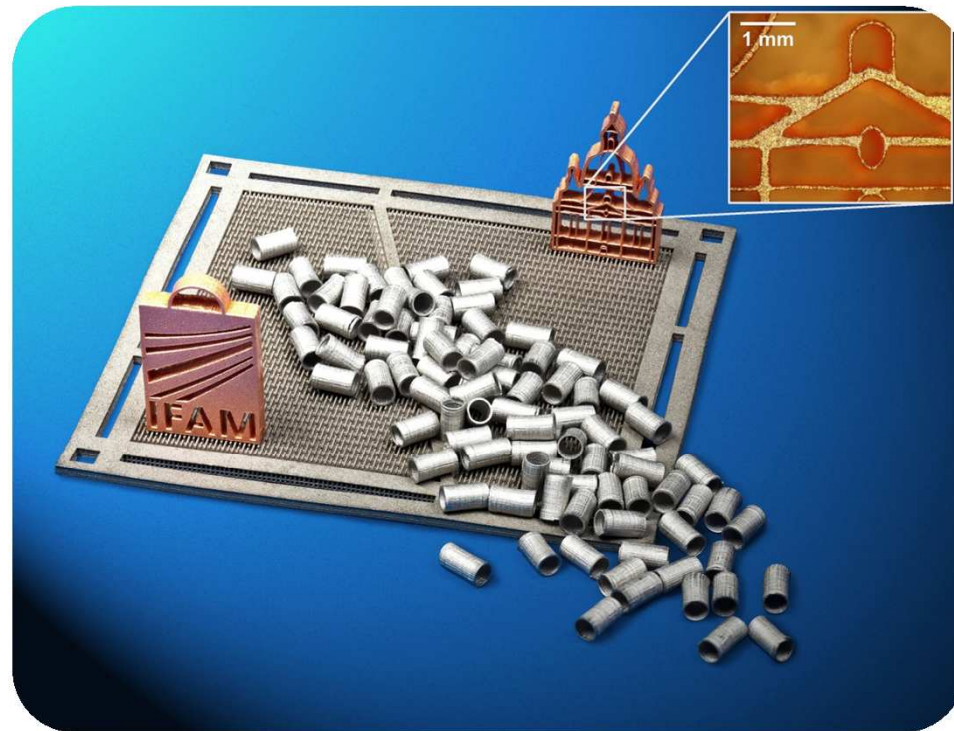
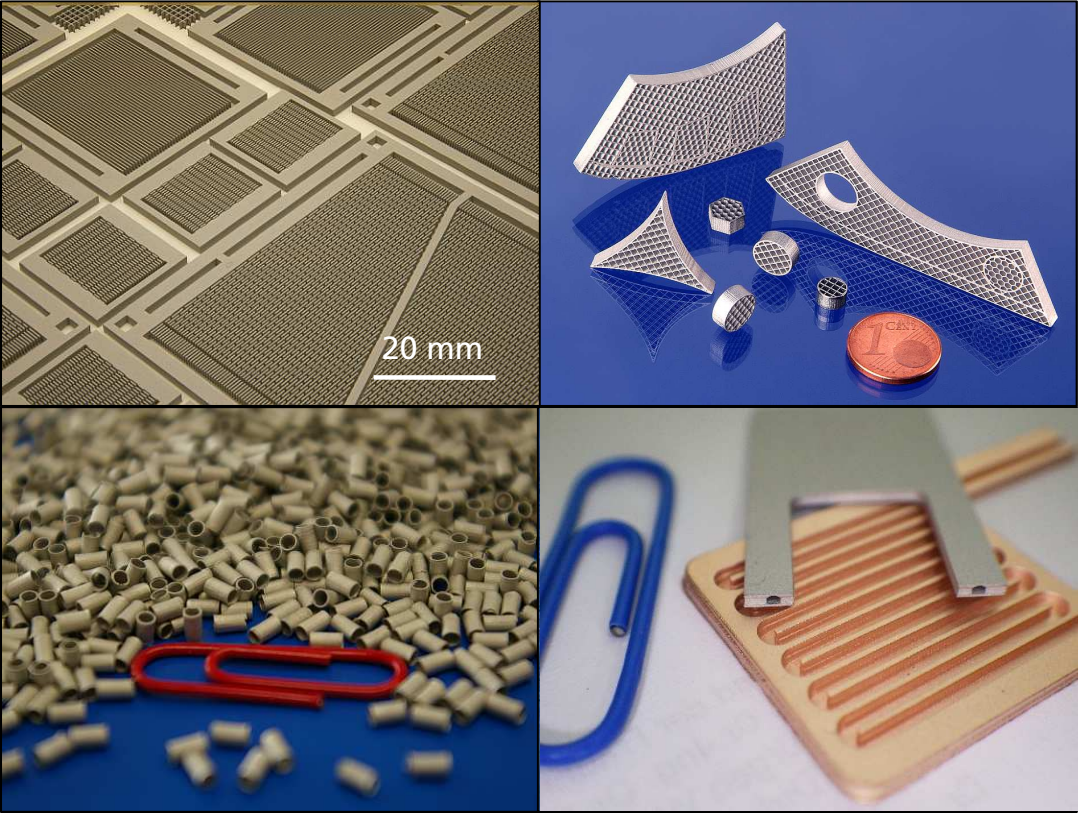

Three-Dimensional Screen Printing of $\text{LaFe}(\text{Co},\text{Mn})\text{Si}$

M. Dressler, T. Studnitzky, B. Kieback



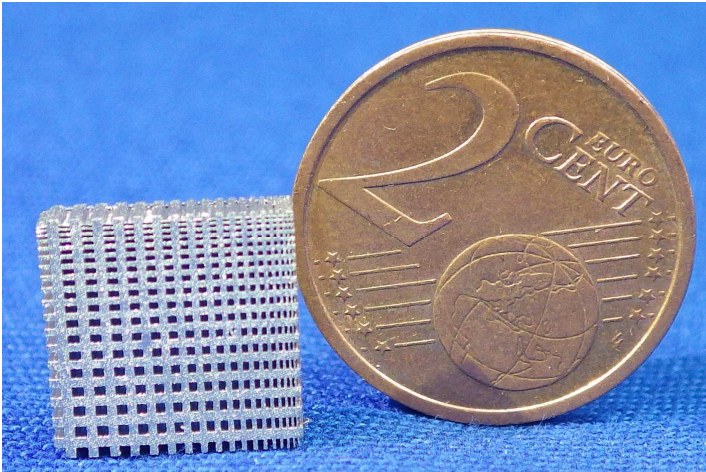
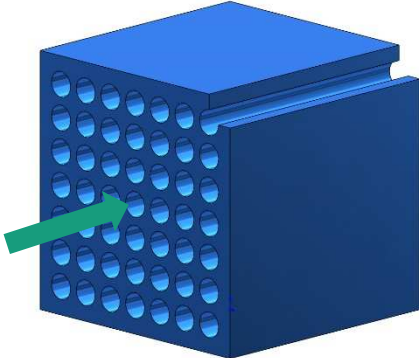
3D-screen printing – sample structures

