ADDITIVE MANUFACTURING TO RESHAPE CATALYTIC REACTORS

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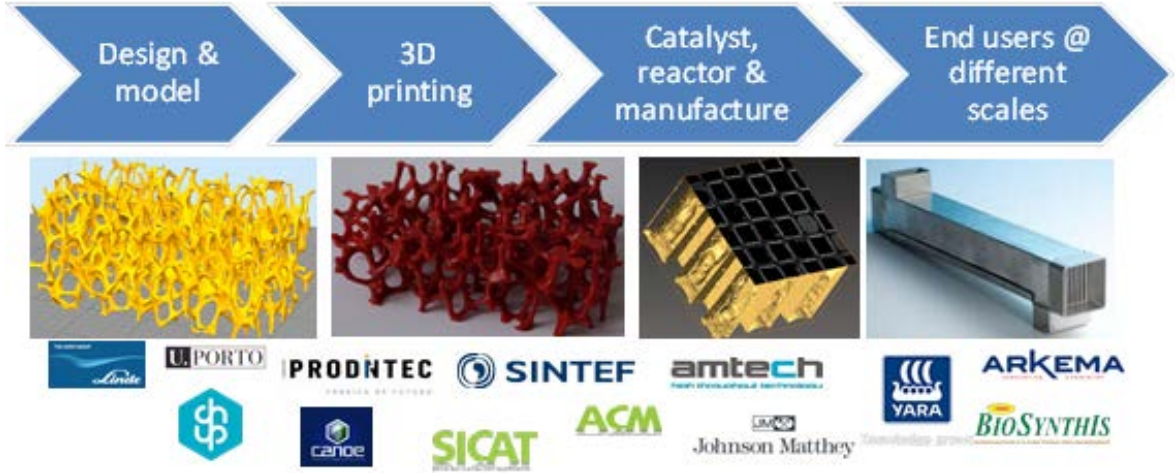
PRocess Intensification through Adaptable Catalytic Reactors made by 3D Printing (PRINTCR3DIT)

Call H2020 : SPIRE-5: Sustainable Process Industries

The main objective of PRINTCR3DIT is to implement a methodology to integrate 3D printing in the advanced design, modelling and manufacture of structured catalysts and catalytic reactors with significant cost reductions, access to new design strategies and faster lead times. The principal target of the project is to increase the efficiency through process intensification in reactions that present heat, mass and momentum transfer limitations, with targeted goals to significantly reduce the energy consumption, increased selectivities and longer lifetimes.



Total budget = 5,494 **K€**

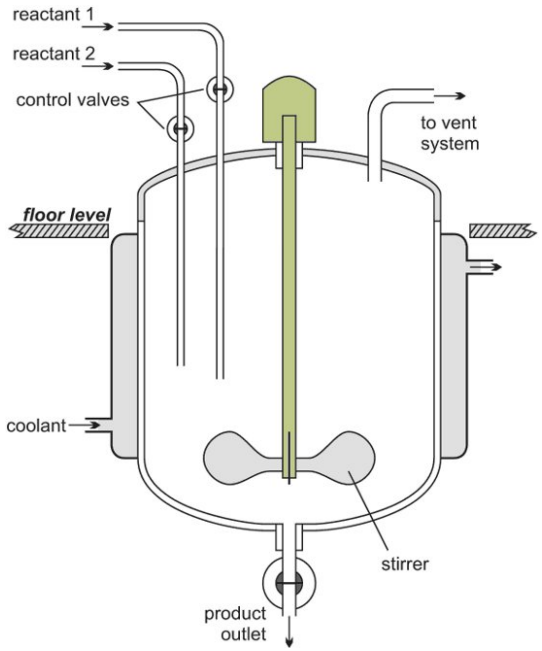
Coordinator: SINTEF MK (Carlos Grande)

