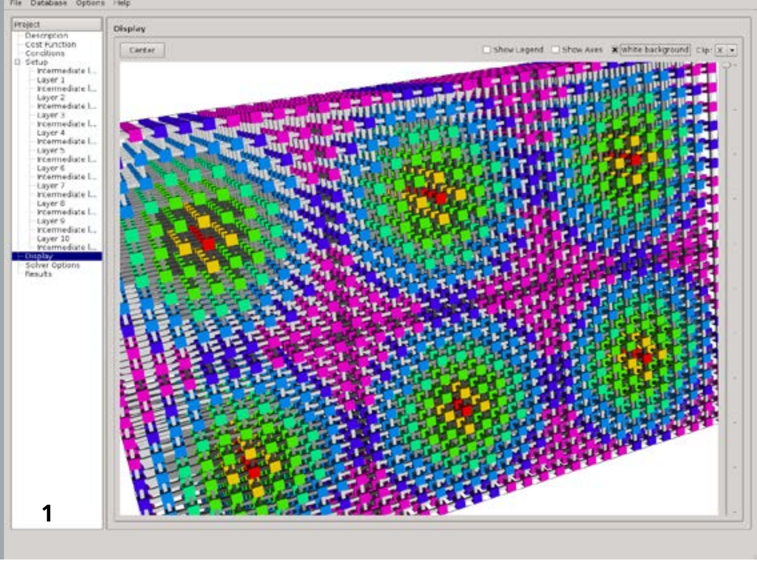

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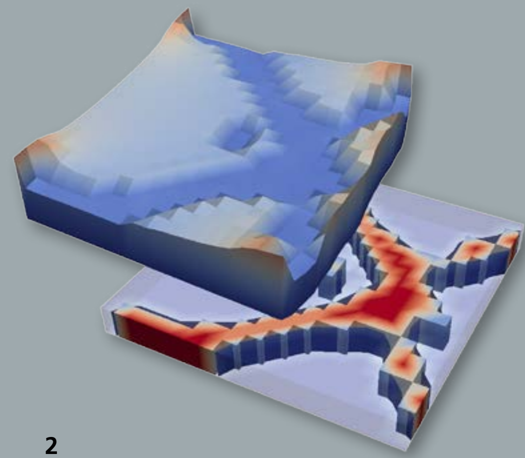


2

PROGRAMMABLE MATERIALS – MECHANICS AND TRANSPORT ON REQUEST

1 *Design study for a meta-material, constructed from different elementary cells*

2 *Non-linear deformation of a topologically opti-mized metamaterial*

Giving materials new functionalities? We are finding ways to do that in various projects in the field of "Programmable Materials." What we find is that not only the basic material itself is changed, but also its internal structures.

New manufacturing methods make it possible to specifically produce structures in the micrometer range. These methods include for example, additive processes like 3D-printing. An engineer uses these methods not only to design the outer shape, but also to target the internal microstructures to give certain properties to a component. In cooperation with other Fraunhofer Institutes, we go one step further and define multiple states for such microstructures and apply external stimuli to switch between them.

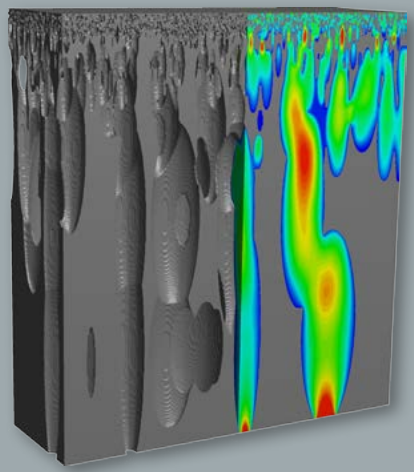
Programmable mechanics and a tool kit full of structural possibilities

At Fraunhofer Cluster of Excellence "Programmable Materials", we develop mathematical procedures for optimizing structures and provide support to engineers in designing production processes and choosing the appropriate microstructures. Working with the Fraunhofer Institute for Mechanics of Materials, IWM, we develop the microstructures for 3D-printing, which can change the internal stiffness or the surface shape as desired when subjected to external mechanical stress. Specifically, we have achieved extraordinary mechanical effects that do not exist in the naturally occurring material.

