Electronic Supplementary Material (ESI) for Faraday Discussions.
This journal is © The Royal Society of Chemistry 2020

Adsorber heat exchanger using Al-fumarate beads for heat-pump application – a transport study

David Farrusseng,*[a] Cécile Daniel,[a] Conor Hamill[b], Jose Casaban,[b], Terje Didriksen,[c] Richard Blom,[c] Andreas Velte,[d] Gerrit Fueldner,[d] Paul Gantenbein,[e] Patrick Persdorf,[e] Xavier Daguenet-Frick[e] and Francis Meunier[f]

SUPPORTING INFORMATION

Please do not adjust margins

Experimental

Description of the dynamic set-up for the measurements on the adsorber heat exchanger

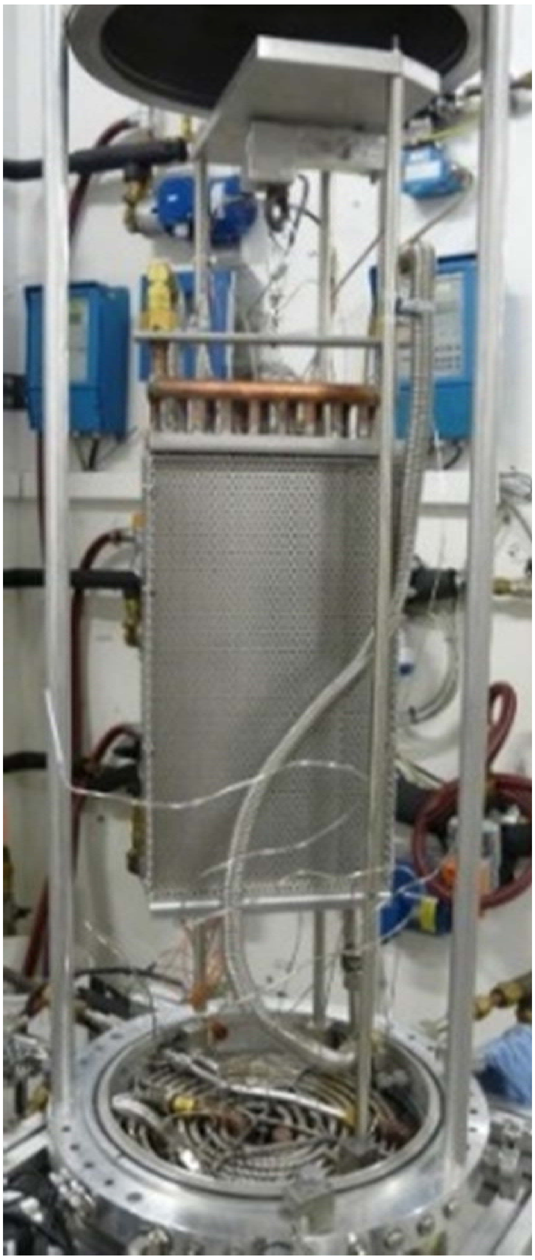


Figure S1: Open single chamber with suspended heat exchanger (adsorber-desorber) and evaporator-condenser (e/c) underneath.