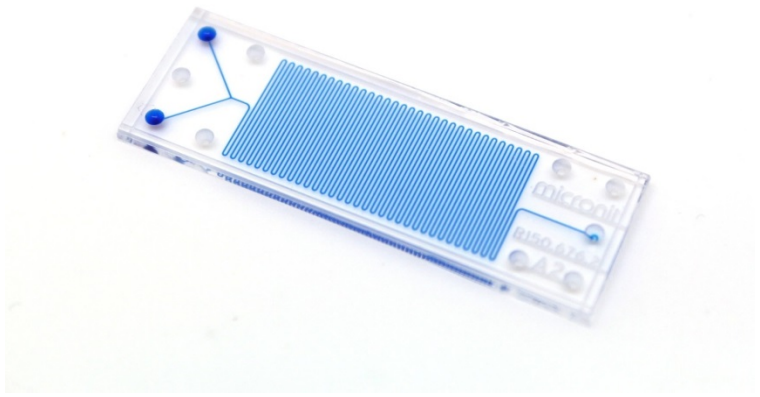
The consortium is composed of 8 industrial partners, of which 4 are SMEs, 4 research institutes and 1 university. The financial resources mobilized by the 13 partners represent a global effort of 590 person months.

The project duration is 36 months for a fast deployment of results into the market.

What is this talk about?

- Why we are considering AM to the chemical industry?
- What will be changed?
- How it will change?





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Design of chemical reactors

- Mass balance

$$\frac{\partial C_i}{\partial t} + \boldsymbol{u} \cdot \nabla C_i = \nabla \cdot (D \nabla C_i) + R_i$$

- Momentum balance

$$\rho \frac{\partial \boldsymbol{u}}{\partial t} + \rho(\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = \nabla \cdot \left[-p\boldsymbol{I} + \mu(\nabla \boldsymbol{u} + (\nabla \boldsymbol{u})^T) - \frac{2}{3}\mu(\nabla \cdot \boldsymbol{u})\boldsymbol{I} \right] + \boldsymbol{F}$$

- Energy balance

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \boldsymbol{u} \cdot \nabla T = \nabla \cdot (\lambda \nabla T) + Q$$

- and more I'm ignoring for simplicity…

Imagine a tool that allows you to tailor each of these terms into precisely what you want.

Don't think too much. 3D printing is around the corner already.

Materials we can print (by now)

- Polymers (mostly all of them)
- Metals (wide variation)
- Ceramics (only some but fast growing)
- Cellulose and other organic molecules
- Food: Chocolate; Pasta
- Glass
- Many hybrid materials

Exponential growing curve.
Anything can be happening
NOW!

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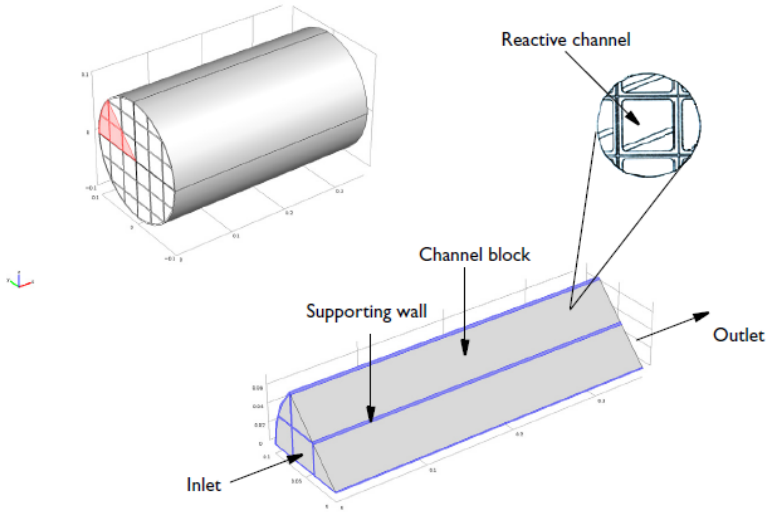
First example: structured materials

- Honeycomb monoliths
  - FANTASTIC (low) pressure drop
  - Mass and heat transfer controlled by diffusion (or film)
  - Produced by extrusion with different sizes and geometries
  - Always have a symmetry (length)