- flat parts 1-10 mm
- wall thickness 100 µm
- openings 80 µm
- material combinations
- mass production

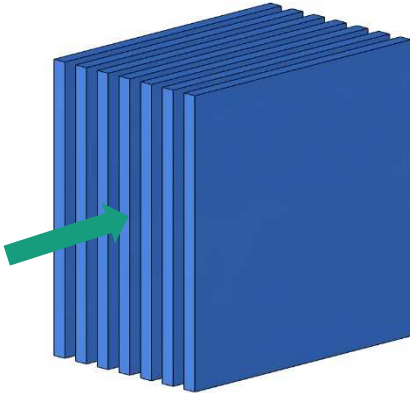


3D-screen printing – application for regenerators

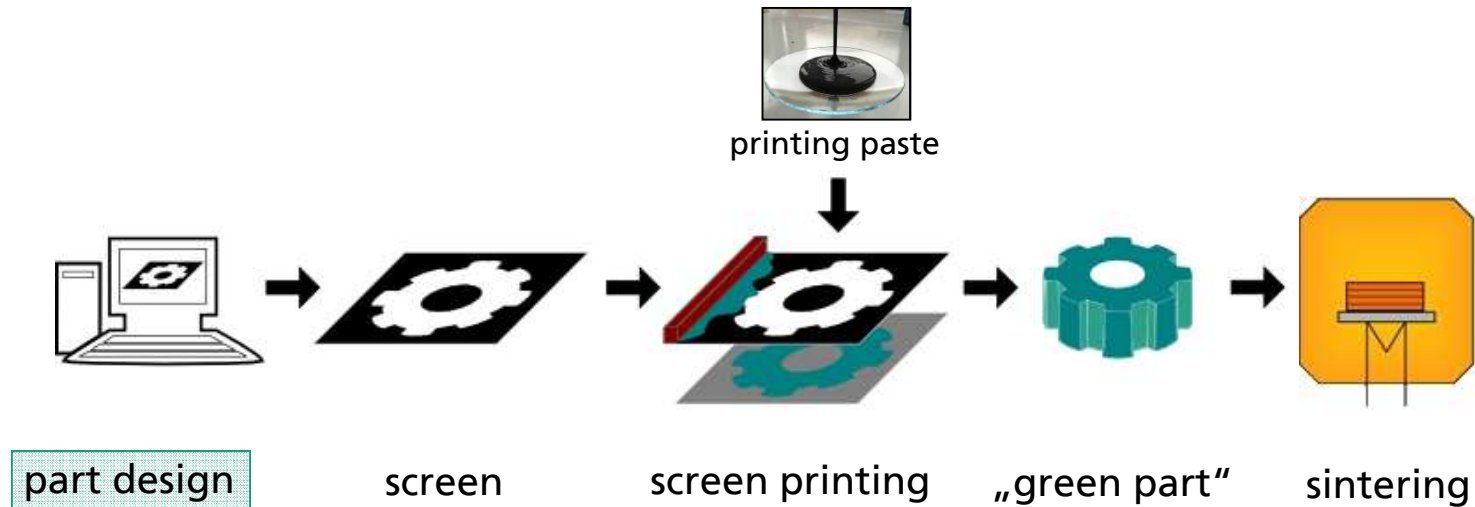
■ channels



■ plates



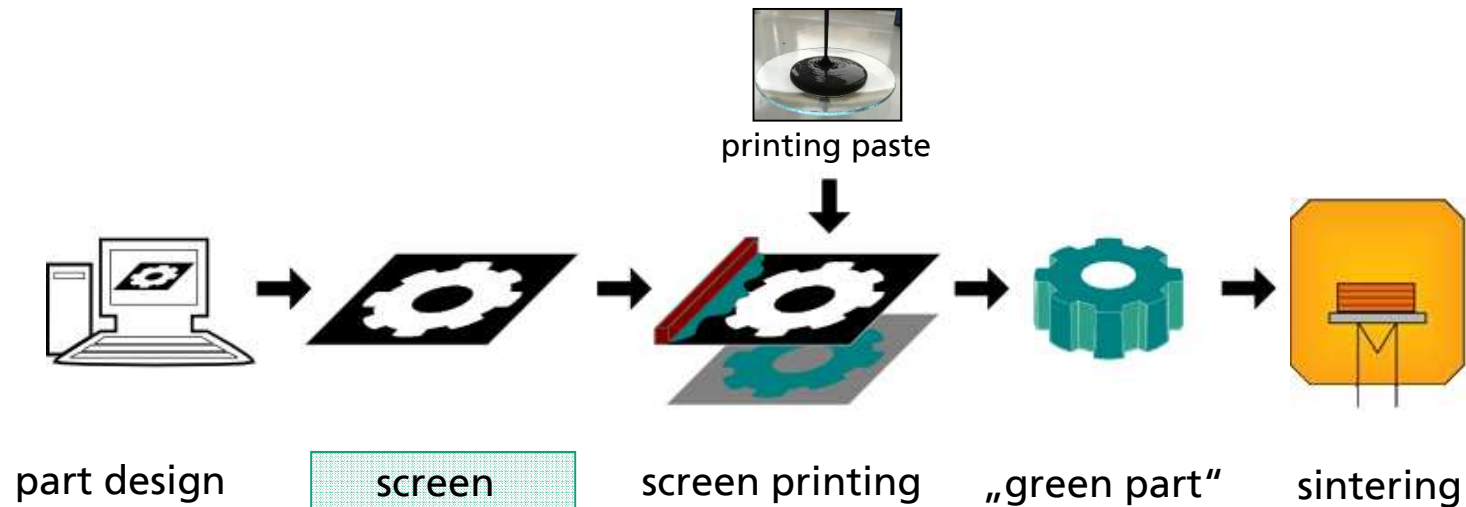
3D-screen printing – process outline



heat exchanger

- FEM optimized part design
- # planes = # screens
- Small # planes preferred
- Screen can be seen as tool

