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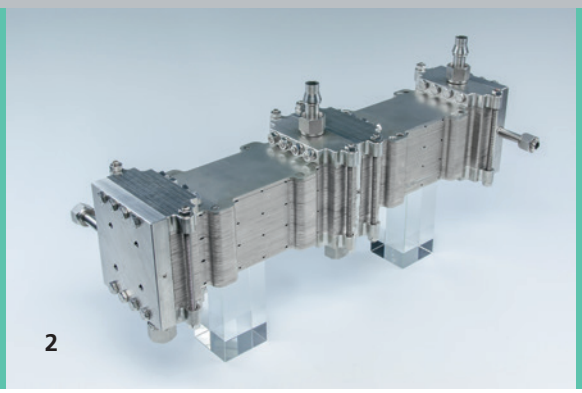

1 *Slice, cut out of a vacuum brazed stacked plate microreactor.*
2 *Modular microreactor, vacuum brazed.*

NOVEL MODULAR MICROSTRUCTURED REACTORS IN INDUSTRIAL SCALE

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IN COOPERATION WITH
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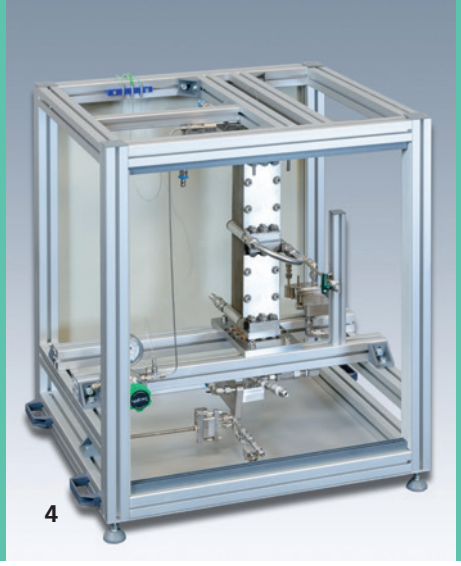
Modular and flexible microreactors

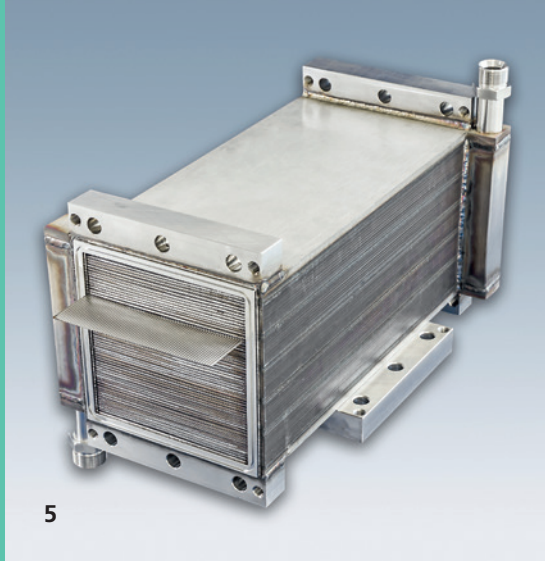
From early on Fraunhofer IMM has considered the modularity and flexibility of its reactor concepts (Fig. 2) and their easy integration in industrial environment as essential for a broader uptake of the technology up to production scale. This fits perfectly to the current trends in chemical processing with buzz words like future factory concepts and modular plants. Flexibility is required for adapting the reactors to the different process needs as throughput, residence time or reaction conditions.

Modularity of the reactor concepts allows realizing a broad range of different reactors, optimally adapted to different chemical reaction processes, and in addition a cost efficient manufacturing process of these reactors.

Novel manufacturing techniques

Microstructured reactors have been successfully applied in lab and in several cases even up to pilot and production scale. But there is still a lack of appropriate and cost-efficient manufacturing techniques for microstructured devices which are suited for the conditions of production scale. Newly developed manufacturing techniques, based on microstructuring of flat metal foils using roll embossing bridge this gap. Plates microstructured by roll embossing can be differently combined and treated, e.g. coated with a catalyst and joined by laser welding or, if increased pressure stability is required, joined by vacuum brazing. Instead of microstructured plates, open-cell metal foam sheets can be applied, e.g. for (re)dispersion of non-miscible fluids.





