3D-PRINTING OF HYDROTALCITE SORBENTS FOR INCREASED PRODUCTIVITY IN SORPTION-ENHANCED WATER-GAS SHIFT REACTION

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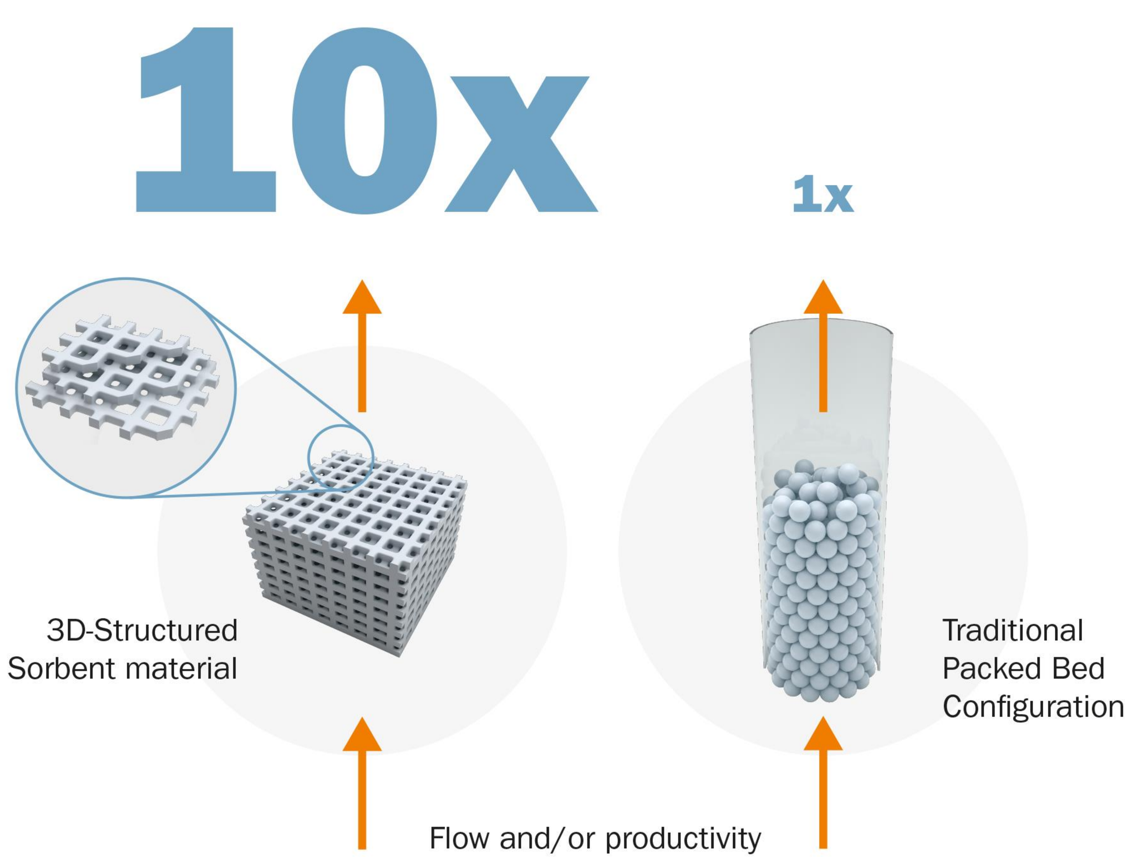
https://3d-caps.eu/