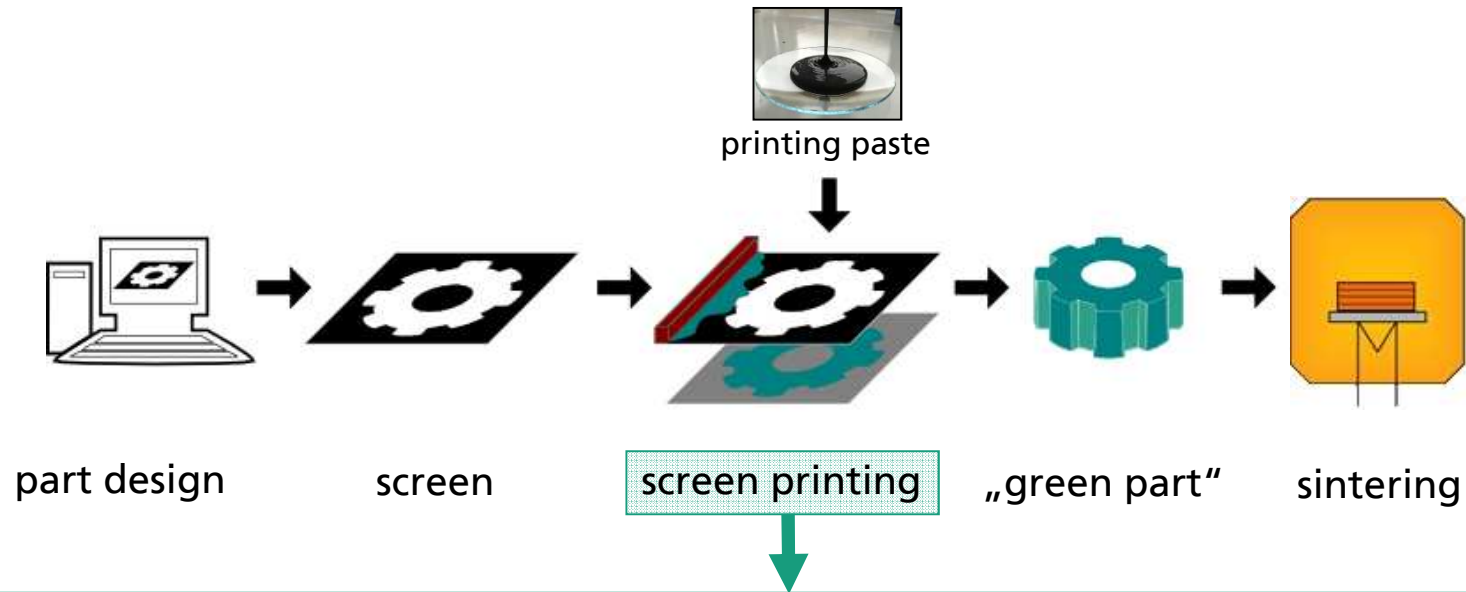
3D-screen printing – process outline



Sample screen (left) and close-up showing coating (right)

- Designing screen layout
- Polymer coating of screen fabric
- Openings transparent for paste
- Manufactured externally
- Fineline-printing: ~60 μm

3D-screen printing – process outline

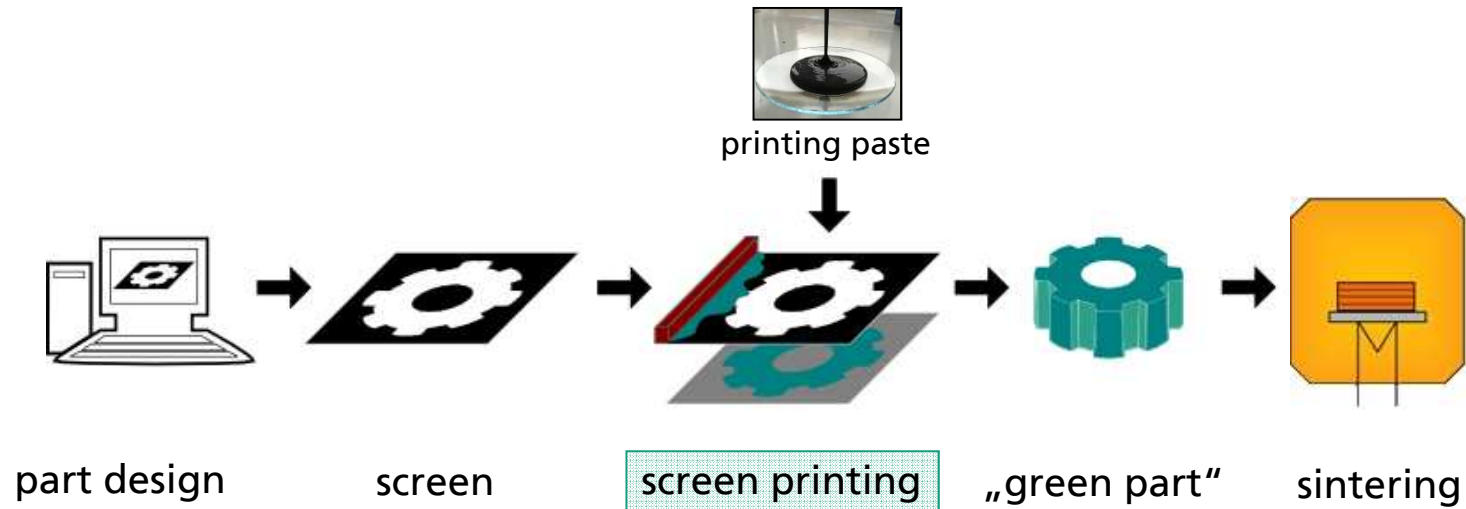


The 'screen printing' step is detailed with the following components and actions:

- Paste preparation**
- Components: powder, additives, binder, carrier**
- Homogenisation of paste**
- Adjusting viscosity for screen printing**

The inset images show: a spoon scooping powder, a bottle of liquid additive, and several small containers of powder.