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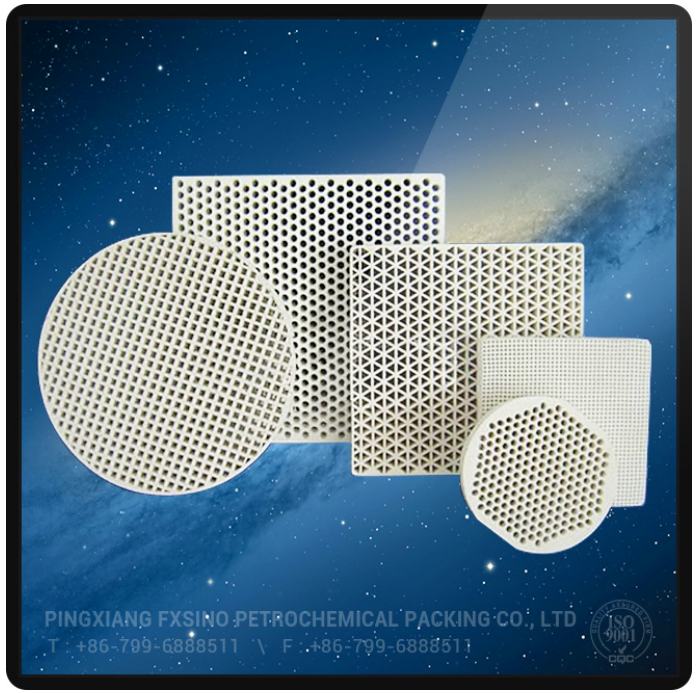

Different honeycombs?

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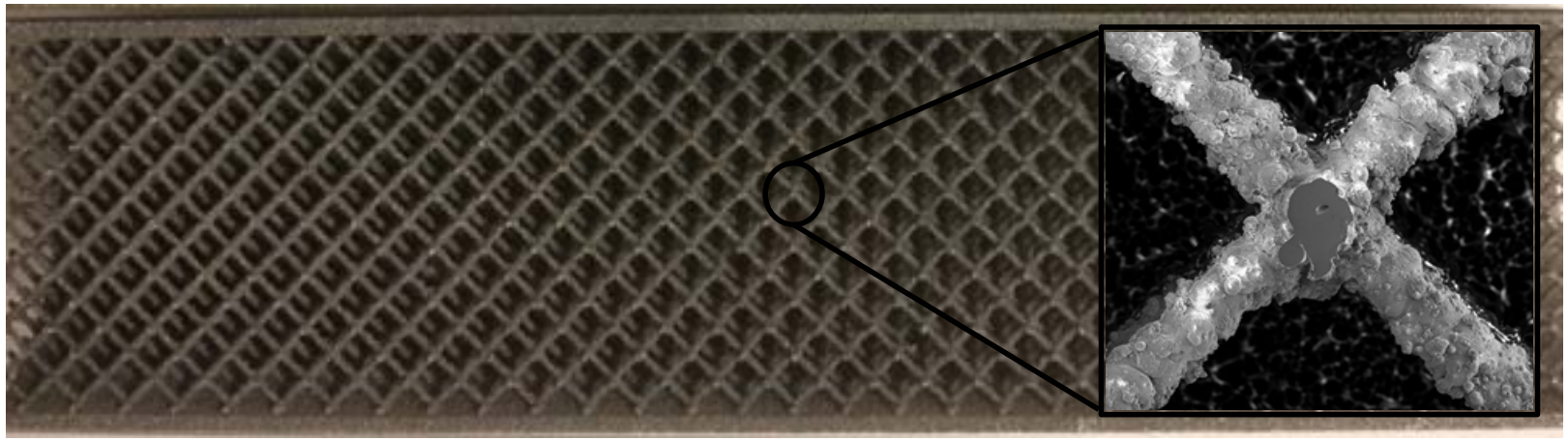
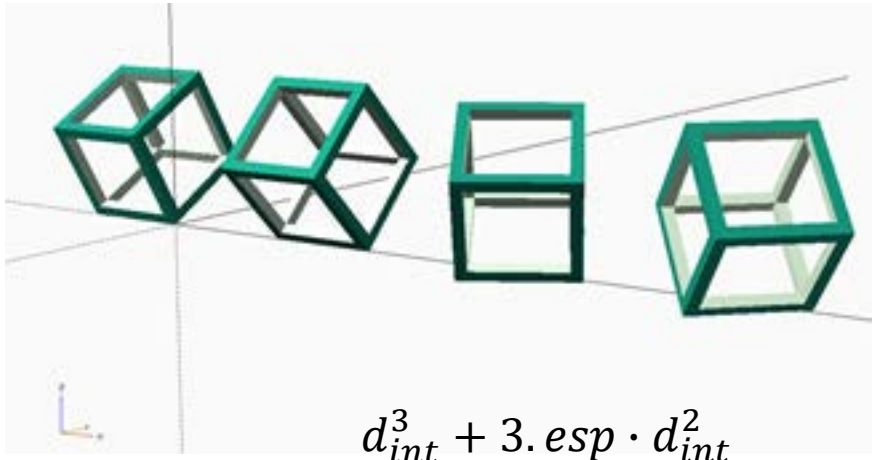
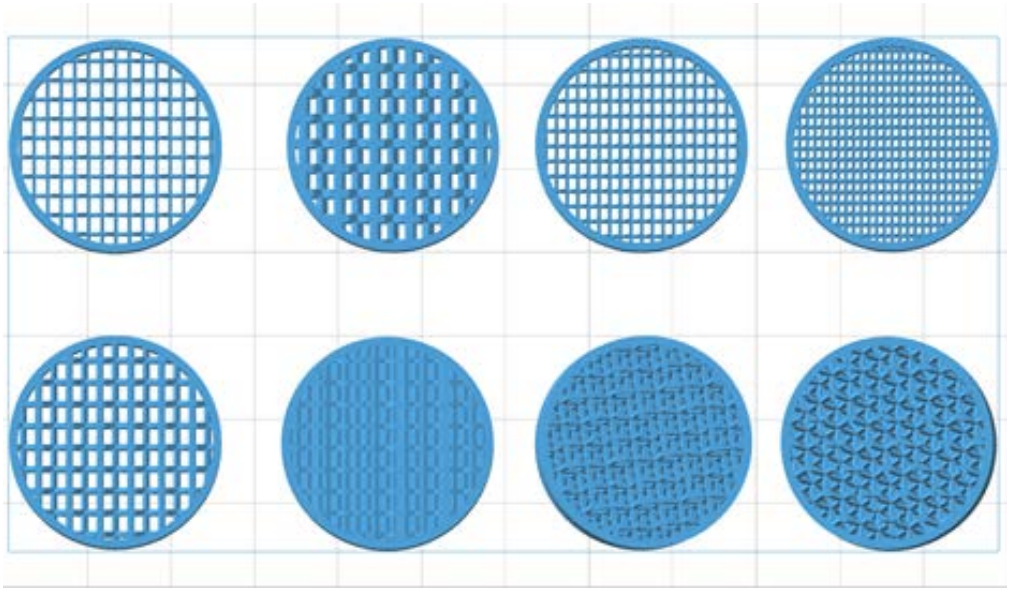
Lattices?





