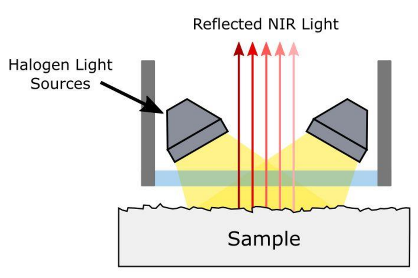
The absorption band at ca. 5150 cm^{-1} ($\lambda \approx$ 1940 nm), representing a combination of bending (ν_2) and asymmetric stretching (ν_3) vibrations of water molecules, is particularly suitable for quantification of adsorbed water in solids.

◄ Fundamental vibrations of the H_2O molecule (a) and the absorption spectrum of pure water (b).

Stomp, M. *et al. ISME J.* 1 (2007) 271

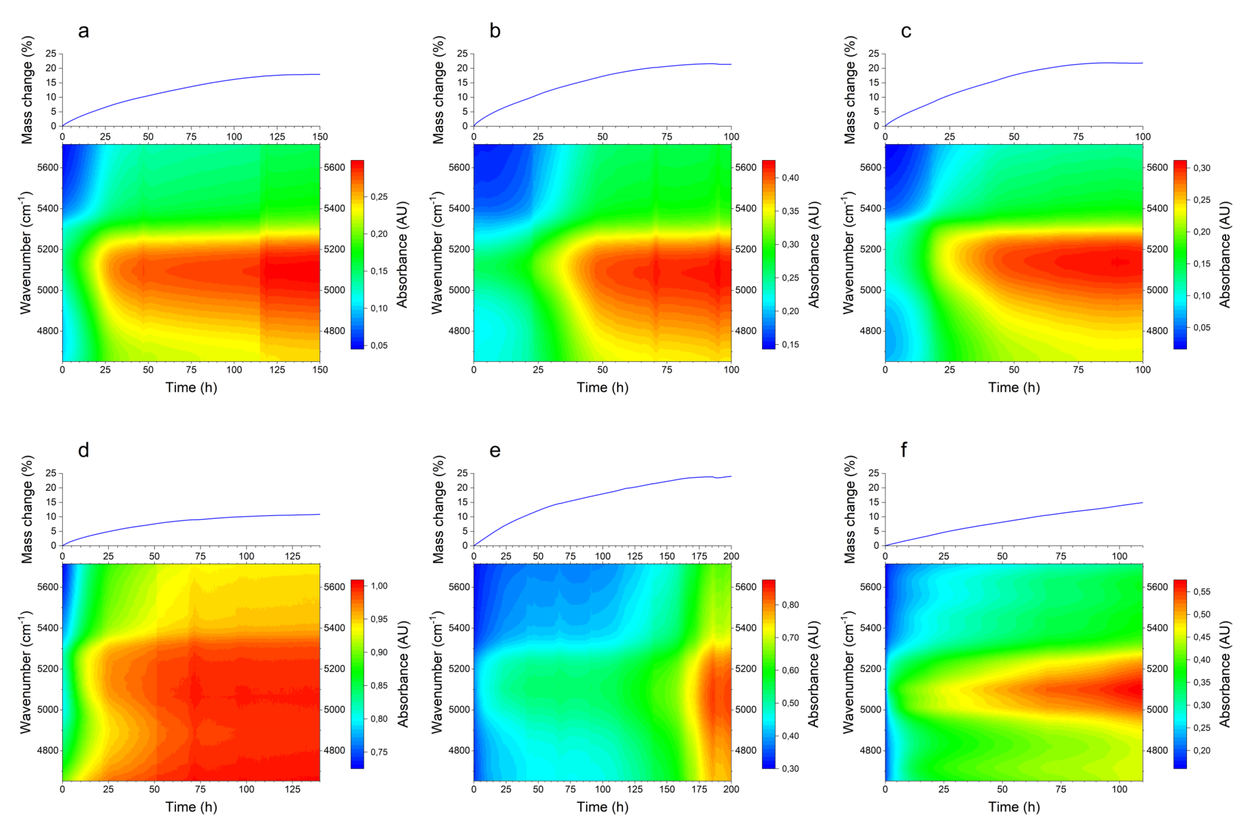
EXPERIMENTAL METHOD

1. Charging (= desorption) in a drying chamber (zeolites: 3 h at 250 °C; silica gel: 3 h at 150 °C; salt-hydrate composites: 2 h at 100 °C + 2 h at 200 °C)
2. Water vapor adsorption measurement with simultaneous mass change and NIR spectra collection: The spectra were collected in the spectral range of 1750–2150 nm using a NIR Fabry–Pérot micro-spectrometer with integrated light sources. The mass changes were recorded using an analytical balance (±0.0001 g precision).
3. Data preprocessing: smoothing, interpolation
4. PLS modelling with absorbances at each wavelength as the independent variables and the relative mass change (in %) as the dependent variable

