ADVANCED MATERIALS SCIENCE

Fields of Expertise TU Graz

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Christof Sommitsch,
Advanced Materials Science

Source: Lunghammer – TU Graz

Smart production of smart materials is a hot topic in the FoE Advanced Materials Science as well as at the Smart Production Graz research center. Many activities are being pursued in materials science, physics, and chemistry.

Powder-based additive manufacturing, e.g. by laser powder bed fusion or plasma direct metal deposition, of functional materials, such as magnetic materials, high-entropy alloys or shape-memory alloys is one example of ongoing research. The process can be advanced for building smart parts, e.g. integrating temperature, pressure, and humidity sensors, realizing porous structures for NH_3 and biofuel synthesis and joining metallic and fiber reinforced polymers in-situ and ex-situ. However, also wire-based additive manufacturing by electron beam, plasma, and arc, as well as hybrid methods are applied for different tasks.

Another example is the technology of bio-based systems, dealing with the development of conjugates based on biomolecules of living organism origin and analogues. This implements the manufacturing, analysis and application of organic structures and inorganic/organic hybrid systems. The focus here is set on the development of biomaterials with emphasis on surface specific processes (surface functionalization) and manufacturing of 3D structured materials and using modern technology as 3D printing or laser lithography, development of bio-inks formulations, cross linking – and self-assembly structures, for example tissue engineering.

A third research area is in in-situ atomic force microscopy enabled by an emerging 3D nano-printing technology. The research program is centered around Focused Electron Beam Induced Deposition which is an increasingly relevant direct-write technology for flexible, bottom-up synthesis of high-resolution nanostructures, applicable on virtually any substrate material and morphology. The research activities are focused on two main aspects, i.e. controlled 3D nanofabrication and defined material properties.

More and more important is the consideration of increasing the efficiency of processes (e.g. by reducing scrap), the reduction of critical raw materials (e.g. rare earth elements), the realization of lightweight structures (e.g. by topology optimization) and taking into account usage of circular materials (e.g. by using recycled materials). Machine learning methods are a means that are used to meet those targets.

Source: Lunghammer – TU Graz

Rupert Kargl

The Potential of Polysaccharides in Biomaterial Science

Natural polymers form the basis of life and understanding and modifying their properties can lead to new applications. From hyaluronic acid in connective tissue to cellulose in plants and peptidoglycans in bacteria, polysaccharides are one of the most important structural components of living things.

The use of naturally occurring or chemically modified polysaccharides in material science, or in contact with living tissue is therefore our main research interest at the Institute of Biobased Systems (institute head Karin Stana Kleinschek). This requires a highly interdisciplinary expertise, which we are trying to create together with collaborators within and outside TU Graz. >