$$\varepsilon_c = \frac{d_{int}^3 + 3.esp \cdot d_{int}^2}{(d_{int} + esp)^3}$$



You can indeed tailor the porosity of the foam

Lattices for catalytic supports

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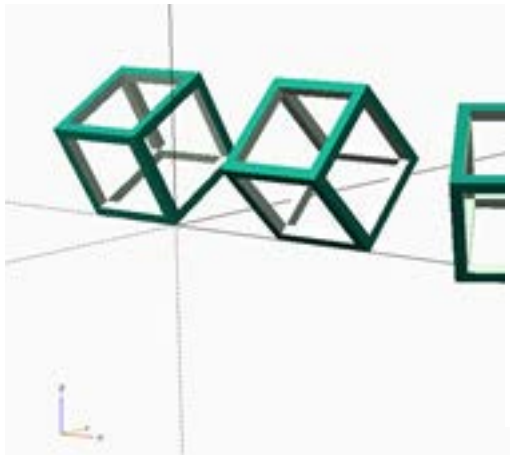
0314 Oslo

Att.: Carlos Grande



Oslo, 6 June 2017 Your ref.: 102012117-2 (PRINTCR3DIT) Our ref.: 126321/LMH/HBS

Dear Mr. Grande,

Patent application no. 20160738 in Norway
SINTEF TTO AS
Method for manufacturing a porous foam support, and porous foam supports for catalytic reactors, adsorption processes and energy storage

Intention to grant
We are pleased to inform you that the Norwegian Industrial Property Office has issued an intention to grant (copy attached) in the above identified patent application.