This journal is © The Royal Society of Chemistry 20xx

Please do not adjust margins

Ageing chamber by fast cycling

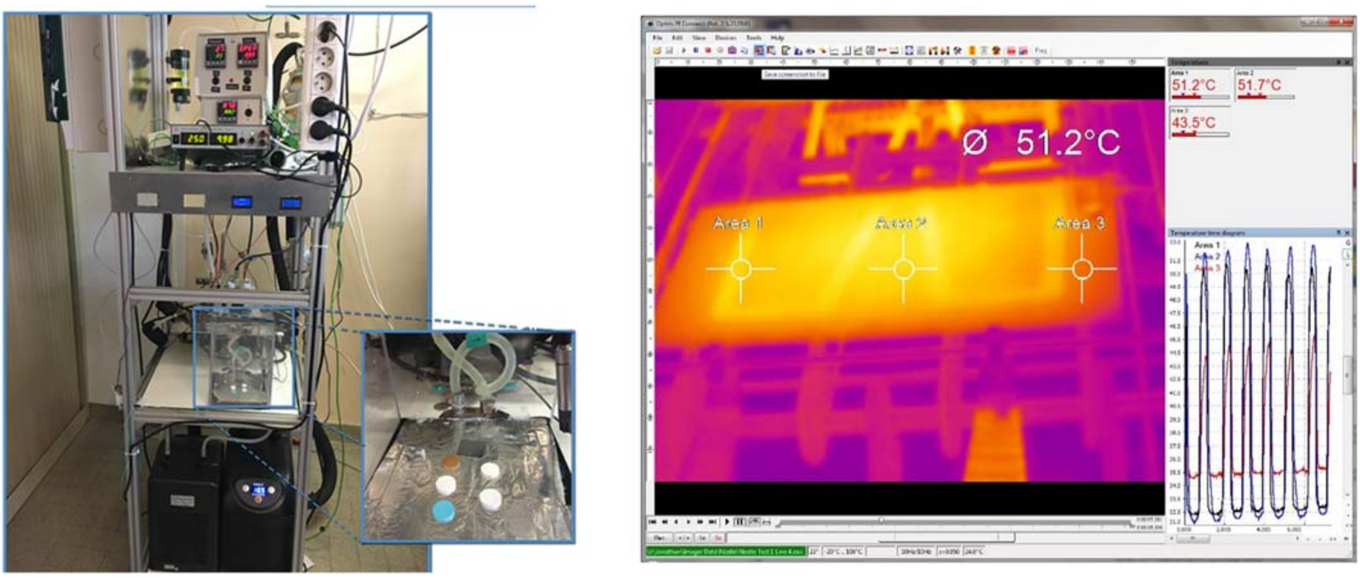


Figure S2: Picture of the ageing chamber (left), picture by Infrared camera of the heating-cooling plate and temperature cycling.

Please do not adjust margins

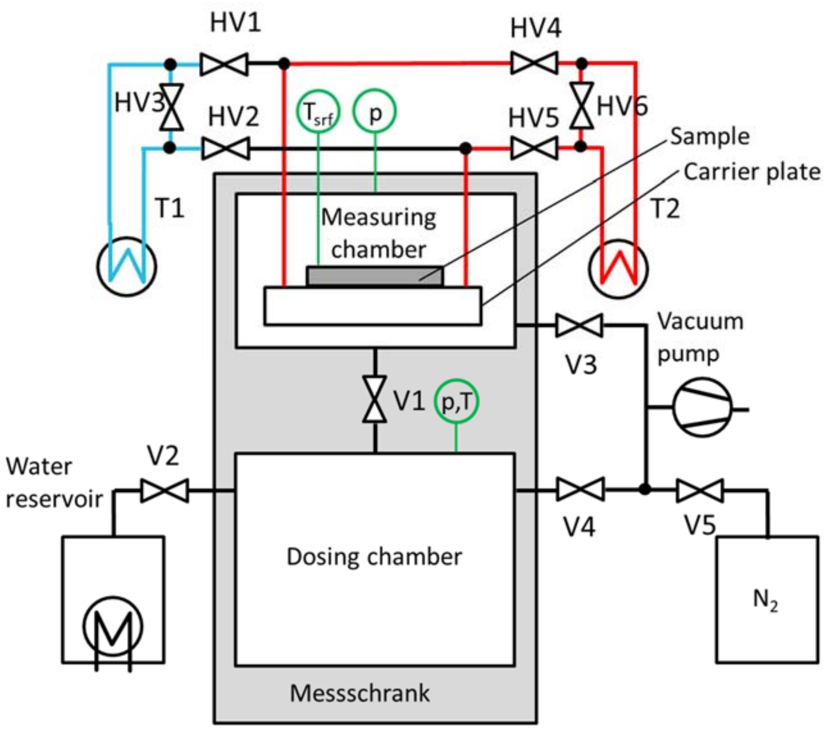
Please do not adjust margins

LTJ Principle and Set-up

The measurement set-up is shown in Scheme 1. Both large pressure jump measurements (LPJ) as described by Schnabel [1] and Füldner [2] and large temperature jump measurements (LTJ) as described by Aristov [3] and Sapienza et al. [4] can be performed. The measured signals are: temperature of the water vapour in the dosing chamber (Pt-100), pressure in measurement chamber and in the dosing chamber.