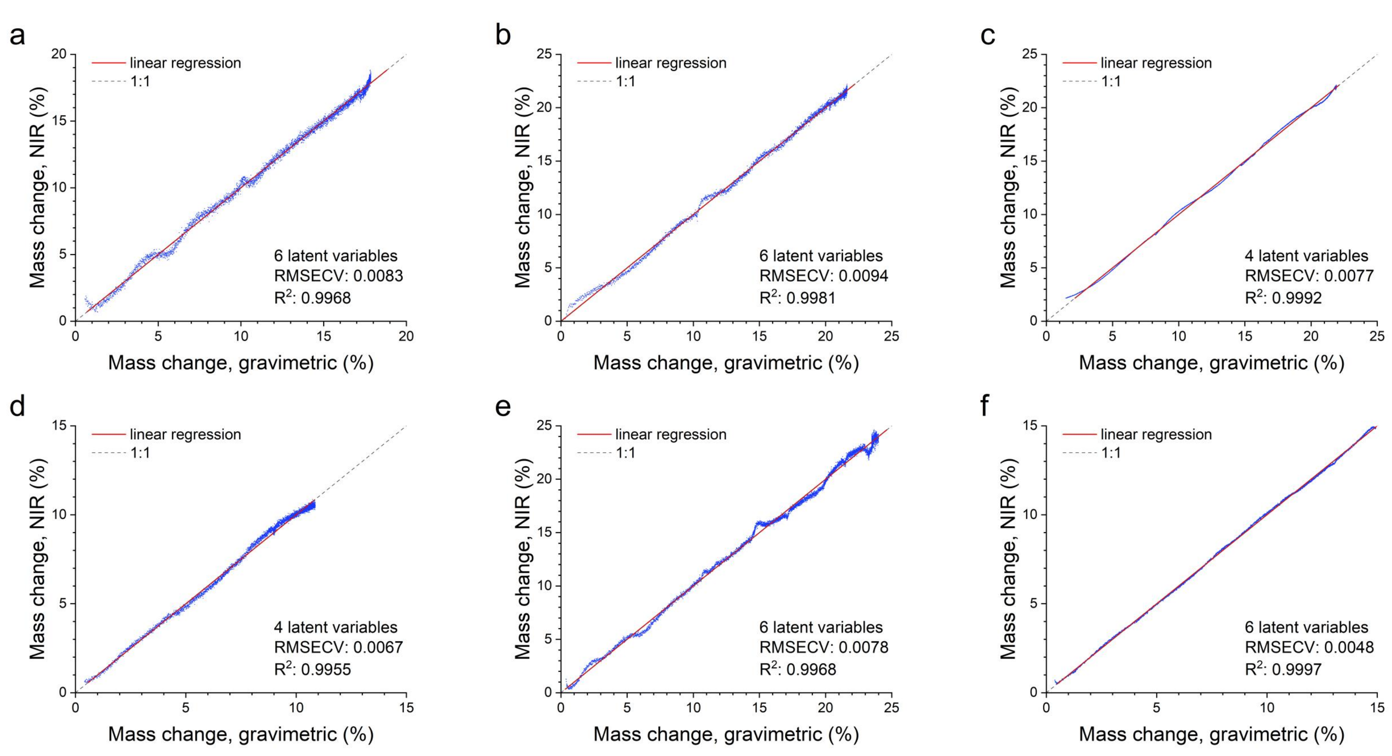


NIR measurement in diffuse reflection geometry

RESULTS



NIR spectra and respective gravimetric curves for the studied materials:
a) A-type zeolite; b) A-type zeolite, binder-free; c) NaY-type zeolite, binder-free; d) microporous silica gel;
e) salt-hydrate composite, 20 wt% salt; f) salt-hydrate composite, 40 wt% salt



Predicted vs. reference plots for the studied materials:
a) A-type zeolite; b) A-type zeolite, binder-free; c) NaY-type zeolite, binder-free; d) microporous silica gel;
e) salt-hydrate composite, 20 wt% salt; f) salt-hydrate composite, 40 wt% salt

CONCLUSION

Based on water adsorption measurements, we developed PLS models showing high accuracy of water content prediction. Novel MOEMS-based NIR spectrometers can provide an adequately precise, compact, and low-cost solution for SOC control of various sorption heat storage systems. Our research findings are useful to assess heat storage capacities, improve balancing local heat supplies and demands, and therefore, increase the resilience of future heat distribution networks.

ACKNOWLEDGEMENT

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REFERENCES

1. G. Issayan, B. Zettl, W. Somitsch. Developing and Stabilizing Salt-Hydrate Composites as Thermal Storage Materials. In: *Proceedings of the 14th International Renewable Energy Storage Conference 2020 (IRES 2020).* Atlantis Press. 49–57 (2021)
2. R. Zimmerleiter, et al. Probeless non-invasive near-infrared spectroscopic bioprocess monitoring using microspectrometer technology. *Anal. Bioanal. Chem.* **412** 2103–2109 (2020)