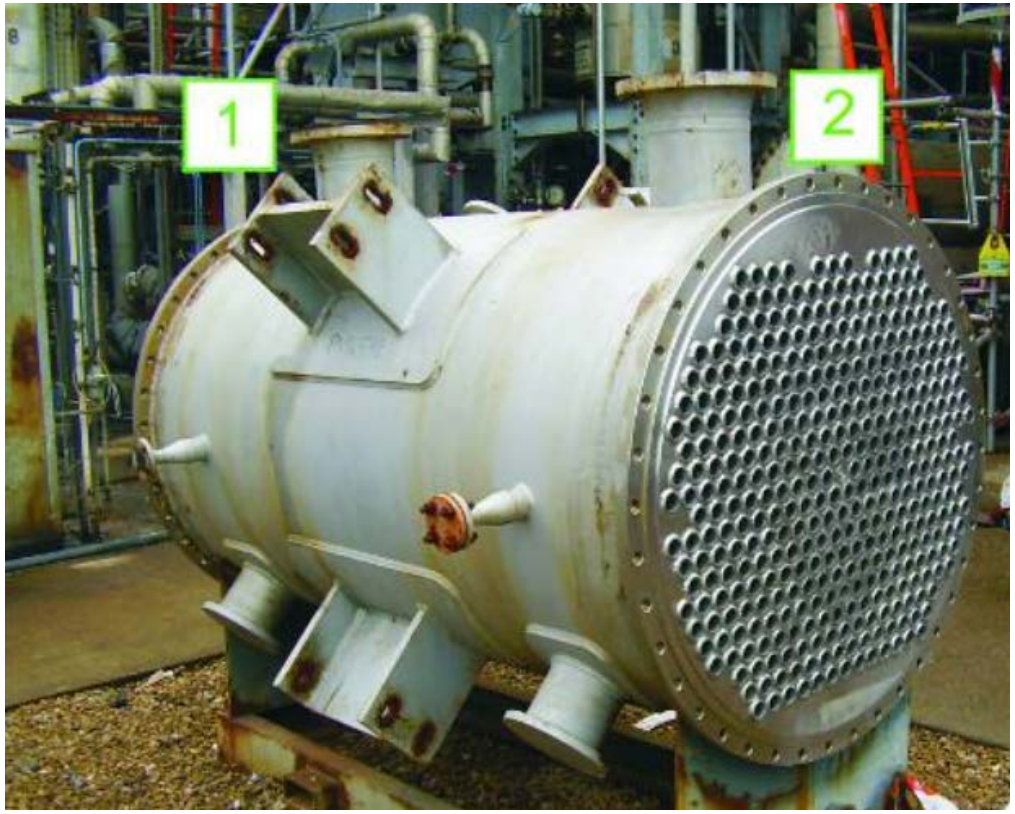
Same unit volume and strut dimension but higher surface area

Lattices in a demo?

- Many issues to be solved at the same time
  - Low pressure drop → high porosity.
  - Material issues → printing in different metals is different
  - 3D printing issues → powder trapped
  - Fitting issues → resolution is around 100 microns…
  - Putting a catalyst on top of them → far away from an ideal surface

Chemical reactors

Equipments where you make reactions.



Industrial reactors exist in many shapes and sizes.