The following steps are taken to measure a sample with the LTJ method:

- A sample is placed on the carrier plate in the measuring chamber
- The set-up is evacuated (V3 and V4 are open)
- The sample is heated up to 95 °C by connecting either thermostat T1 or thermostat T2 with the carrier plate.
- The thermostats T1 and T2 are running in their own cycles (HV3 and HV6 open, all other hydraulic valves closed) to reach the desired temperature levels
- The dosing chamber is filled with water vapour at a certain pressure (V2 is open, V1 and V4 are closed)
- Dosing chamber and measuring chamber are connected via V1, all other valves are closed
- Thermostat T1 is connected with the carrier plate, the sample is at its initial temperature and its initial pressure
- Thermostat T1 is disconnected and thermostat T2 is connected to the carrier plate. Now the sample starts to adsorb or desorb water vapour due to the change in temperature. The temperature of the carrier plate changes within 5 s (time constant of 1 s).
- Since dosing chamber and measuring chamber are a closed volume during the measurement the ad- or desorbed mass of water vapour can be calculated out of the pressure change with the law of the ideal gas.



Scheme 1 – Schematic drawing of the measurement set-up at Fraunhofer ISE as shown in Velte et al. [5]

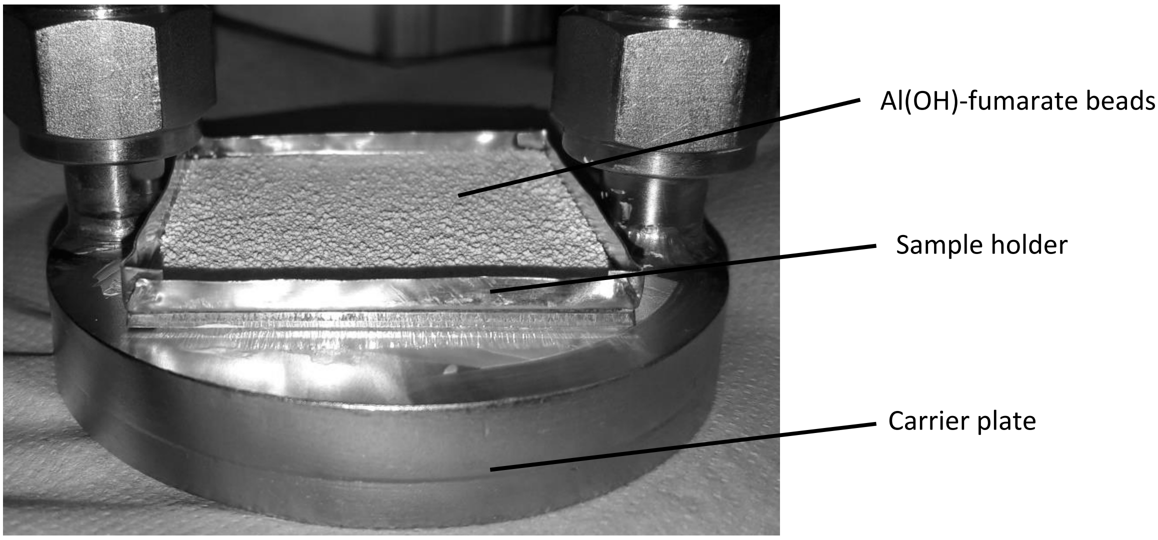
This journal is © The Royal Society of Chemistry 20xx

Please do not adjust margins

Please do not adjust margins

With the nitrogen dosing unit (“N_2” in Scheme 1) both measuring chamber and dosing chamber can be filled with dry nitrogen. Under typical temperature conditions (between 20 and 100 °C) and pressure conditions (below 100 mbar) the sample will neither ad- or desorb nitrogen if the sample temperature is changed. Thus, the dynamics of the change of the sample temperature will only depend on the heat capacity of the sample and the heat transfer resistance between sample and carrier plate. For this kind of measurement (called inert-LTJ in the following), basically the same steps are taken as described above for the LTJ measurement. Instead of filling the dosing chamber with water vapour, it is filled with dry nitrogen. A method to evaluate this data was described by Velte et al. [5] earlier.

For the measurements of the Al(OH)-fumarate beads, a sample holder (aluminium) as shown on the picture was used. The beads are placed on the sample holder and the sample holder is attached to the carrier plate with a thin layer (0.1 mm) of thermal grease (Thermigrease TG 20032, Dr. Dietrich Müller Ahlhorn, Germany).