Introduction

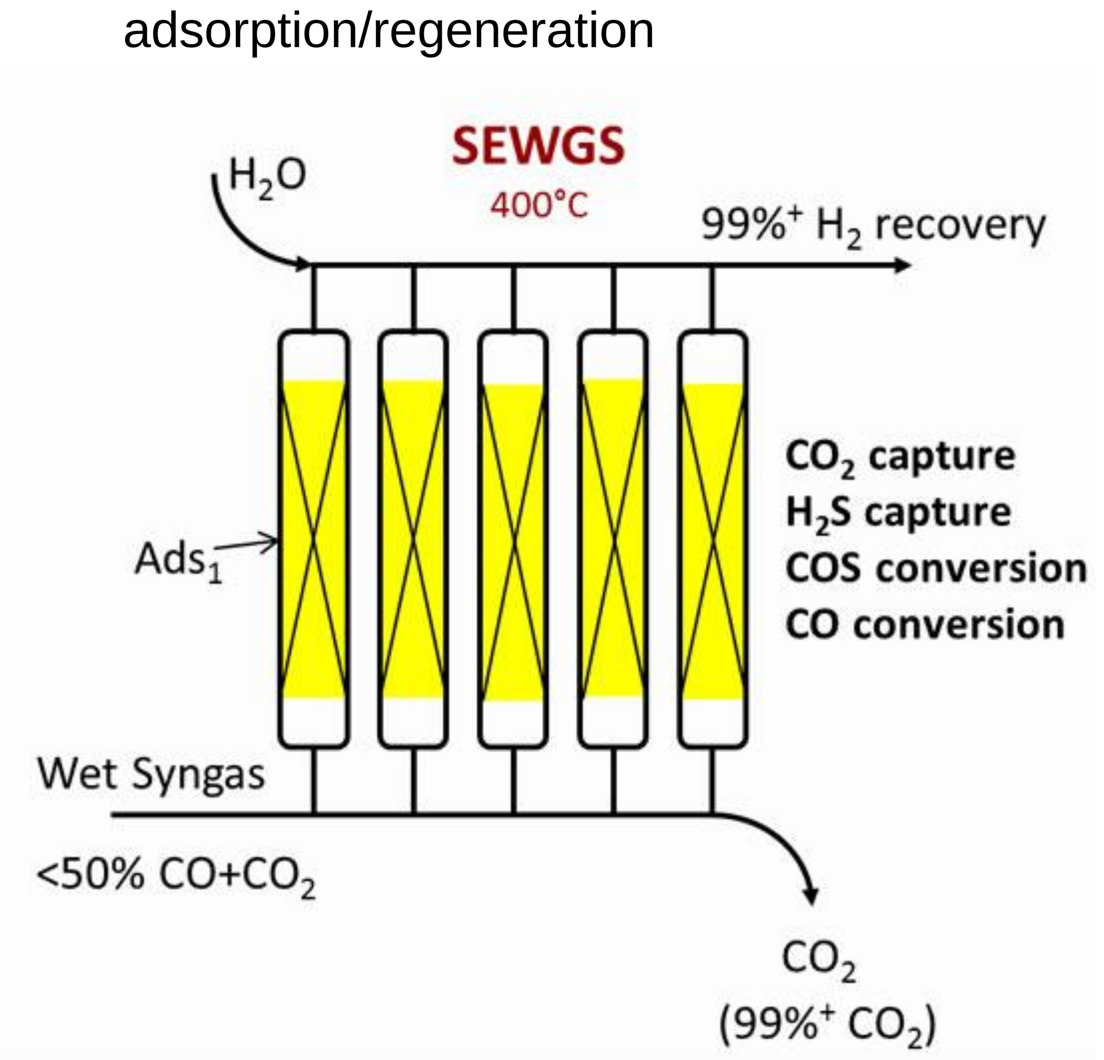
- Improvement of structured adsorbents and catalyst compared to traditional pellets,[1] due to:
  - Lower pressure drop
  - Faster mass transfer
  - Higher volumetric capacity
- Increased productivity leads to smaller reactors and lower costs
- 3D printing allows production of materials with unlimited tailored structures
- In 3D-CAPS, two sorbents for CO_2 capture are developed
  - K_2CO_3 impregnated hydrotalcite (HTC) for Sorption Enhanced Water Gas Shift (SEWGS)
  - Immobilized amines on silica for post-combustion capture



The 3D-CAPS project aims at a 10-fold productivity (kg CO_2 m^{-3} h^{-1}) increase for structured sorbents over conventional packed bed configurations.

Sorption Enhanced Water Gas Shift

- High temperature PSA process for CO_2 capture and H_2 production from syngas[2]
- Increase productivity by increasing flow (faster cycling) without loss in adsorption/regeneration