3D-screen printing – process outline



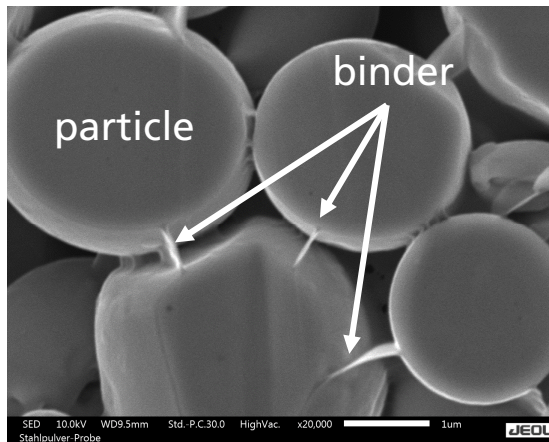
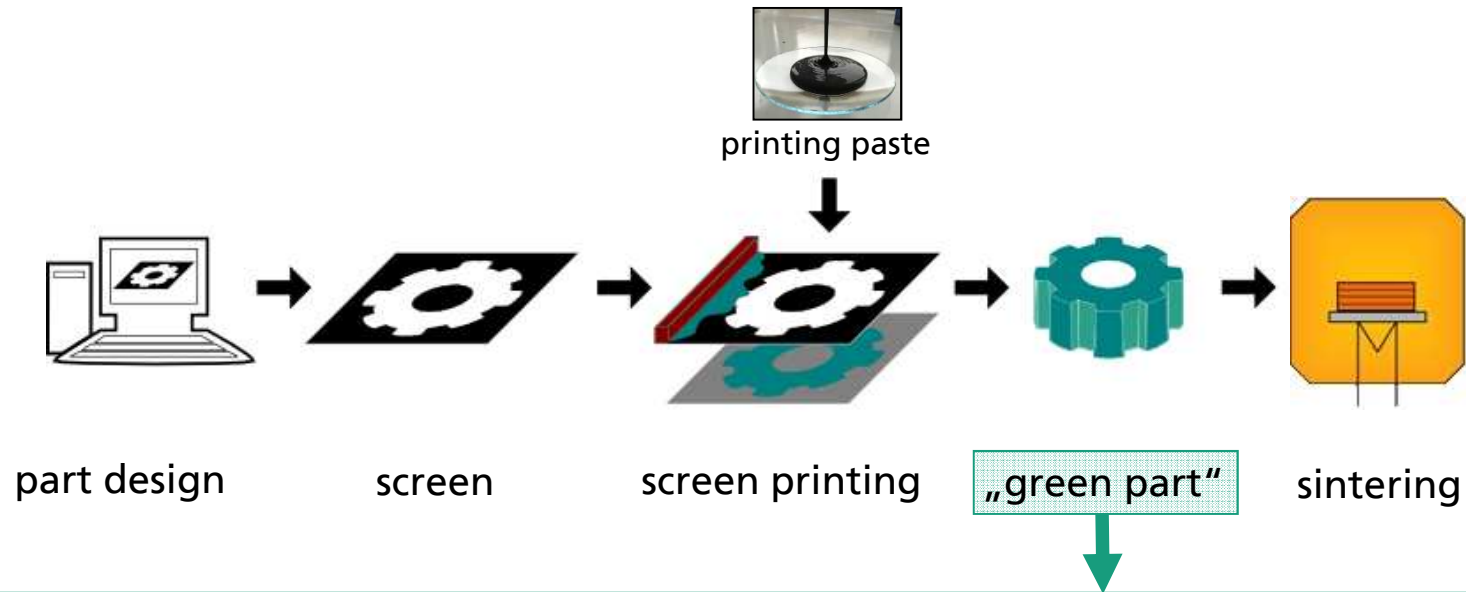
The diagram shows two cross-sectional views of the screen printing process. In the top view, a squeegee (blue) is shown pushing a layer of printing paste (orange) through a screen (grey) onto a substrate (grey). In the bottom view, the substrate is supported by a yellow frame, and the paste has been deposited into a cavity.

- Screen printing
- Repeated printing and curing
- Layer thickness 10-300 μm
- Print-sealing of cavities possible

3D-Siebdruck – Grundlagen

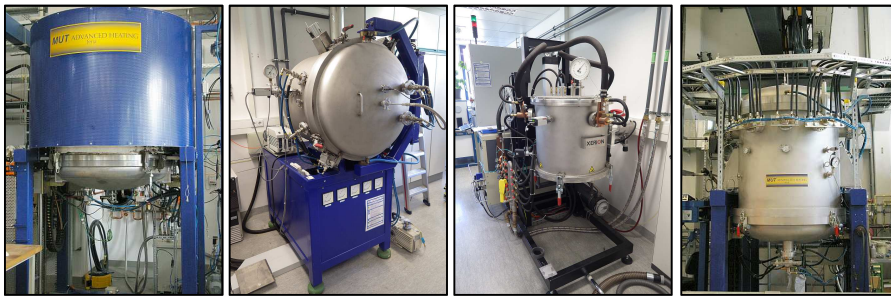
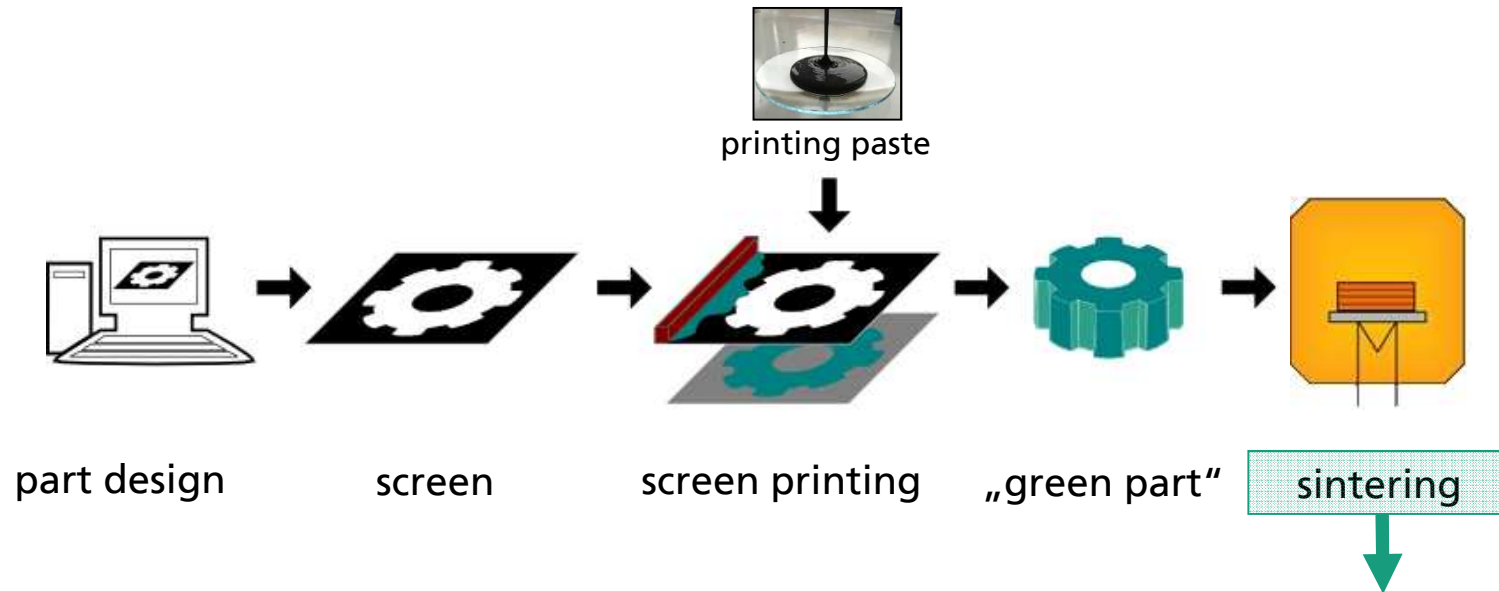


3D-screen printing – process outline



- green part: powder particles glued together with binder
- Direct printing on sinter substrate – no transfer step
- Green machining possible

3D-screen printing – process outline



Heat treatment facilities at Fraunhofer IFAM, branch lab Dresden

- Heat treatment
- Removal of binder/additives
- FTIR assisted optimization
- Sintering to nearly full density

