3D Matter Made to Order

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In our digital age, including the rapidly growing possibilities of artificial intelligence, the access to digital blueprints of three-dimensional (3D) matter in the sense of materials, structures, devices, and systems is rapidly improving. Yet, to turn such digital blueprints into reality, i.e., into hardware, versatile and powerful converters from the virtual world to the real world are needed. 3D additive manufacturing, often used synonymously with the notion of 3D printing, serves as such a converter. Therefore, 3D additive manufacturing, in which one locally adds material rather than subtracting it from a solid block by machining, drilling or etching, has become a vast field worldwide. This statement is especially true for the macroscale, for which not only scientific but also industrial applications have emerged already. The situation is different for shaping 3D matter on demand towards the nanometer scale. The development of such technologies has started later and is subject of active scientific research in the Excellence Cluster 3D Matter Made to Order (3DMM2O), a a joint research cluster of Karlsruhe Institute of Technology (KIT) and Heidelberg University funded within the German Excellence Strategy.

One part of the scientific challenges can be summarized as "finer, faster, and more", i.e., to reach better spatial resolution, to make manufacturing scalable and much faster, and to open the door to more dissimilar materials. Another part of the challenges lies in exploring novel applications in the engineering sciences and the life sciences that take advantage of the particular strengths of 3D additive manufacturing driven towards the nanometer scale.

The current *Special Issue* provides a snapshot of some of the corresponding research ongoing in 3DMM2O.

Concerning **digital blueprints**, Frank Tristram et al. review the state-of-the-art of digitalized data management and its impact on material system workflows. Payam Kalhor et al. discuss digital blueprints for functional material systems enabled by automated data extraction and machine learning. Benedikt Zerulla et al. present blueprints for functional photonic devices by multiscale computational methods. Modan Liu et al. present the theory of layer-by-layer assembly of asymmetric linkers into non-centrosymmetric metal organic frameworks.

With respect to the **molecular materials basis** for 3D additive manufacturing, Guangda Zhu et al. introduce dynamic bonds in light-based 3D printing. Dimitry Schmidt et al. discuss selective peptide binders with applications in fuel cells. Zhenwu Wang et al. discuss tough PEGgels for 4D printing. Yolita M. Eggeler et al. review 3D architected pyrolytic carbon made by 3D additive manufacturing on the micro- and nanoscale. Valentina Ferraro et al. review recent advances in transition metal complexes for photopolymerization and 3D printing using visible light. Christin Bednarek et al. provide a perspective on bioconjugation in materials science and 3D printing.

Regarding **advanced materials characterization**, Irene Wacker et al. review the present state-of-the-art in terms of deconstructing 3D structured materials by modern ultramicrotomy based on electron microscopy. Tanja Schmitt et al. investigate the ultrafast excited-state dynamics of orthogonal photoswitches. Qing Sun et al. present in-situ pyrolysis of 3D printed building blocks for functional nanoscale materials.

Various routes of self-assembly can potentially be combined synergistically with 3D additive manufacturing. Along these lines, Peter Thissen et al. present epitaxially grown monolithic metal-organic framework thin films on Si(111) substrates. Kevin Jahnke et al. discuss DNA origami in the context of synthetic cells, which can also be modified by 3D laser printing.

Applications of 3D additive manufacturing driven towards the nanoscale can be divided into the engineering sciences and the life sciences. Concerning **applications in the engineering sciences**, Md Mofasser Mallick et al. present high-sensitivity flexible thermocouple sensor arrays via printing and photonic curing. Hongrong Hu et al. present an ink-jet printed tungsten oxide memristor that can be applied as non-volatile memory or neuromorphic computing. Salma Begum et al. present disulfide-bridged dynamic covalent triazine polymer thin films by interface polymerization with optical applications in terms of high refractive index and excellent transparency. Yi Chen et al. design, manufacture by 3D laser printing, and characterize 3D chiral micropolar metamaterials exhibiting roton-like phonon dispersion relations.

To **applications in the life sciences**, Mohammadreza Taale et al. report on the in-situ fabrication of constraints for multicellular micro-spheroids using two photon lithography. Rabea Link et al. review the experimental and conceptual possibilities of influencing cell and organoid shape and forces in elastic and structured 3D environments. Natalie Munding et al. introduce the notion of bio-metamaterials made by laser printing and apply them to the mechano-regulation of mesenchymal stem cells.

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We believe this Special Issue is of interest to a broad readership in the field of Functional Materials and hope it will inspire future progress in this fascinating interdisciplinary area of research.

Conflict of Interest

The authors declare no conflict of interest.