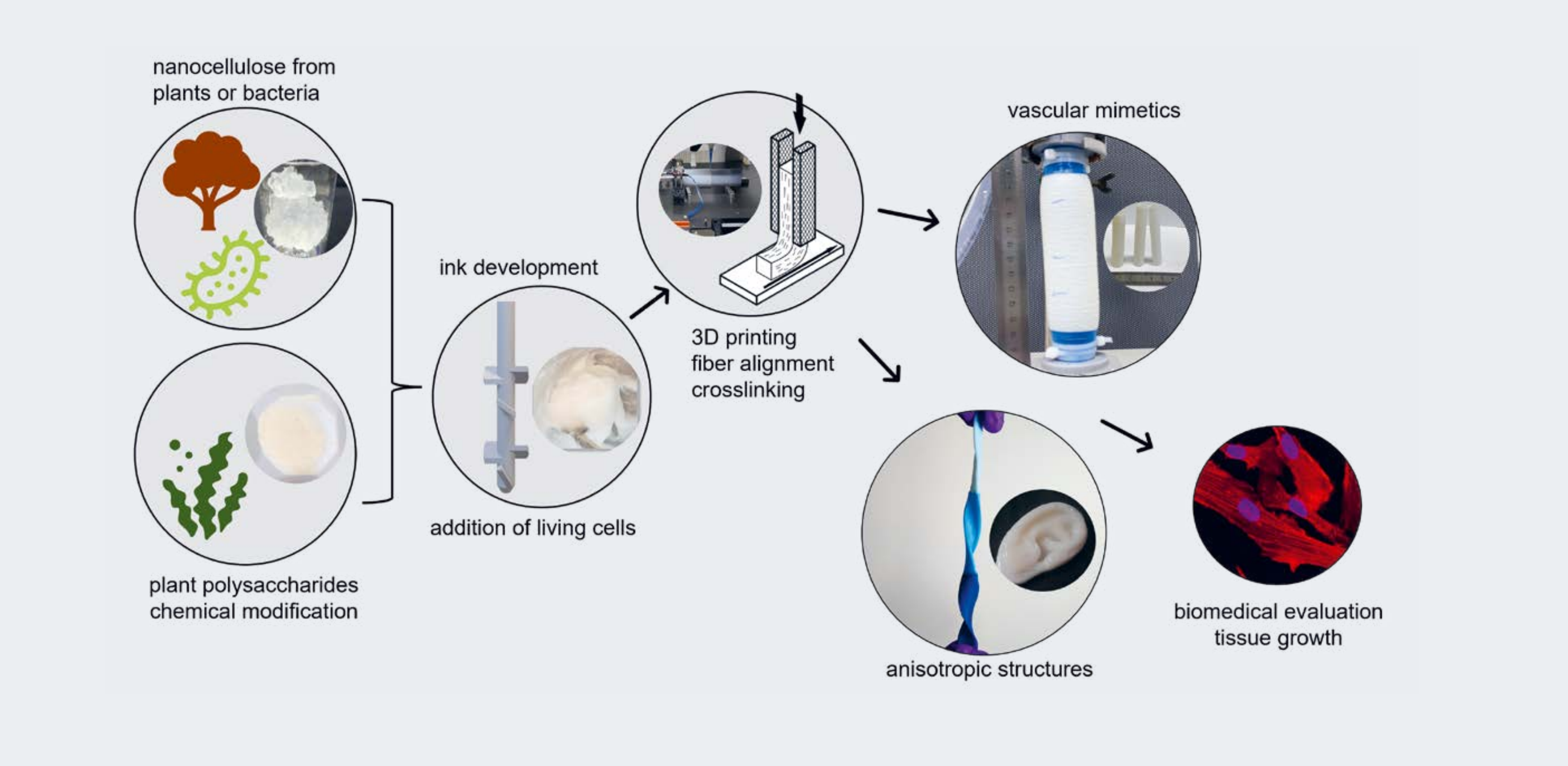


Figure 1:
Workflow of exemplary biomaterial research at IBIOSYS. Nanofibers are formulated into 3D printable inks with chemically modified polysaccharides optionally containing living cells. Extrusion is used to align nanofibers into desired directions. Various shapes are produced and evaluated for mechanical and biological properties. Parts of the work are funded by FoE Advanced Material Science (initial funding programme) and performed within the doctoral studies of Florian Lackner. Our colleague Tamilselvan Mohan is highly acknowledged for his contributions.

Source: Rupert Kargl

Two examples are given of how IBIOSYS attempts to utilize polysaccharides in advanced (bio-)material science. Figure 1 shows a general concept of how polysaccharide nanofibers with a diameter of 10 - 500 nm and a length of several hundred micrometers are used in the manufacturing of extrudable inks that can be 3D printed [1] into macroscopic shapes of advanced materials. The basis for our nanofibers form plants, but more interestingly also bacteria, that might be capable of delivering well defined polymeric sequences and supramolecular structures. Chemical modification of the components and the addition of living cells to our inks can be used to create tissue mimetics that could find application in regenerative medicine for skin or in the vascular system. The chemical modification is driven by our endeavor to find new ways to construct defined and complex polysaccharide peptide co-polymers that can be crosslinked into stable gels through enzymatic or non-covalent means. [2, 3]

We are also interested in the biomechanical properties of these materials in collaboration with Gerhard Holzapfel and team, Institute of Biomechanics, TU Graz. We could show in preliminary studies that water- and pressure-resistant tubes comprising hydrophilic components can be manufactured (Figure 1 right top) and that these tubes have similar tensile strength and elongation when compared to porcine tissue. The aim is to imitate the fibrous structure of native vascular or connective tissue which is comprised of collagen and elastin fibrils surrounded by proteoglycans. Cell tests and growth studies are planned in collaboration with Petra Kotzbeck and team, at the COREMED facilities of Joanneum Research, Graz.

(Poly)saccharide interfaces are decisive when biological molecules and living cells interact with solids. To elucidate basic mechanisms of semi-synthetic carbohydrate interactions, another interest is in the manufacture and study of defined and novel carbohydrate solid-liquid interfaces on a range of substrates [4] (Figure 2). These can be gold, silicon, polystyrene, and polyester, among others. Chemical methods are devised to synthesize and couple unusual carbohydrates to surfaces in collaboration with the Glycogroup of Tanja Wrodnigg at IBIOSYS. These surfaces are evaluated with respect to their interaction with proteins and living cells and conclusions are drawn from irreversible binding, cell layer formation, enzymatic activity, or antimicrobial action. Layers and coating methods can find use in biosensors, for drug screening, for enzyme immobilization or again in tissue growth. Integration into fluidic systems and cell culture plates are parts of the planned work.