Please do not adjust margins

Please do not adjust margins

Characterisation

Mercury Intrusion

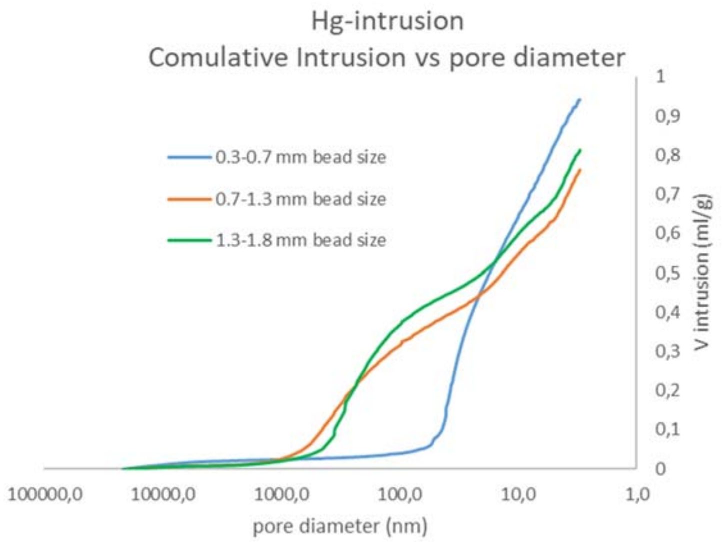


Figure S3: Hg-intrusion cumulative plot

Bead size distribution by Chemsizer

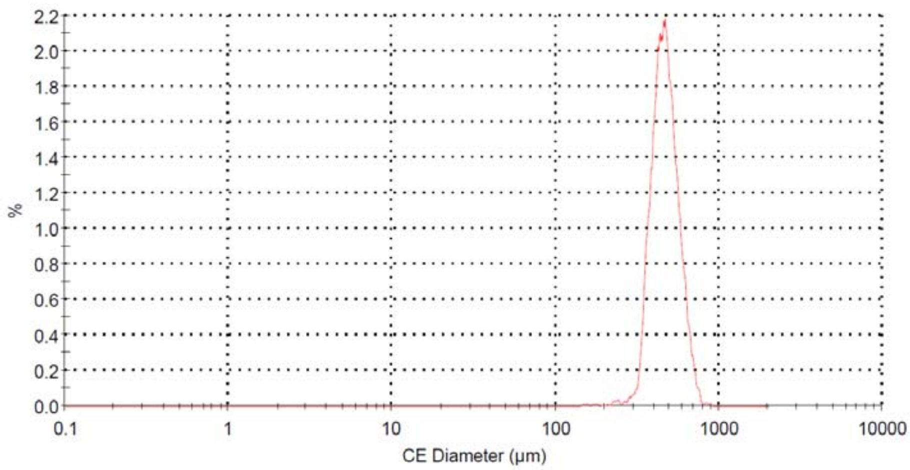


Figure S4: Distribution of bead size diameter for the small-size bead of Al(OH)-fumarate placed in the heat-exchanger