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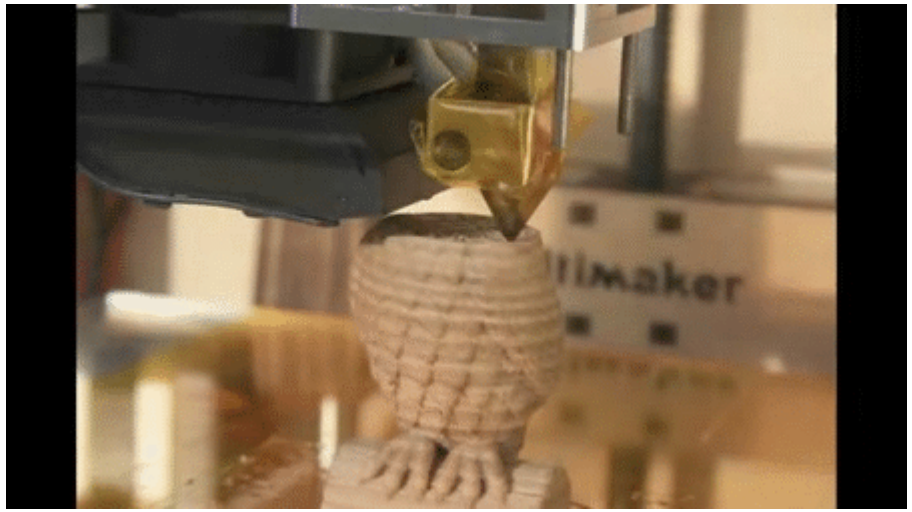
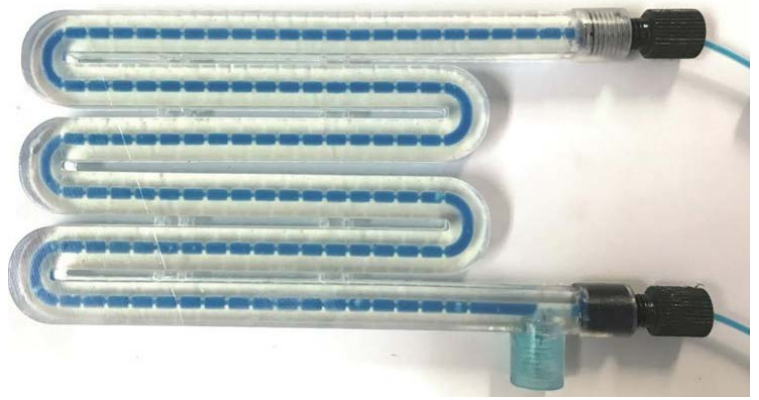
The 3D printing generation

Additive manufacturing is a technique to build things layer by layer.





First reactors are starting to come to life now.

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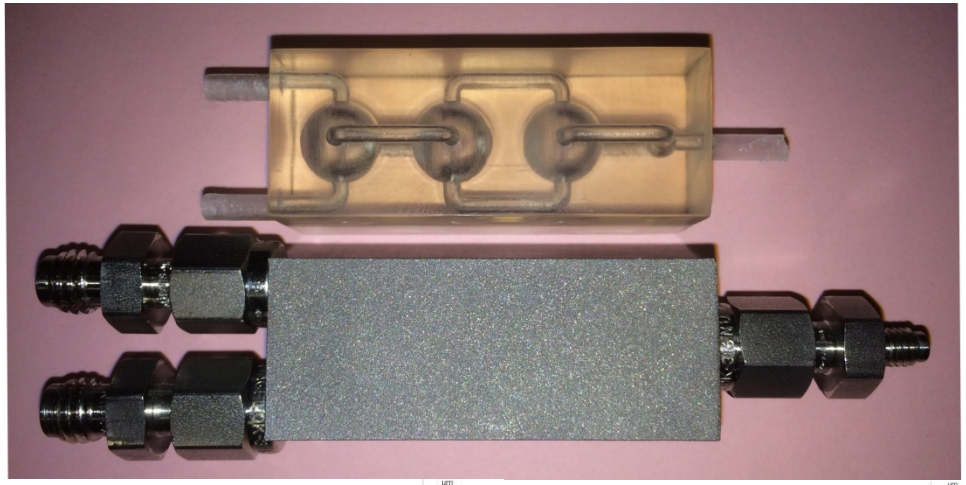
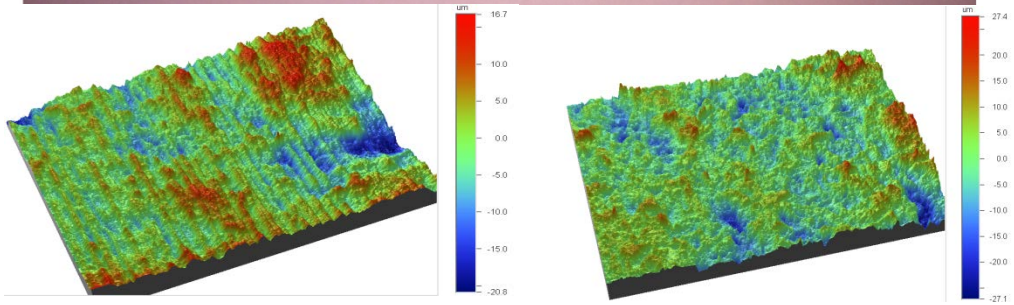
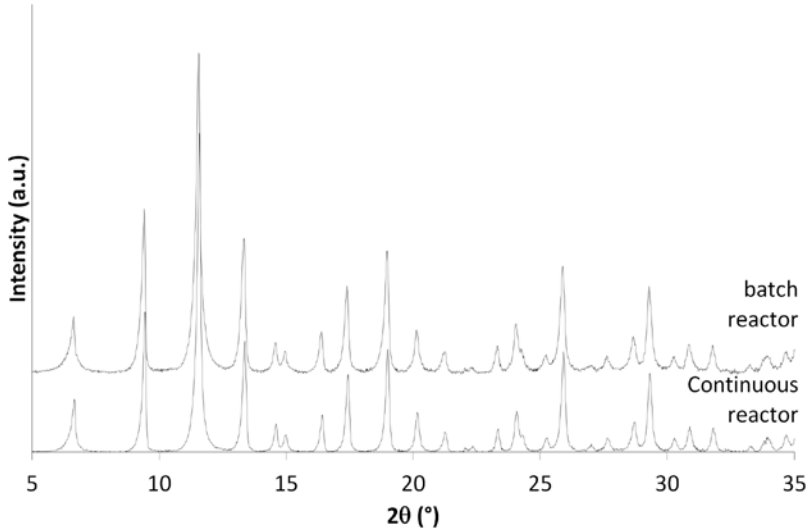
3D static mixer