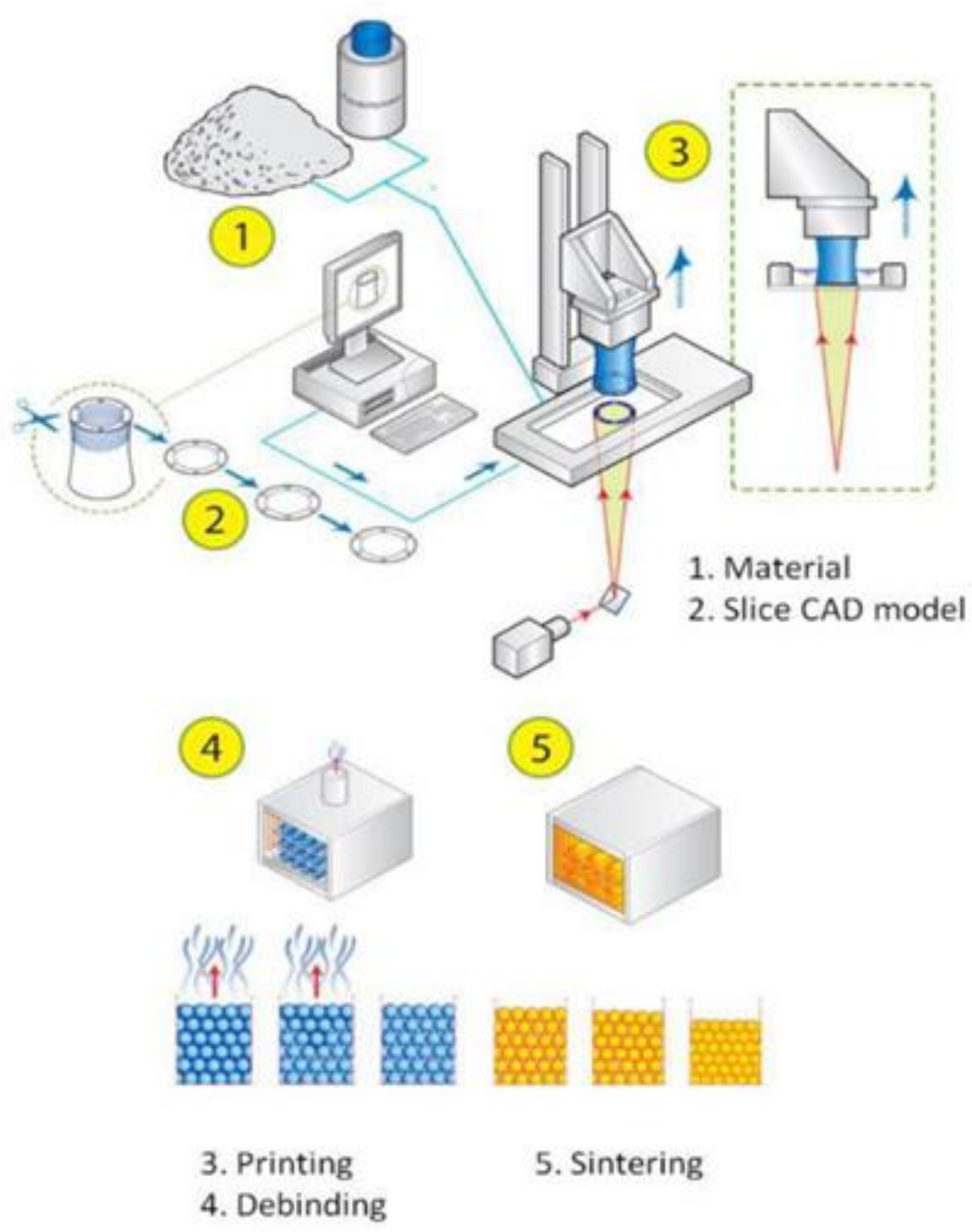


SEWGS is a reactive hot CO_2/H_2 separation process (PSA) catalyzed by HTC. By combining multiple columns a continuous process is obtained.

[1] C. Parra-Cabrera; et al. *Chem. Soc. Rev.* **2018** 209;
[2] J. Boon et al. *Chem. Eng. J.* **2014** 406.

3D printing technology (DLP)

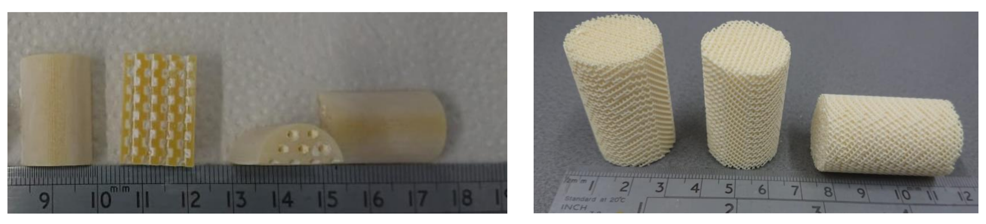
- Indirect printing technique
- Suitable for printing porous ceramics
- High resolution
- Faster than SLS due to projection of cross section
- Post-treatment is required and key step!



Schematic overview of the steps in the Digital Light Projection (DLP) 3D printing technique.

Material & structure development

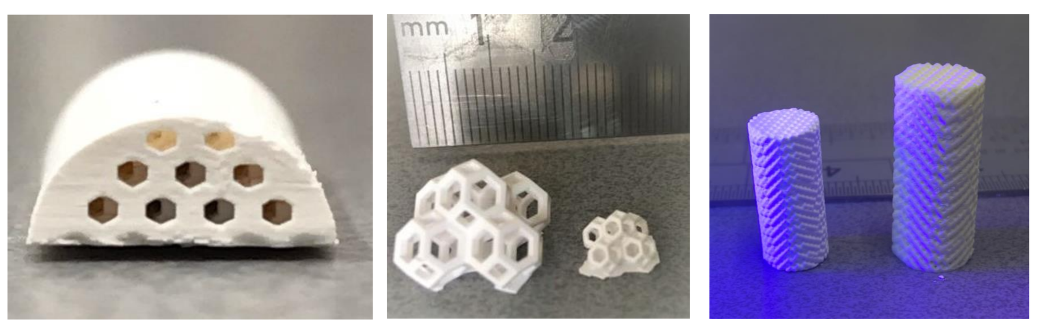
- Optimize paste formulation: high % HTC, photo initiator, monomer and additives to obtain printable paste
- Printing structures:



Examples of 3D printed structures with various channel sizes, zig-zag channels and foam structures.