This journal is © The Royal Society of Chemistry 20xx

Please do not adjust margins

Please do not adjust margins

Water adsorption isotherms of small beads containing different amount of binder

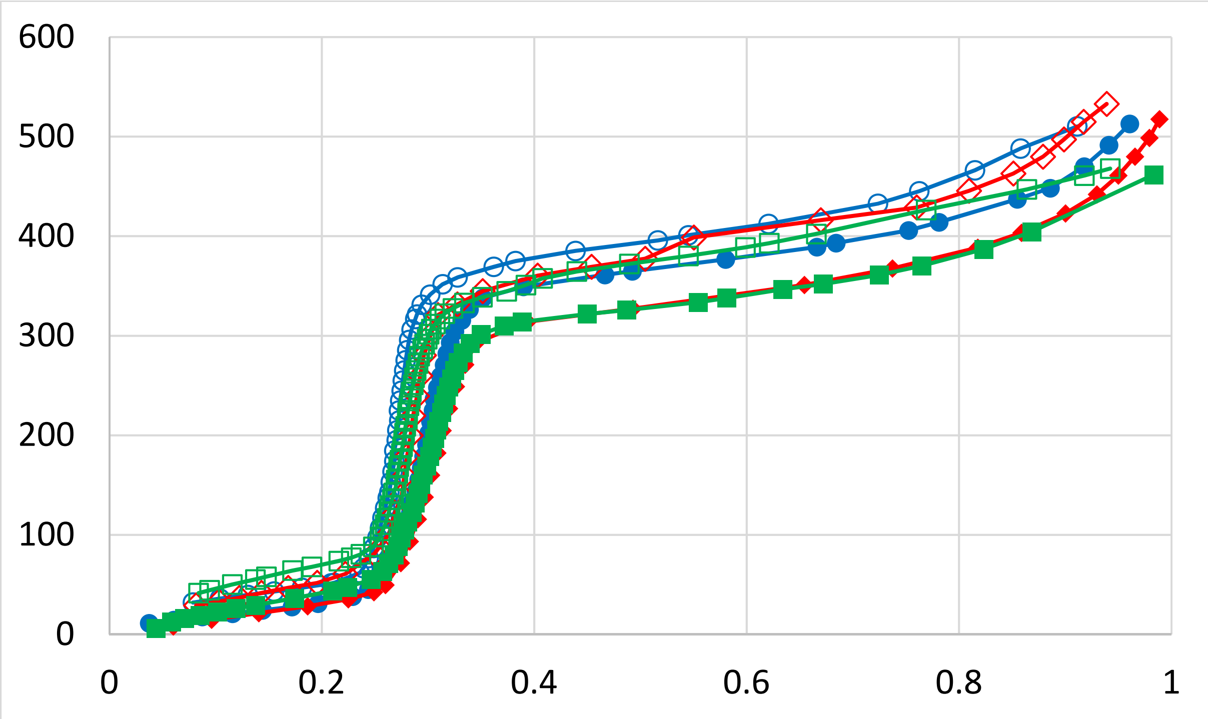


Figure S5: Water adsorption isotherms at 30°C of of Al(OH)-fumarate small size beads (SS) at various binder content, low loading (circle), medium loading (diamond), large loading (square).

Please do not adjust margins

Please do not adjust margins

SEM pictures

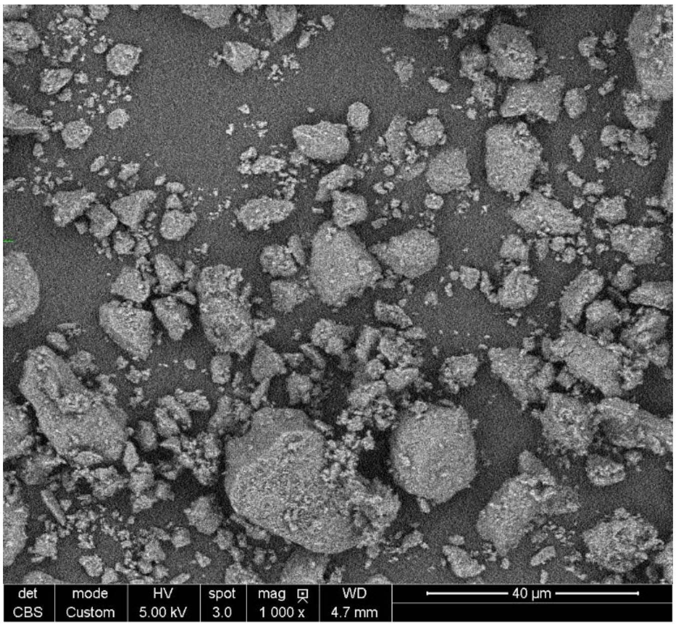


Figure S6: SEM pictures of Al(OH)-fumarate powder as prepared by mechano-chemical synthesis

SEM pictures of SS-LL beads overview and close-up.