- The reactor is short but efficient (process intensification)
- Metal reactor handles 80 bar very well.
- We have produced MOF material in it (Cu-BTC or HKUST-1)







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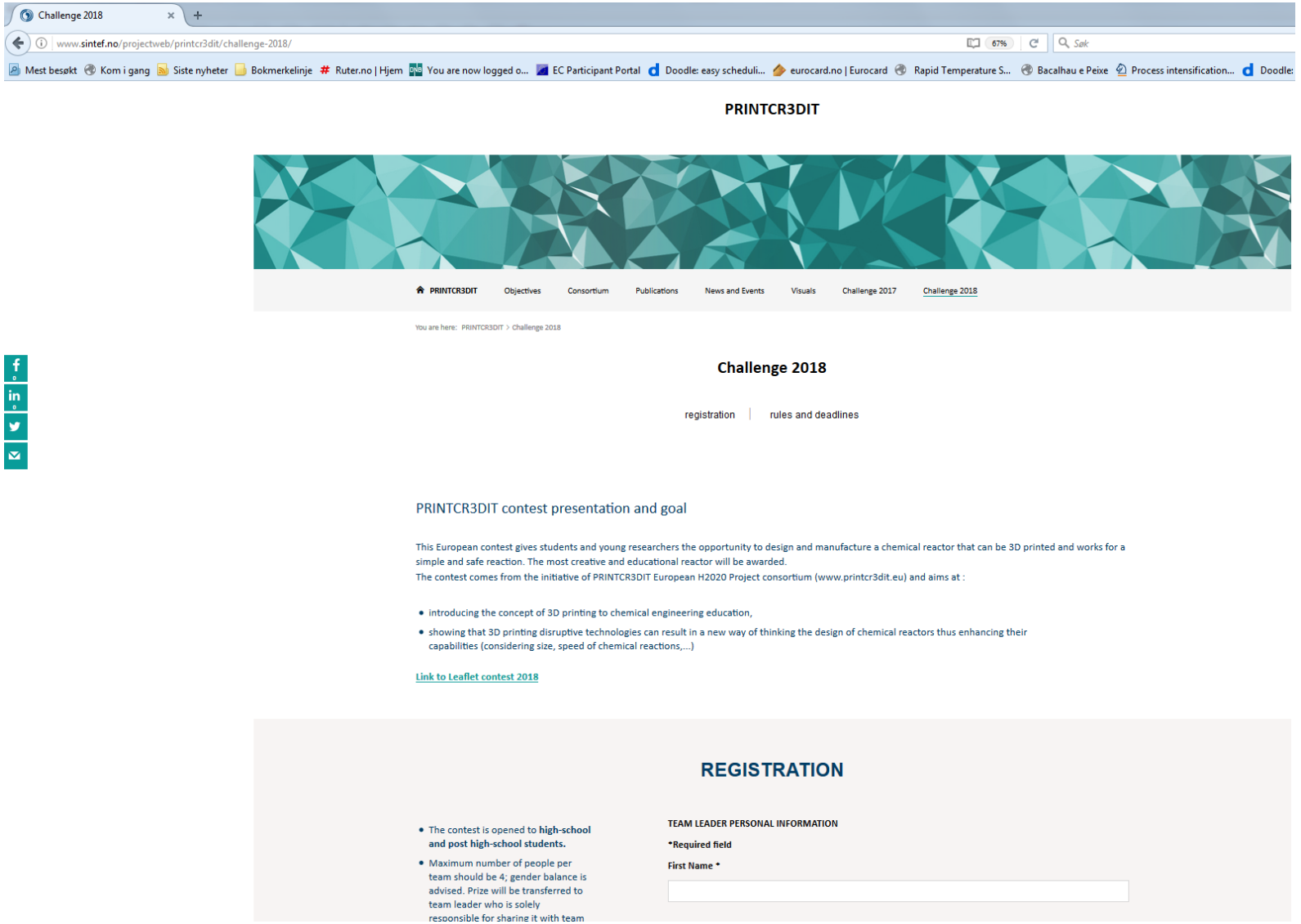
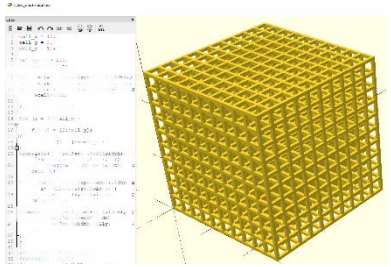
Can you do it? You are more than welcome

