TITLE: Development of advanced nanoporous materials for low-T heat storage/transformation applications

Summary: Thermal energy storage (TES) is important technology in enabling more efficient use of renewable energy. Over the last decade, several studies have proved that porous materials are useful in the exploitation of solar energy and waste heat in adsorption-driven heat exchangers. The main principle is based on the consecutive adsorption and desorption process of water into the pores of the materials. In the search for an even better energy-storage material with even higher capacity and overall performance in dynamic conditions, at NIC we have focused on microporous aluminophosphates as alternative materials to well-known and easily accessible porous zeolites. One of our materials, $AlPO_4$-LTA, outperforms most of other porous materials tested so far, i.e. it adsorbs water in an extremely narrow relative-pressure interval, it exhibits superior water uptake and energy-storage capacity (495 kWh m^{-3}) and it shows remarkable cycling stability; after 40 cycles of adsorption/desorption its capacity drops by less than 1 wt%. As such, these materials are also very interesting for other adsorption driven applications, like water harvesting from the atmosphere for drinking water production. The issues of aluminophosphates are however syntheses in the presence of complex organic templates and in powdery forms, which may hinder effective application. During the doctoral study, the candidate will be responsible to develop innovative green synthesis approaches for selected aluminophosphates, to establish structure-function relationship and to develop efficient shaping methods (granulation, extrudation, coatings, etc.) for low-T heat storage/transformation applications. The focus will be on simultaneous optimization of the materials properties and heat/mass transfer in the predicted system, which will include introduction of mesoporosity in the materials and which will be aligned with the shaping of materials. The aim will be to offer new heat-storage material/solutions to the market.

Research techniques used: Hydrothermal, solvothermal, iono-thermal and mechanothermal synthesis of micro-/mesoporous powders and/or composites with porous matrices/foams. Different approaches will be used to tailor hydrophilic-hydrophobic properties of adsorbents and dynamics of water sorption. Structural and sorption properties of new materials will be studied by basic and advanced characterisation techniquies (XRD, SEM, TEM, ssNMR, physisorption, thermal analysis, etc.), with an emphasis on in-situ XRD water sorption (experimental cell with controlled humidity), and characterization of performance of products for selected heat storage application (water sorption dynamics at defined conditions, calculation/measurement of heat of adsorption, hydrothermal stability-cycling, etc). Possible scaling-up of the materials will be done in cooperation with the company Silkem d.o.o.

The reason why the topic is innovative: The state-of-the art laboratory materials, concerning the heat storage capacities and stabilities, will be shaped and possibly scaled up to semi-industrial scale. The mesoporous/composite-based shaping and scaling up of proposed type of materials have not been done so far. The new product will also open new possibilities for its applications in energy (energy storage, cooling, heating), automotive (cold engine start), environmental and other industries (drinking water from the atmosphere, etc.).

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