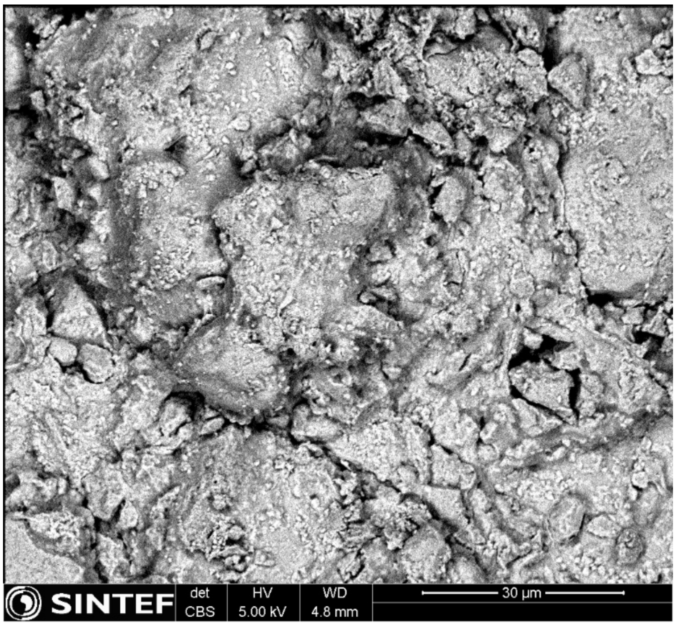


Figure S7: SEM pictures of the surface of Al(OH)-fumarate small size bead

 This journal is © The Royal Society of Chemistry 20xx

Please do not adjust margins

Please do not adjust margins

Water adsorption isotherms of small beads containing different amount of binder

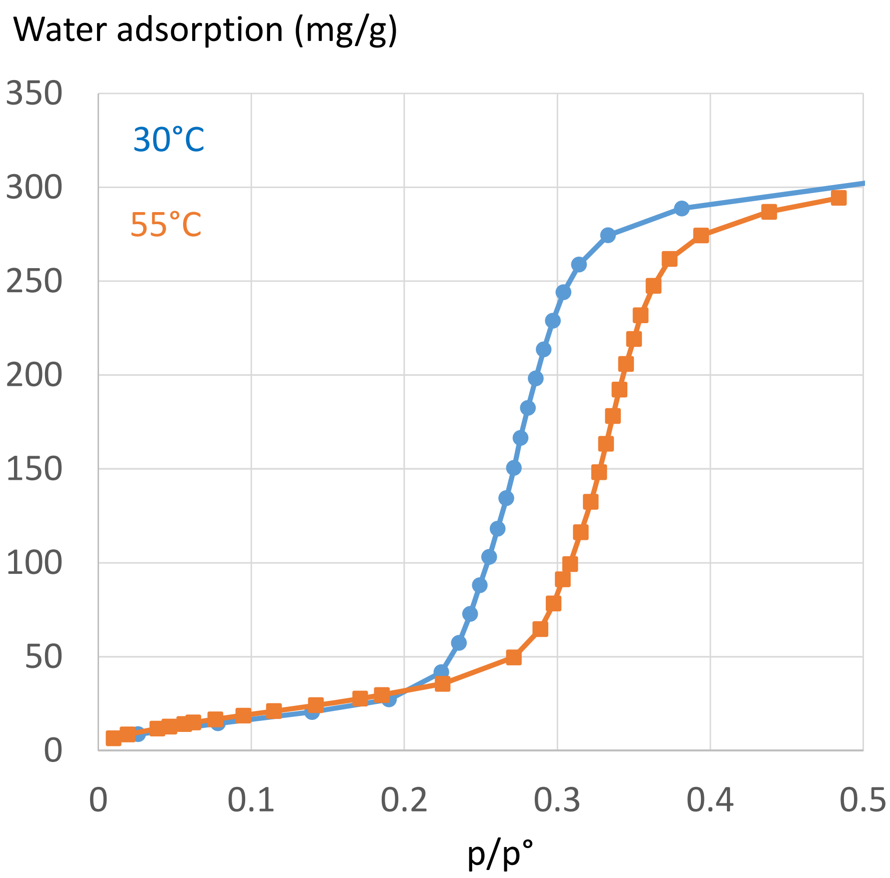


Figure S8: “Shift” of water adsorption isotherms of Al(OH)-fumarate with the temperature (y scale: mass of wet samples)

Please do not adjust margins

Please do not adjust margins

References

[1] L. Schnabel, „Experimentelle und numerische Untersuchung der Adsorptionskinetik von Wasser an Adsorbens-Metallverbundstrukturen“. Dissertation, Technische Universität Berlin, Berlin, 2009.

[2] G. Füldner, „Stofftransport und Adsorptionskinetik in porösen Adsorbenskompositen für Wärmetransformationsanwendungen“. Dissertation, Freiburg, 2015.

[3] Y.I. Aristov, B. Dawoud, I. S. Glaznev und A. Elyas, „A new methodology of studying the dynamics of water sorption/desorption under real operating conditions of adsorption heat pumps: Experiment“, *Int. J. Heat Mass Tran.*, Jg. 51, 19-20, S. 4966–4972, 2008.

[4] A. Sapienza, A. Velte, I. Girnik, A. Frazzica, G. Füldner, L. Schnabel und Y. Aristov, „“Water - Silica Siogel” working pair for adsorption chillers: Adsorption equilibrium and dynamics“, *Renewable Energy*, Nr. 110, S. 40–46, 2017.

[5] Velte, A. Füldner, G. Laurenz, E., Schnabel, L., „Advanced Measurement and Simulation Procedure for the Identification of Heat and Mass Transfer Parameters in Dynamic Adsorption Experiments“, *Energies*, Jg. 10, Nr. 8, S. 1130, 2017.

This journal is © The Royal Society of Chemistry 20xx

Please do not adjust margins