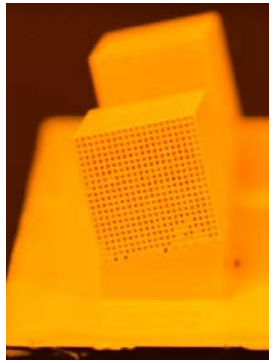


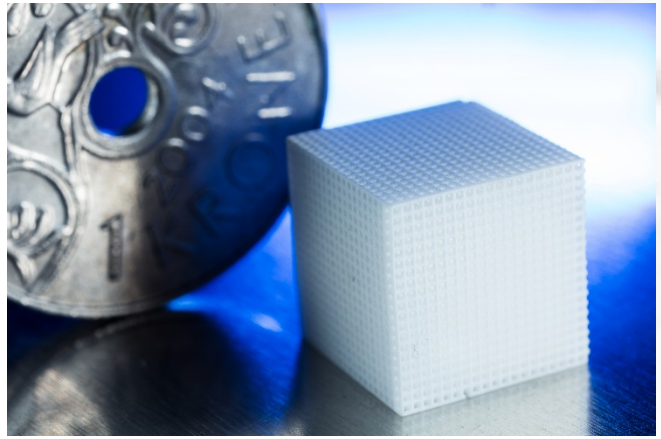
Can you do it? You are more than welcome

Winner in contest of 2017: Jan Klusak from Czech Republic.

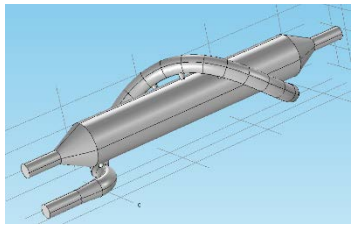
Potential for replication:

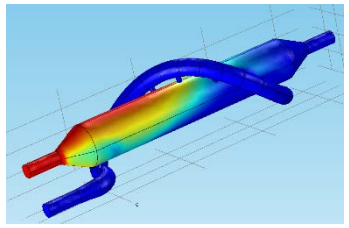


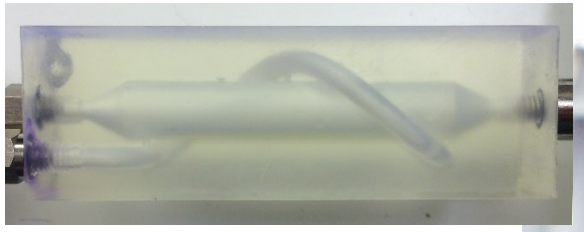




Design & model → 3D printing → Catalyst, reactor & manufacture → Life Sciences / Pharmaceutical







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The project belongs to the SPIRE programme www.printcr3dit.eu.

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