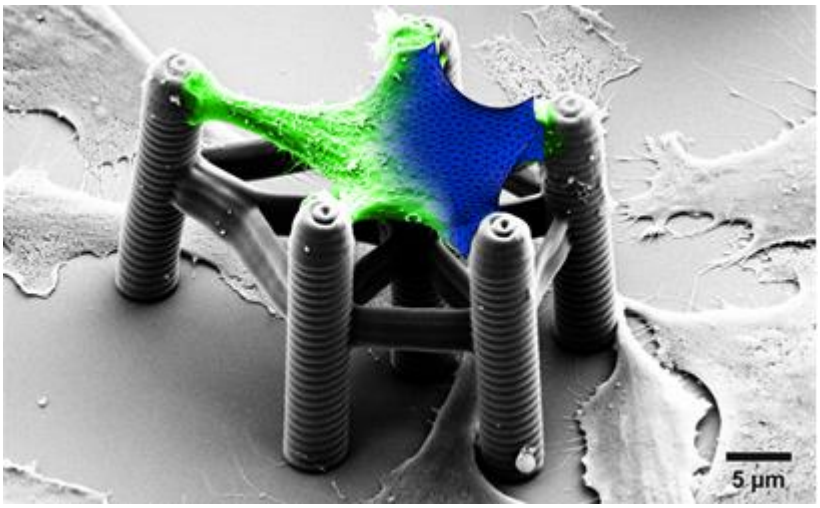
Materials Design in 3D: from the Molecule to the Macrostructure

"3D Matter Made to Order" Cluster of Excellence of KIT and Heidelberg University Starts and Focuses on Printed Three-dimensional Design Structures



3D printing enables many big and very small applications: with special ink, bioscaffolds for cell tissue can be produced. (Photo: Martin Bastmeyer, KIT)

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Additive processes, such as 3D printing, can be used to produce nearly any structure, even in the nanoscale. Depending on the "ink" applied, the structures produced fulfill various functions: from hybrid optical chips to bioscaffolds for cell tissue. Within the Cluster of Excellence "3D Matter Made to Order," researchers of Karlsruhe Institute of Technology (KIT) and the University of Heidelberg plan to raise three-dimensional additive manufacture to the next level. The goal is to develop new technologies for flexible, digital printing of structures from the molecular to the macroscopic scale.

"3D printing opens up big opportunities in the micro- and nanoscale in particular. But the challenges to make these options accessible are equally big," says Martin Wegener, Professor of the Institute of Applied Physics and Director of the Institute of Nanotechnology of KIT as well as spokesperson of the Cluster of Excellence "3D Matter Made to Order" (3DMM2O). Technologies and processes are needed

to quickly produce smallest structures of highest quality based on digital construction data. “This is the point of departure of our cluster. We plan to completely digitize 3D manufacture and materials processing from the molecule to the macrostructure and to develop new fabrication technologies for concrete applications.”

“This will only be possible with new inks and photoresists developed by chemists. For application in biology, for instance, we need materials that are degradable under physiological conditions at the push of the button, so to speak. And we need conductive materials that can be printed in three dimensions with nanometer precision,” says Uwe Bunz, Professor of Organic Chemistry at Heidelberg University, member of the Centre for Advanced Materials (CAM; www.cam.uni-heidelberg.de) there and spokesman of 3DMM2O.

New Approaches to Digital 3D Printing

They are to be finer, faster, and more diverse: additive processes and technologies enabling applications in materials research and life sciences. To reach this goal, natural scientists and engineers work along three interconnected lines: in the area of “Technologies,” novel tools will be developed to produce structures down to 10 nm. The new tools are to enable faster and more precise printing with different inks and photoresists developed in the area of “Molecular Materials.” Customized artificial materials are to have a wide spectrum of properties and can be combined. The area of “Applications” will cover applied research. Here, the focus lies on optics and photonics, materials sciences, and life sciences. The printed 3D structures are to improve the performance of optical chips in information processing or to be used in artificial retinas.

“Our approach is to translate digital information into customized, functional materials, devices, and systems,” Wegener says. The long-term objective of 3DMM2O consists in building a type of desktop printer that does not need too much space or special conditions, such as a big production hall, vacuum or certain temperatures.” We want to open up so far inaccessible scientific applications for use at home and to enable 3D printing at the push of a button,” Wegener says.

3DMM2O won the approval of the German Research Foundation (DFG) in the funding line “Cluster of Excellence” in 2018. The total annual amount of funding available in this line is about EUR 385 million. In addition, Carl Zeiss Foundation will fund the cluster with EUR 8 million for a period of six years. These funds will be spent for a scholarship program for doctoral researchers, a new professorship at CAM, a new user laboratory at KIT, and an accompanying “Vision Assessment” study of social and ethical implications of 3DMM2O.

HEiKA Graduate School "Functional Materials"

A central element of the cluster is the HEiKA Graduate School "Functional Materials." HEiKA stands for the Heidelberg Karlsruhe Strategic Partnership that covers all joint bilateral activities of KIT and Heidelberg University. The Graduate School integrates master's and doctoral students into the highly interdisciplinary research area. Here, a broad module program plays an important role. Every year, Carl Zeiss Foundation will fund up to four master students who intend to gain a doctorate in the area of 3DMM2O. In addition, the Foundation will support up to 20 doctoral students writing their theses in the areas covered by the cluster.

Customized Mix of Materials and Movable Microstructures: Examples of Research within the 3DMM2O Cluster

Researchers of KIT and Carl Zeiss AG have developed a system for additive manufacture of multi-colored, fluorescent security features in three dimensions. These can be used to protect banknotes, passports, and branded products against counterfeiting. The basis is 3D laser lithography, in which a laser beam is passed through a liquid photoresist and hardens the material at the focal point of the laser beam only. Scientists integrated a self-developed microfluidic chamber into the lithography device for printing with a variety of materials. Now, a single device can print three-dimensional micro- and nanostructures from several materials in a single process step. More information: http://www.kit.edu/kit/english/pi_2019_017_customized-mix-of-materials-for-three-dimensional-micro-and-nanostructures.php.

Direct laser writing can be used today already to produce precise structures on the microscale. For many applications in biomedicine, however, it would be advantageous if the printed objects were not rigid but movable systems that can be switched after 3D printing. Researchers of KIT have now been able to produce three-dimensional structures from hydrogels that change shape under the influence of temperature or light. The 3D structures produced in this way are functional in aqueous environments and thus ideal for applications in biology and biomedicine. More information: http://www.kit.edu/kit/english/pi_2019_011_movable-microstructures-from-the-printer.php.

Being "The Research University in the Helmholtz Association", KIT creates and imparts knowledge for the society and the environment. It is the objective to make significant contributions to the global challenges in the fields of energy, mobility and information. For this, about 9,300 employees cooperate in a broad range of disciplines in natural sciences, engineering sciences, economics,

and the humanities and social sciences. KIT prepares its 25,100 students for responsible tasks in society, industry, and science by offering research-based study programs. Innovation efforts at KIT build a bridge between important scientific findings and their application for the benefit of society, economic prosperity, and the preservation of our natural basis of life.

This press release is available on the internet at http://www.sek.kit.edu/english/press_office.php.

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This year's **anniversary logo** recalls the milestones reached by KIT and its long tradition in research, teaching, and innovation. On October 1, 2009, KIT was established by the merger of its two predecessor institutions: the Polytechnic School and later University of Karlsruhe was founded in 1825, the Nuclear Reactor Construction and Operation Company and later Karlsruhe Research Center in 1956.