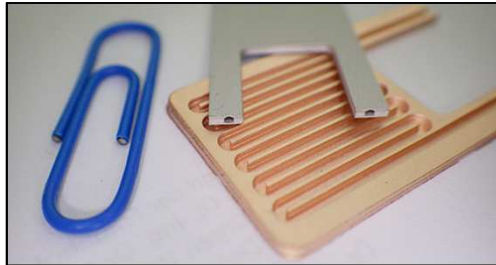
3D-screen printing – equipment



- 1 μm precision height increment
- 100 μm feature resolution (xy-axis)
- automatic screen alignment
- printing area 200 x 300 mm²
- air-conditioned printing chamber
- 2 printing tables
- IR- and UV-curing
- net-buildrate ca. 200 cm³/h (sintered)

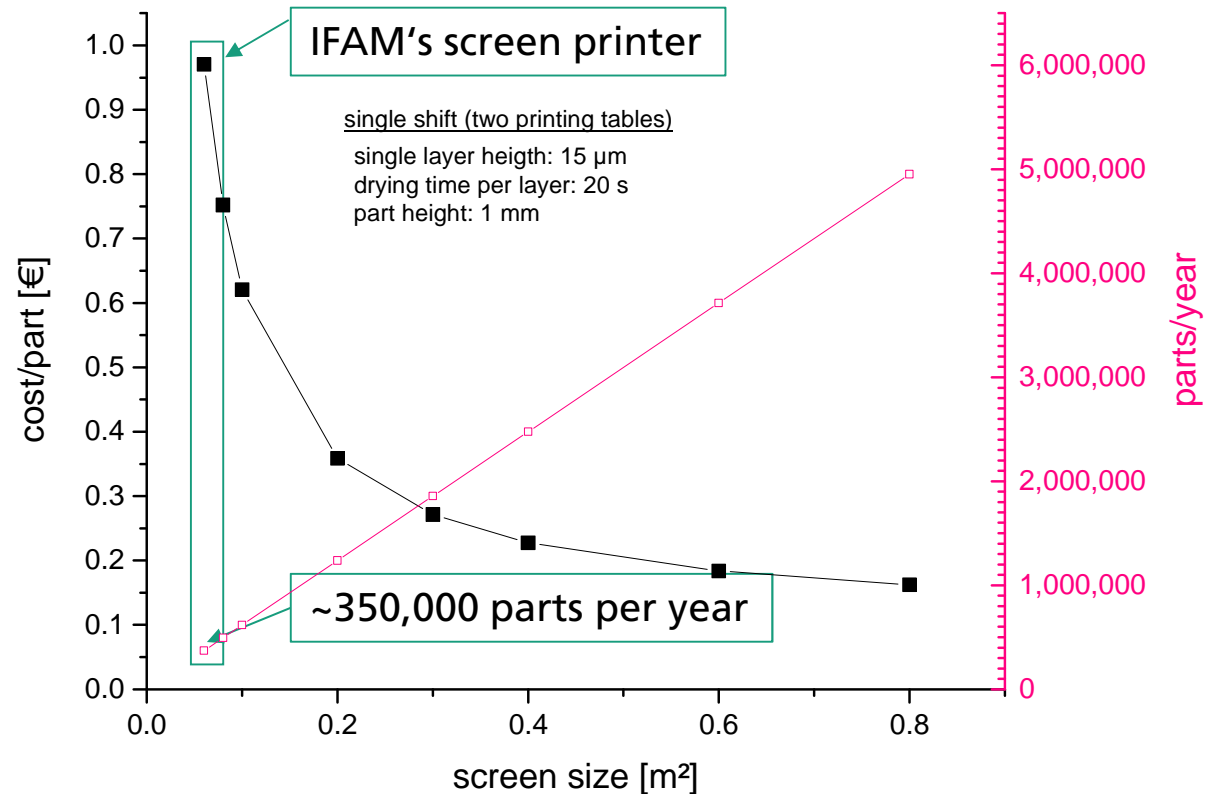
3D-screen printing – case study

sample part



- cost reduction
- bigger screens
- flat parts
- faster curing
- thicker layers

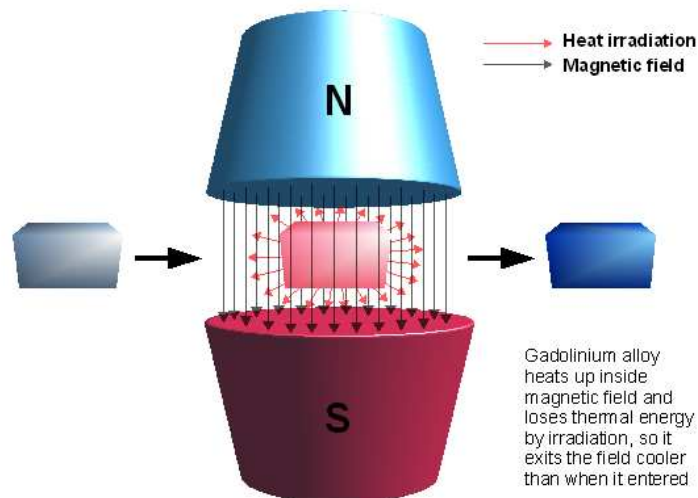
influence of screen size on cost/part (2x3 cm)



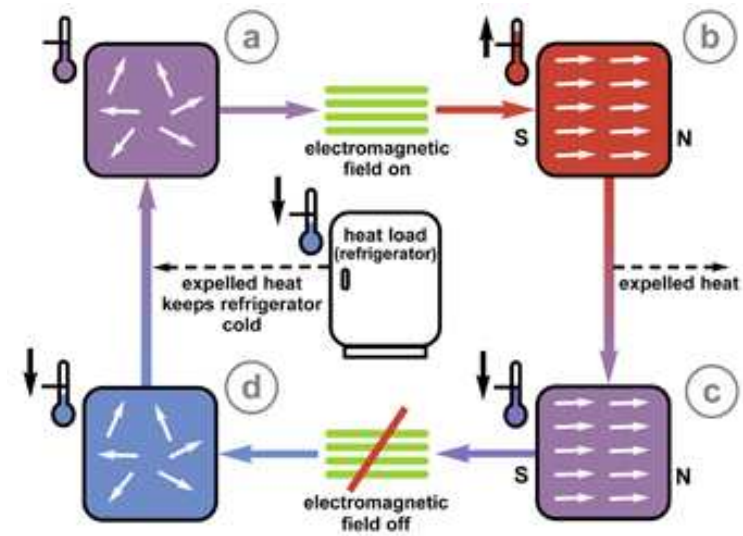
3D-screen printing – application for LaFe(Co,Mn)Si

