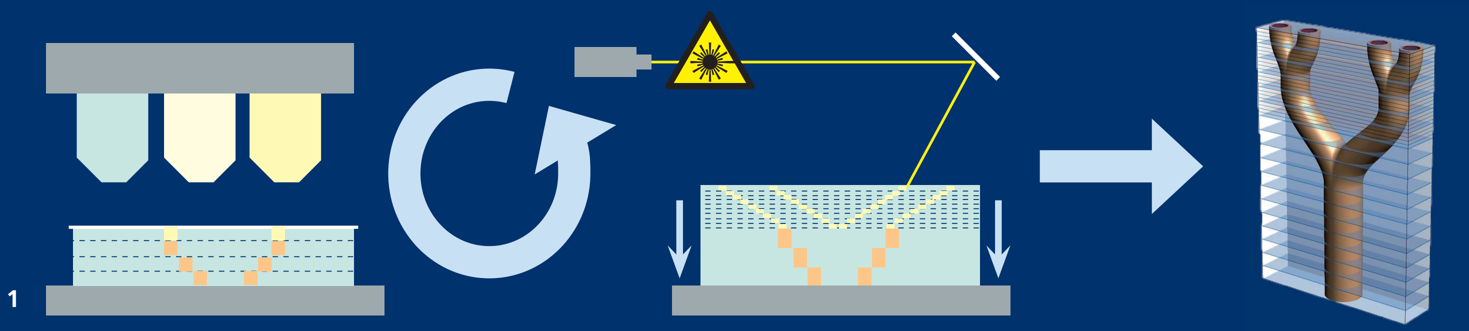

1 *Scheme of the combined inkjet and TPP manufacturing process.*

RAPID MANUFACTURING OF ARTIFICIAL BLOOD VESSEL SYSTEMS FOR TISSUE ENGINEERING APPLICATIONS

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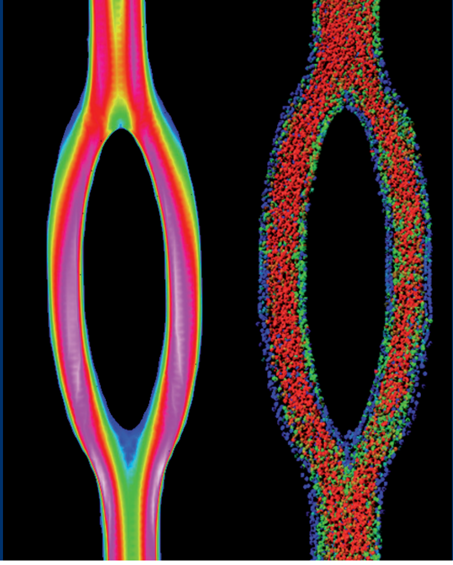
The objective in tissue engineering is to create functional tissues and organs *in vitro* and to use them as transplants or *in vitro* test systems. The generation of larger tissue constructs is limited due to the lack of a proper supply of nutrients to the tissue by a vascular system. As part of an ongoing research project, a consortium of five Fraunhofer Institutes has joined together to develop an artificial blood vessel supply system.

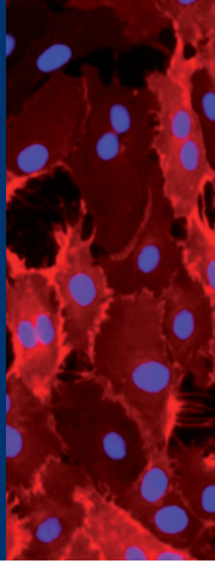
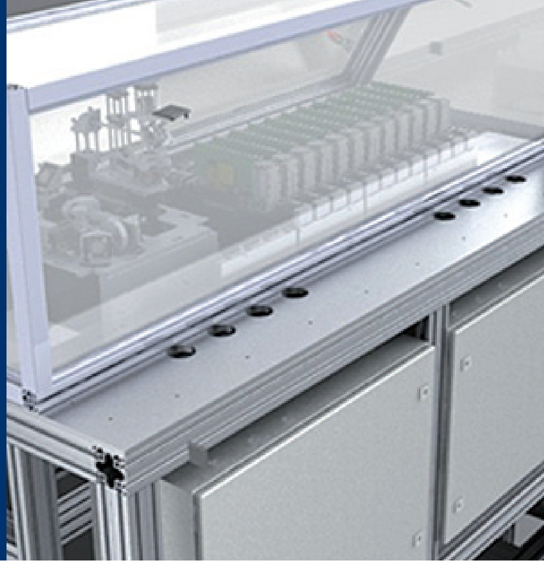
With rapid prototyping and biofunctionalization to artificial blood vessels

We use modelling and simulation in order to develop a bio-inspired technical realization of a vascular system, which provides the same functions as a natural blood vessel system.

We provide the technology for industrial manufacturing of biofunctional structures for tissue engineering and medical applications.

- Material: Synthesizing photo-curable and printable resins to generate biocompatible materials with customized elastic properties
- Process: Combining 3D inkjet-printing and two-photon polymerization (TPP) to achieve micrometer to centimeter structures
- Modelling: Functional design of a branched vascular system and generation of CAD data
- Biofunctionalization: Immobilizing biopolymers and colonization of endothelial cells onto the material surface



Printable resins

Resins for 3D rapid prototyping need to fulfill a wide range of characteristics to achieve material requirements of the prototyped component.

We composed photo-curable blend systems in regards to viscosity, curing speed, wavelength, and cytocompatibility. The post-cured materials are adjusted for flexibility, tensile strength, hydrophobicity, and are ready for further (bio-)functionalization.

Freeform fabrication with high resolution

Additive manufacturing methods enable production of objects of complex geometries, such as artificial blood vessels.

We combine 3D inkjet printing and TPP to generate artificial blood vessel systems, including small diameter capillaries and vessels with a larger diameter in a reasonable amount of time. The 3D inkjet printing serves to quickly build up parts and to deposit various materials, while TPP generates micro-scale features within inkjet printed material layers.

Simulation and characterization

We optimize the geometry of the artifical vascular system using computational fluid dynamics simulations. We focus on two requirements: shear stresses at the walls must fall within a certain range in order to stimulate growth of endothelial cells and dead flow zones must be avoided thereby taking into account the complex blood rheology and the elasticity of the walls.

For characterization of materials and structures, in addition to validating the model predictions, an experimental set-up allows for the study of pulsatile flows and mechanical responses in the artificial vascular system.

Biofunctional materials

The cured synthetic materials surfaces are functionalized with modified biopolymers. Such biofunctional coatings promote cell colonization of the material surface. The formation of a functional endothelium is essential for both, the generation of biomimetic *in vitro* test systems, and future applications of vascular structures as implantable systems.

We currently achieve formation of a confluent sheet of endothelial cells by immobilization of heparin and the anchoring peptide arginine-glycine-aspartic acid (RGD).

Services

- Selection, synthesis and characterization of polymers for additive manufacturing processes (IAP)
- Biopolymer modification for coatings and ink formulations (IGB)
- Printing systems and process development for industrial and medical inkjet applications (IPA)
- Laser-based polymerization processes and photochemical functionalization for life science applications (ILT)
- Optimum lay-out of branched vascular systems and modelling of complex fluids (IWM)
- Experimental (fluid-)mechanical characterization of linear and branched systems (IWM)
- Cytotoxicity testing (DIN ISO 10993-5) and *in vitro* tissue test systems (IGB)

Funding

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