For example, the so-called pentamode mechanical meta-materials are solid structures that behave like liquids. These materials consist of three-dimensional arrays of cubic cells. Each cell exhibits a non-linear mechanical behavior and multiple stable states. Such cells are developed, printed, and tested at Fraunhofer IWM.

Algorithms for very special cells

There are many different ways to shape these cells. One type is known as auxetic cellular material that expands orthogonally when under tension, that is, it becomes thinner when compressed and thicker when stretched. Many more options are created when thousands of these unit cells are arranged into an array. We develop an algorithm that computes a possible selection and arrangement of the cells on request. We developed a graphical user interface for the design of programmable materials made from these unit cells – similar to the CAD software used in architecture. In the long term, these computed structures will be output for immediate use as input to 3D-printers.



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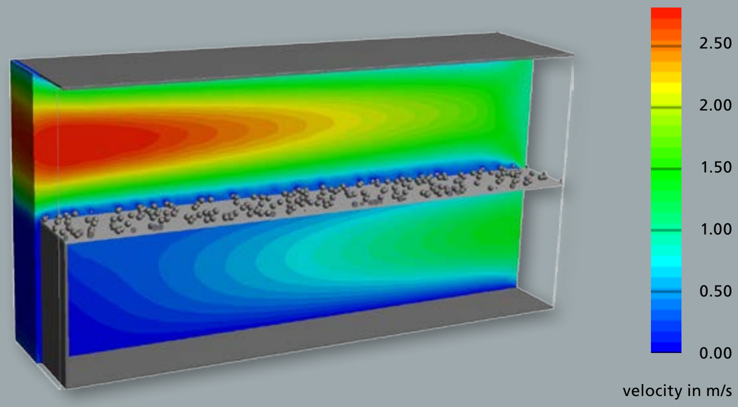

2

Programmable transport: Clean filters with smart materials

Together with the Fraunhofer Institute for Applied Polymer Research IAP, we are developing filter membranes. In this case, the focus is on the use of programmable materials that can change their properties as a result of external stimuli, in particular, in the area of effective filter cleaning.

These membranes are made from thermally activated shape memory polymers, with or without a porous structure, that can change form at the time of cleaning and make the process more effective. Shape memory polymers are polymers that seem able to "remember" their previous form. The project also studies membranes with additional surface structuring for applications with cross-flow filtration. Such structuring can delay the fouling process during the filtration phase, for example, by keeping away bacteria from the membrane. Another kind is the chemo-selective membranes, where permeability can change depending on the presence of certain chemicals. This effect is used to block pollutants. In all cases, we assist project partners with simulations to support their development efforts.

Adaptive filtration using membrane structure

The "Programmable Materials in Science and Engineering (ProMiSE)" project is a collaborative project with other Fraunhofer Institutes, with a research focus on new programmable materials, specifically, "programmable porosity."

As possible trigger mechanisms, we are exploring piezoelectrical and thermo-mechanical effects. The aim is to achieve a deformation of the pore geometry on the micro-scale and, in this way, change the material porosity. This ability can be used in adaptive filtration, for example, in water treatment or chemical processes.

The modeling and simulation of the piezoelectrical effects poses a challenge. These methods describe the changes in electrical polarization and show the presence of electrical current in solids under conditions of elastic deformation. The expansion and orientation of the polymer must be mechanically modeled on a continuum scale. We then compare the effects of differently structured pore geometries. Project partner Fraunhofer Institute for Applied Optics and Precision Engineering IOF, produced the necessary membrane geometries using laser irradiation. The required adaptive filtration is achieved through deliberate deformation.

1 *Flux through a virtual microstructure*

2 *Transversal filtration through a membran with surface structure*