DRREAM

Drastically Reduced Use of Rare Earths in Applications of Magnetocalorics



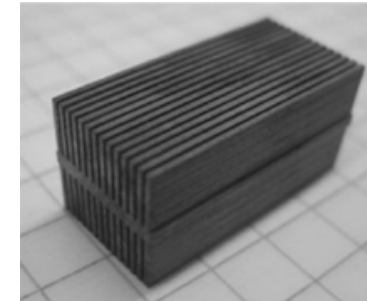
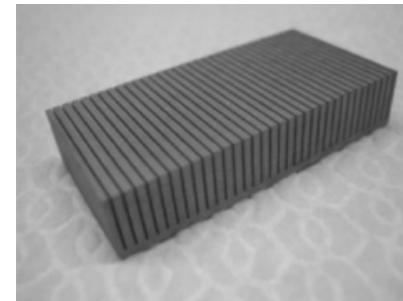
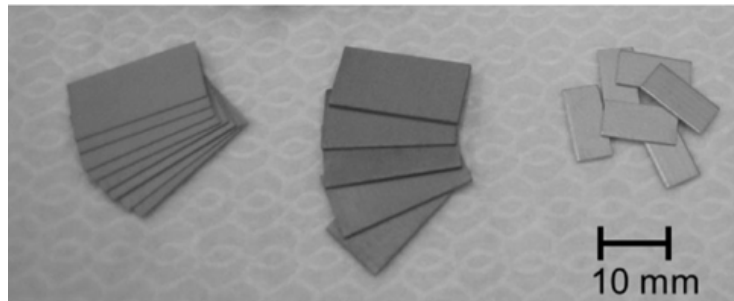
<http://www.wikipedia.org>



http://www.nist.gov/ncnr/refrigeration_012709.cfm

3D-screen printing – application for LaFe(Co,Mn)Si

■ State of the art



A. Barcza et al., *Magnetic Materials for the 21st Century*

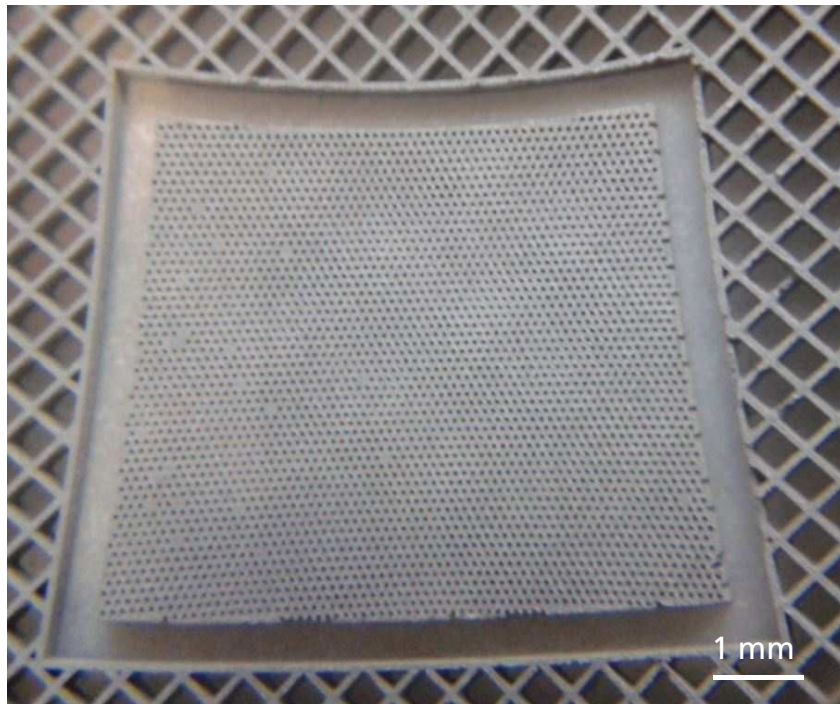
- hard to machine
- brittle material
- material loss

3D screen printing

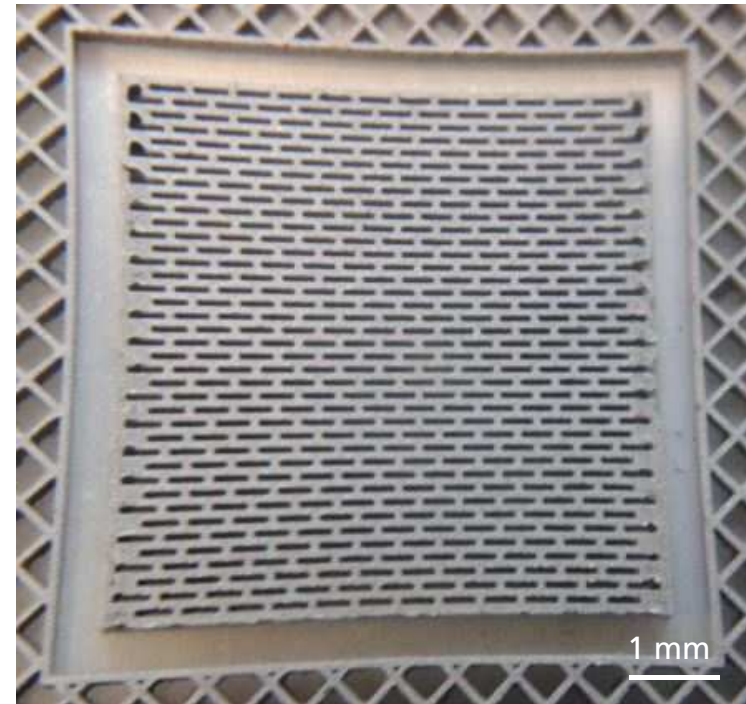
- no machining needed
- suitable for brittle materials
- less material loss