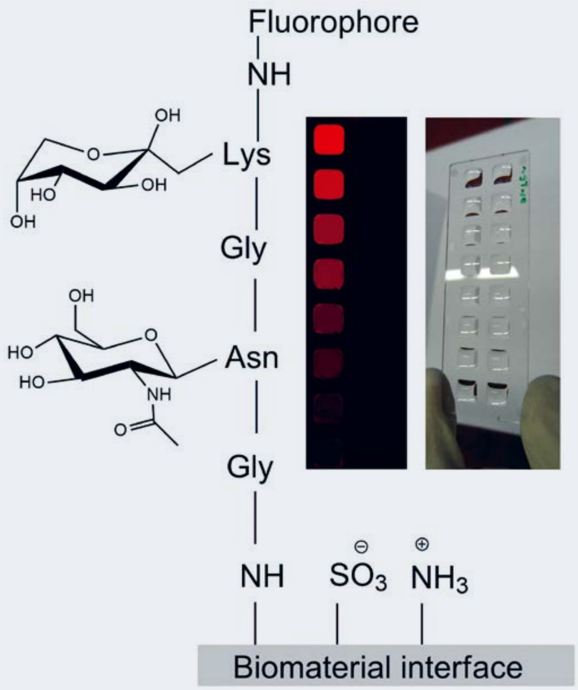
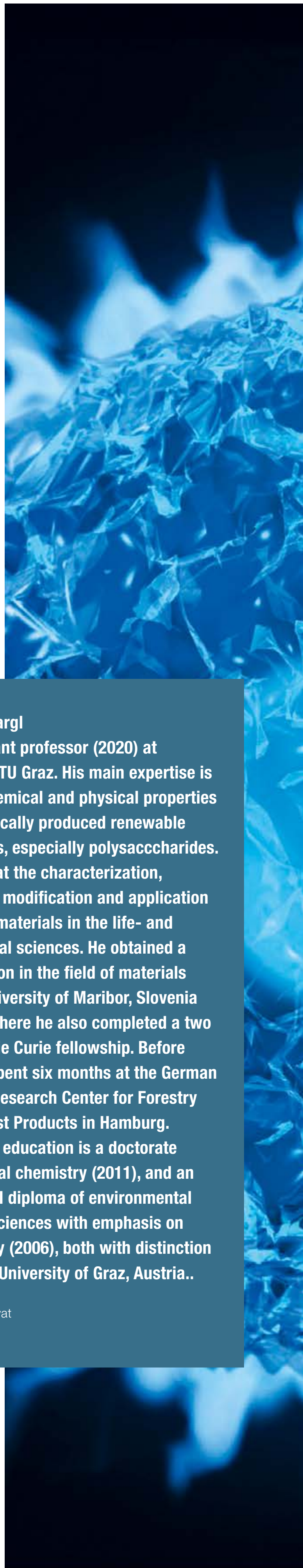


Figure 2:
Glycosylated peptides on amino group containing biomaterial surfaces. The glycosides can be naturally occurring or chosen from a very large library of saccharides including (pseudo-) C-glycosides. The aim is to investigate surface interactions with biomolecules or cells. The inset shows microscope glass arrays of fluorescently labelled biomolecular surfaces. Ongoing work in collaboration with DI Tobias Dorn, currently performing his doctoral studies at IBIOSYS.
Source: Rupert Kargl



Overall, we are convinced that biopolymers and carbohydrates have a significant potential to be used as biomaterials due to their very large structural variability and biological origin to which living cells respond. New chemical and physical methods are still needed to better understand and to finally utilize the beneficial properties of such materials. In any case a network of strong collaborators and an openness to disruptive ideas are necessary to reach the aims described.

Rupert Kargl
is assistant professor (2020) at IBIOSYS, TU Graz. His main expertise is in the chemical and physical properties of biologically produced renewable resources, especially polysacccharides. He aims at the characterization, chemical modification and application of these materials in the life- and biomedical sciences. He obtained a habilitation in the field of materials at the University of Maribor, Slovenia (2016), where he also completed a two year Marie Curie fellowship. Before that he spent six months at the German Federal Research Center for Forestry and Forest Products in Hamburg. His basic education is a doctorate in physical chemistry (2011), and an individual diploma of environmental system sciences with emphasis on chemistry (2006), both with distinction from the University of Graz, Austria..

Source: Privat

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