- Post-treatment:
  - No K_2CO_3 reduction
  - Shrinkage of around 20-25%

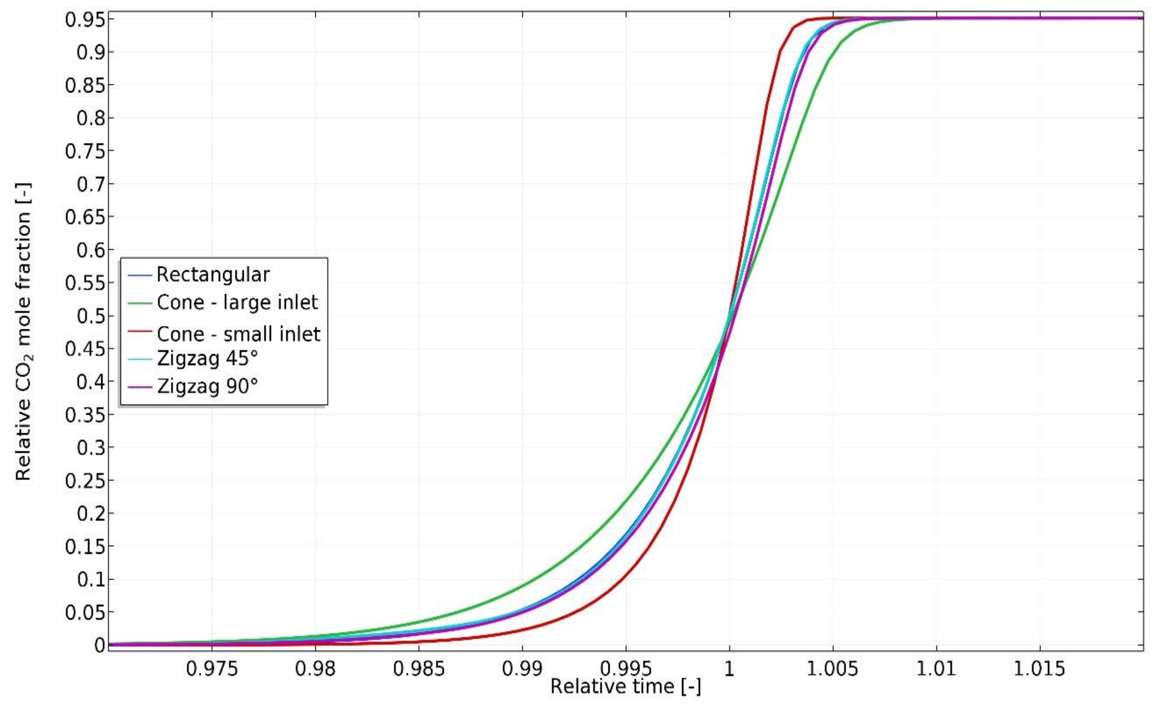
Sample (Sinter T)	Crush strength	Surface area
KMG30 reference	-	113 m^2/g
HTC (470 °C)	32 N	93 m^2/g
HTC (550 °C)	48 N	75 m^2/g



Examples of 3D printed structures after sintering: half cylinder with zig zag channels; kelvin cell & foams.

Testing 3D printed materials

- Adsorption capacity printed structures: to be tested (CO_2 breakthrough curves packed-bed *vs* structured sorbent)
- Evaluate effect structure on:
  - Adsorption and regeneration (100% steam) kinetics
    - Mass transfer
    - Axial dispersion
  - Water-gas shift activity



The effect of various geometries on the CO_2 breakthrough curve as modelled by COMSOL monolith reactor model of UBB: steeper curves enable faster cycling and higher productivity.

- End goal: test 3D-structured HTC on 2 m (height) scale for decarbonized H_2 production
  - Nominal flow: 20 L/min → 200 L/min

Highlights

i. Development of 3D-printed microporous ceramic materials.
ii. Testing of structured materials and comparison to traditional packed bed.
iii. Increased (CO_2 capture) productivity by 3D-structured materials.

Next steps

- Test different structures and printed materials to determine material properties and structure effects
- Modelling to determine productivity increase

Acknowledgements

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