3D-screen printing – application for $\text{LaFe}(\text{Co},\text{Mn})\text{Si}$

- Printing results



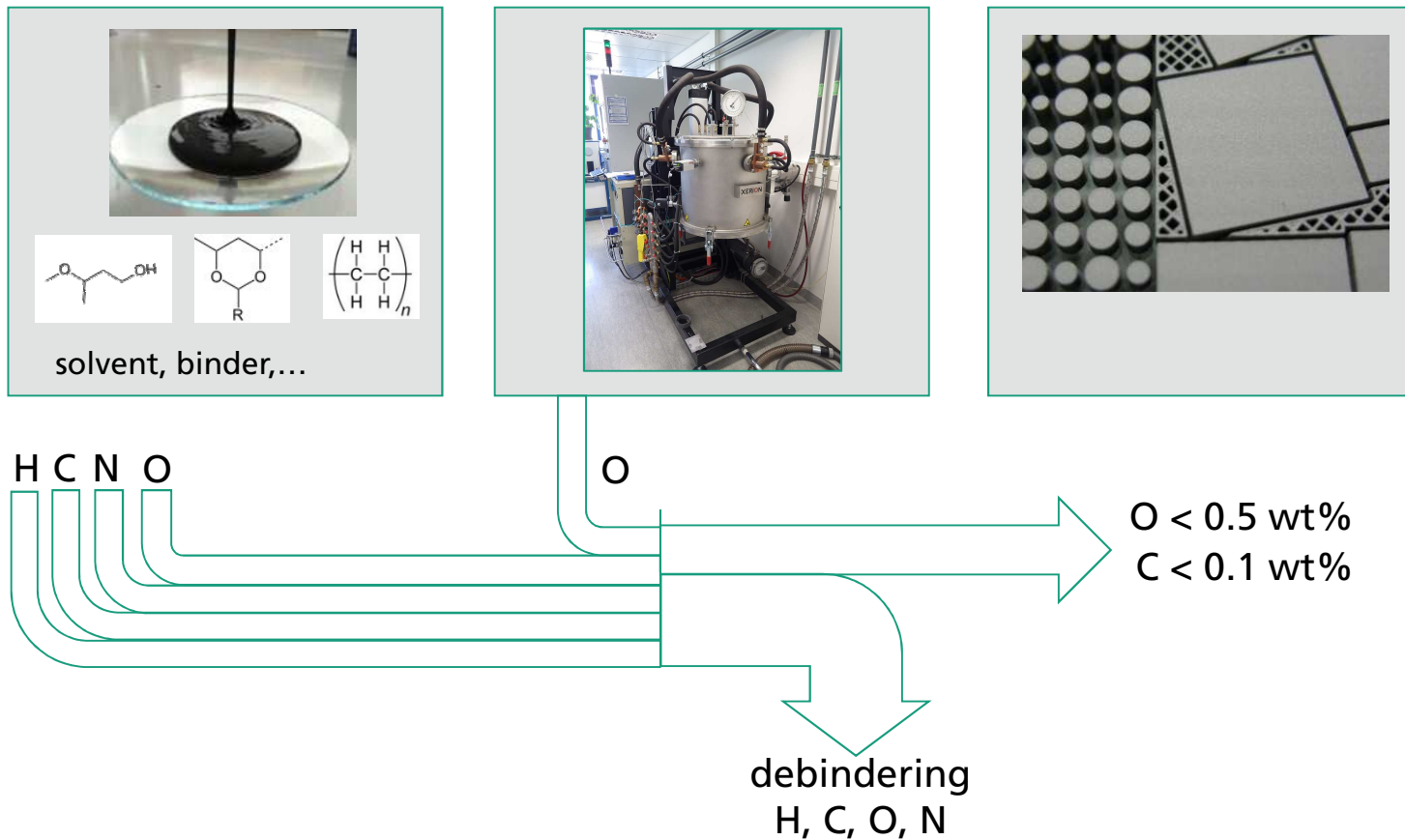
M. Dressler, IFAM-Dresden



M. Dressler, IFAM-Dresden

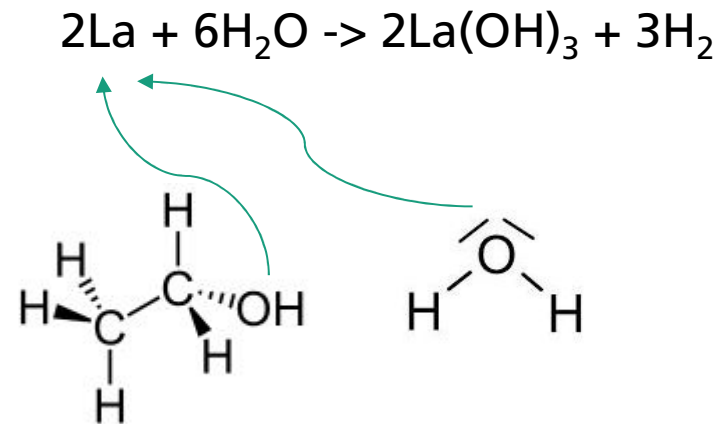
3D-screen printing – application for LaFe(Co,Mn)Si

- Lanthanum is extremely oxygen sensitive



3D-screen printing – application for LaFe(Co,Mn)Si

- New non-aqueous paste is needed. New binder required.



