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Addressing Materials and Resolution Challenges in the 3D Printing of Chromatography Columns

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Additive manufacturing has recently transformed the chromatography landscape thanks to its capability to fabricate porous stationary phases with perfectly ordered structure. Industrial implementation of 3D printed stationary phases must now accelerate, with the goal to offer regular morphologies with improved separation performance which can easily integrate into the production line.
This presentation will delve into the recent strides taken to tackle the two primary challenges inherent in creating chromatography columns using 3D printing technology: i) the identification of materials compatible with both 3D printing processes and chromatographic operations, and ii) the rapid, high-resolution, and large-scale printing of such materials.
The initial segment of this work will outline formulations for the direct 3D printing of chromatography columns in a single step. These materials are rooted in methacrylate chemistry, rendering them compatible with Digital Light Processing (DLP) printing technology. Columns with anion and cation exchange modalities are obtained by incorporating functional monomers in the ink formulation, obviating the need for subsequent functionalization steps. A practical application will be showcased, detailing the capture and purification of c-phycocyanin, a protein of significant industrial relevance.
The second part of the talk will focus on multiscale control of 3D printed matrices, from mm to µm to nm, to rapidly achieve tuneable stationary phases for bioseparations. A different material formulation, employing epoxy chemistry to facilitate straightforward functionalization, will be introduced. The material's development, characterization, chemical derivatization, and subsequent evaluation for capturing and separating model proteins will be outlined. Impressively, these formulations offer an unprecedented level of control over morphology at sub-millimeter scales (achieving features as small as 50 µm for linear structures and 200 µm for complex geometries) and feature tunable porosity at sub-micrometer scales. Notably, these structures can be swiftly 3D printed in as little as one hour, enabling the creation of intricate large-scale models (up to 100 mL columns). The integration of anion and cation exchange ligands onto 3D-printed gyroid structures was accomplished, successfully demonstrating i) the separation of model proteins under dynamic conditions, and ii) the capture of proteins from a clarified cell harvest. These experiments exhibited dynamic binding capacities ranging from 5 to 16 mg mL–1 and yielded up to 86% purity in a single run.
These findings serve as a robust foundation for propelling the implementation and utilization of 3D-printed chromatography stationary phases to the forefront of practical applications.