IMPRS on Functional Material Design

Project description

Title: From well-defined glycans to responsive nanomaterials
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Project description: Polysaccharides are among the most abundant and diverse biomaterials on earth, yet all currently available sources rely on extraction from natural systems, yielding inherently heterogeneous samples with broad chain-length distributions, variable branching, and uncontrolled substitution patterns. Attempts to combine different polysaccharides into functional materials have so far relied on blending, which introduces additional heterogeneity, or on covalent block architectures that lack control over the monomer sequence. Sequence-defined polysaccharides, where the identity and order of every sugar unit is programmed, remain completely inaccessible, and their properties entirely unexplored.

This project addresses this gap by combining automated glycan assembly (AGA) and enzymatic methods to produce well-defined glycan block polymers with programmable sequences. As a proof of concept, we already created a defined cellulose-xylan di-block polysaccharide that displays remarkable self-assembly behavior (Figure 1): depending on assembly conditions, it organizes into either cellulose-like fibers or xylan-like hexagonal platelets, demonstrating that sequence directly controls nanoscale morphology.

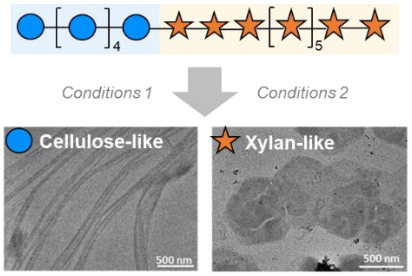

Figure 1: Sequence-defined cellulose-xylan polysaccharide and its tunable self-assembly behavior.

Building on this result, you will systematically expand the structural space of sequence-defined polysaccharides and explore how block identity, length, and order determine self-assembly outcome. Moreover, you will explore how external stimuli (e.g. humidity, temperature, pH) could trigger structural rearrangements between different morphologies, opening the path toward sequence-encoded responsive materials. Nanomaterials will be characterized by transmission electron microscopy (TEM) and electron diffraction (ED). Computational modelling and mathematical approaches will be used to rationalize the observed geometries and identify the design principles that link sequence to structure, enabling predictive control over assembly.

Required background: MSc degree in chemistry or related subjects. Experience in organic chemistry and/or materials science. Motivation to learn new characterization methods and molecular modelling, independent thinking, team spirit, and communication will be the main drivers of a successful project.
Paper to read before the interview: *Angew. Chem. Int. Ed.*, **2024**, e202410634
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