3D-screen printing – application for LaFe(Co,Mn)Si

- Optimization task: debinding vs. paste viscosity for printing

organics content



debinding

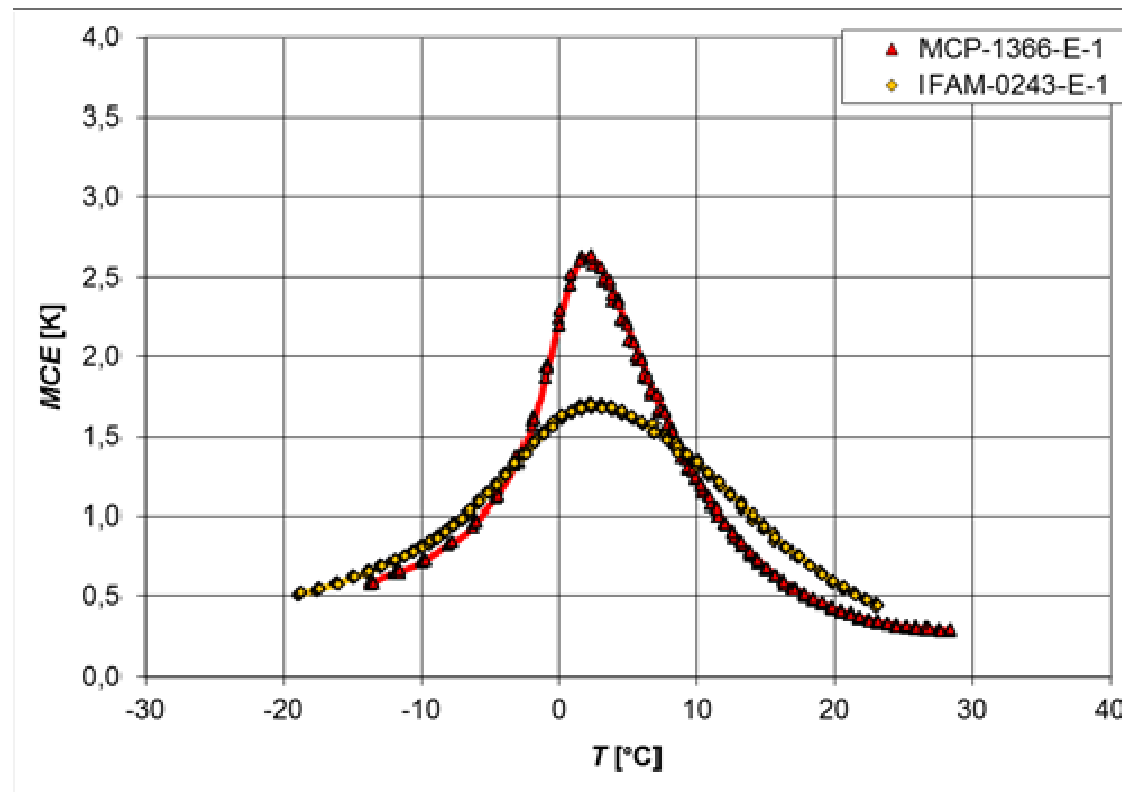
viscosity

printability

—	+	+
+	+	+
+	—	—

3D-screen printing – application for LaFe(Co,Mn)Si

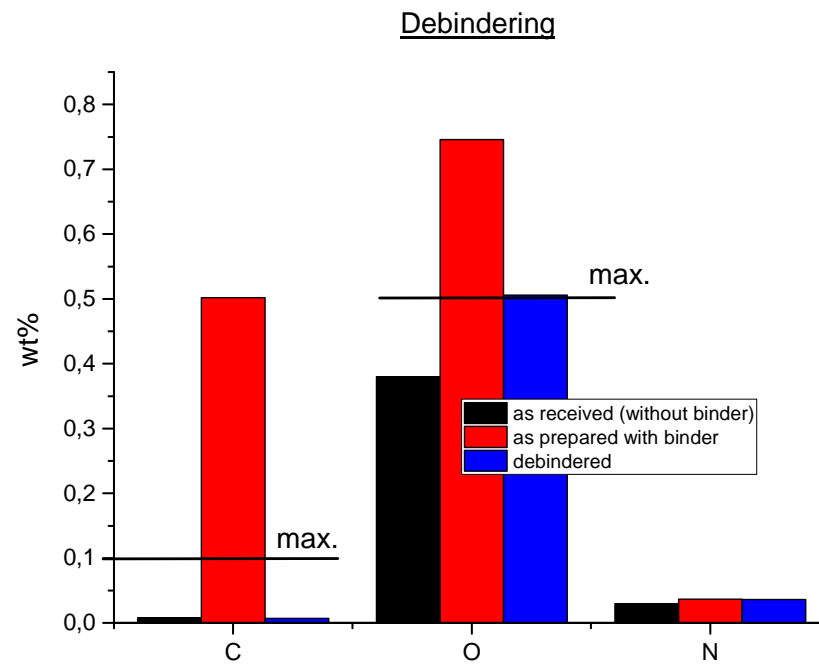
- T_c well controllable. ΔT susceptible to oxygen pick-up



H. Vieyra, Vacuumschmelze GmbH & Co. KG

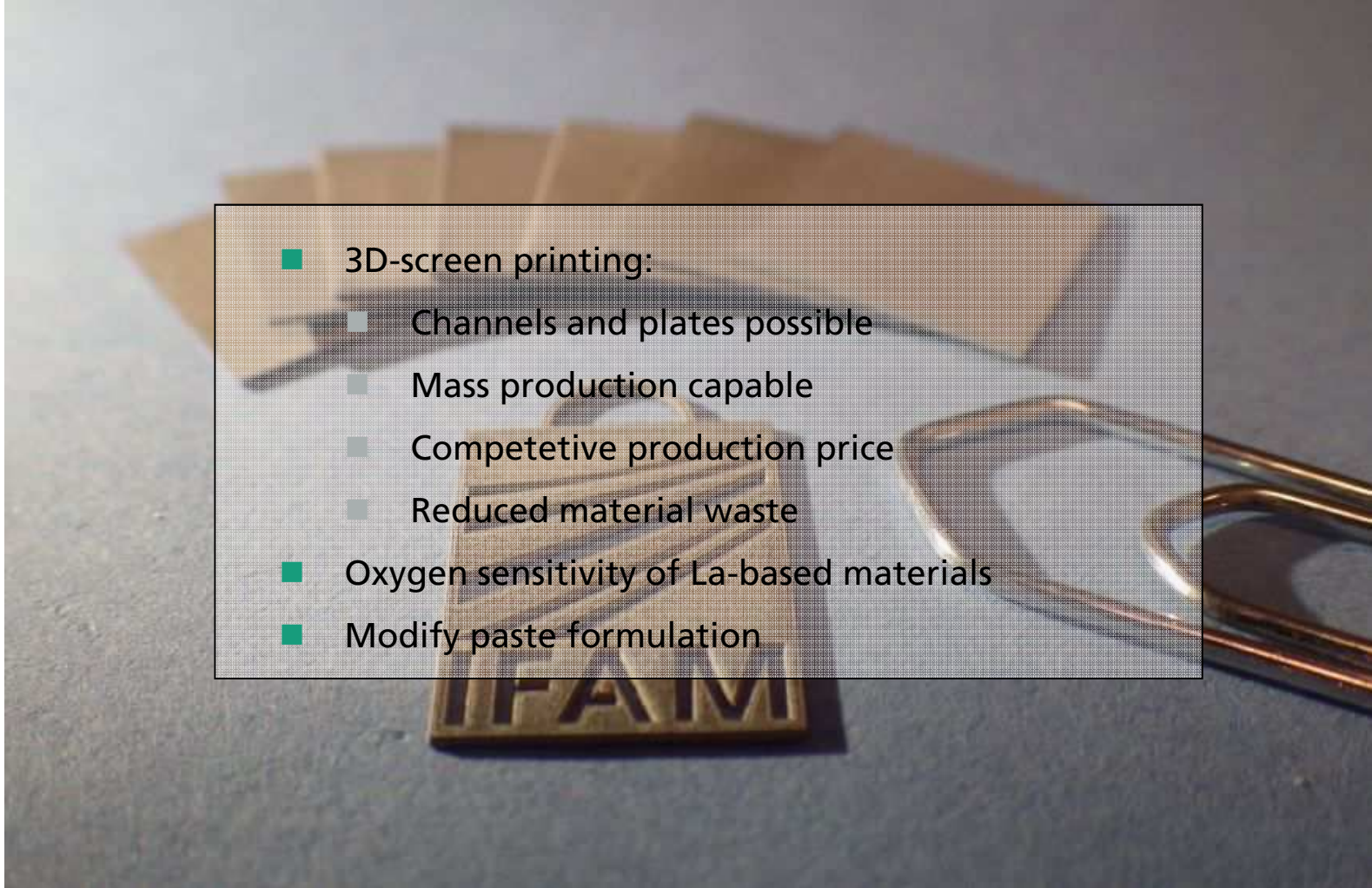
3D-screen printing – application for LaFe(Co,Mn)Si

- Well debinderable binder substance



data provided by H. Vieyra, Vacuumschmelze GmbH & Co. KG

Druckergebnisse mit $\text{La}(\text{Fe},\text{Si})_{13}$

- 
- 3D-screen printing:
 - Channels and plates possible
 - Mass production capable
 - Competitive production price
 - Reduced material waste
 - Oxygen sensitivity of La-based materials
 - Modify paste formulation