Microreactor modules based on roll embossed plates

Microstructuring by roll embossing (Pic. 3) is suited for both mass production and for larger dimensions than previously possible. It overcomes technological limits of chemical and mechanical structuring methods. Roll embossing is automatable and enables cost-savings with increasing lot size. This technique is also applicable for other corrosion resistant metals like Hastelloy® or Titanium.

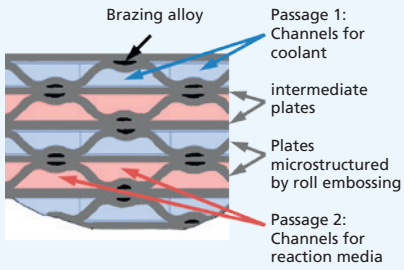


Fig. 1: Schematic of a microreactor using roll embossed plates.

Fig. 1 exemplarily shows the basic design of a vacuum brazed stack comprising both on the reaction and the cooling side plates which were microstructured by using roll embossing. This solution is protected by national and international patents.
Whereas the coolant enters and leaves the channels of the passage 1 sideways, the reaction medium flows through the straight open channels from one to the other front side of a module. This allows connecting several reaction modules in series to increase the residence time and to temper each module at an individual level.
In case of laser welded reactors, the flat and the corrugated plates are not joint together, which enables exchanging corrugated plates coated with catalyst if it has to be renewed (Pic. 5).

Microreactor modules with open-cell metal foam plates

Optionally the reaction side can comprise slits for the insertion of metallic or ceramic open-cell foam plates which are beneficial in creating and sustaining a high interfacial area required for two phase reactions. Furthermore, such foam plates can also be coated with high loads of catalysts, enabling the renewal of catalysts also for vacuum brazed reactors.

Sample applications in pilot plants

Due to their compact design and superior properties, microstructured reactors are well suited for process intensification and for use in modular and compact chemical plants. Both aspects played a role for the first application of such modular microreactors as main component of the reaction module for Microinnova's modular Flow Miniplant (Pic. 4).

A vacuum brazed reactor (Pic. 2) was applied for the highly exothermic epoxidation of soybean oil, a liquid-liquid biphasic process. A similar laser welded reactor was used for a single-phase propoxylation process, which is also highly exothermic. Furthermore, a special high pressure/high temperature version of the foam reactor was made for the supercritical production of biodiesel.

References

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3 *Roll embossing tool for microstructuring of metal strips (by courtesy of Wetzel GmbH).*
4 *Flow Miniplant reaction module.*
5 *Laser welded large microreactor with exchangeable reaction plates.*

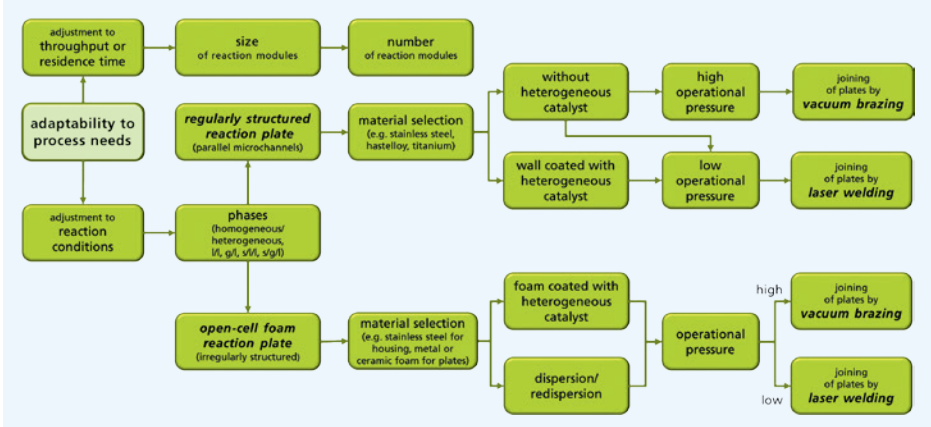

Fig. 2: Concept of modular and flexible microreactors.