Development of Engineered Gas Diffusions Layers via Micro-scale Manufacturing

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Abstract

As CO_2 capture evolves as a component in reducing greenhouse gases, the issue of storage or processing becomes ever important. **CO_2 reduction reactors** can **generate simple hydrocarbons**. This process relies on porous membranes, **gas diffusion layers (GDLs)**, which allow gaseous CO_2 to interact with a water-electrolyte fluid.

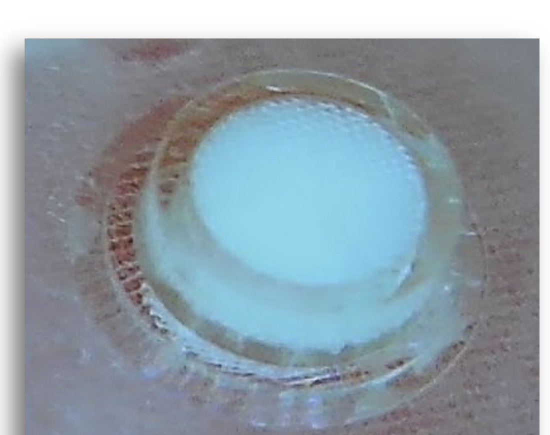
Conventional GDLs, such as expanded PTFE or PTFE coated carbon paper **can typically only operate for a period of hours** before efficiency begins dropping precipitously as the generation of simple alcohols and acids alter the electrolyte composition and the GDL begins to wet. In order to overcome these inefficiencies, **additively manufactured GDLs** are of interest, as components such as **pore structure, pore density, and morphology can be tightly controlled**.

This project leverages the Nanoscribe Photonic Professional GT2 two-photon polymerization printer to produce microfluidic devices with micron-scale features. **Samples were produced in 2D and 3D variations**, with the 2D versions consisting of high aspect-ratio channel of varying axisymmetric geometry. 3D samples are similar to planned GDL morphologies, testing varied lattice structures, surface texturing, and the impact of coatings.

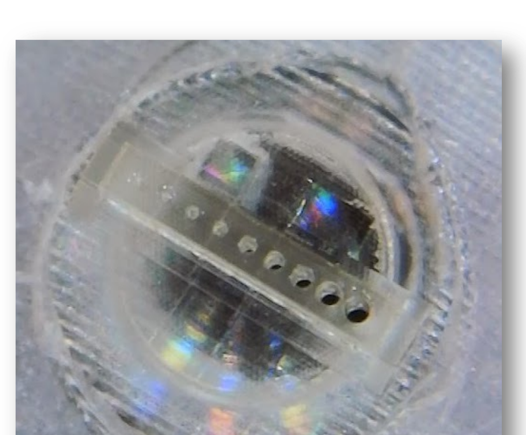
Advanced diagnostics in the form of high energy X-ray imaging, both **radiography and X-ray computed tomography (XCT)** is used to gain **micron-scale resolution** and **high-speed capture of dynamic fluid processes**.

Objectives

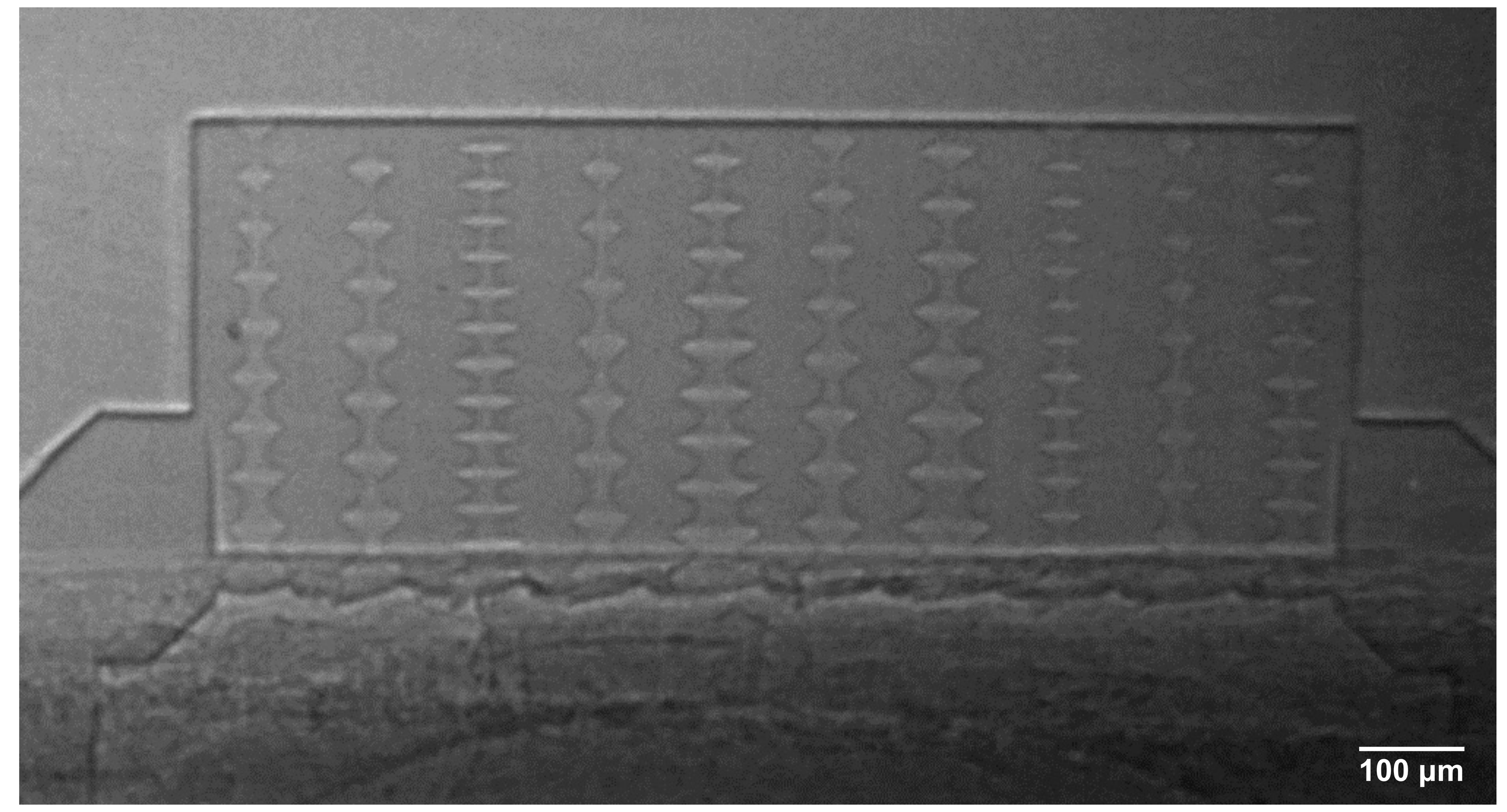
- Determine suitability of micro-additive manufacturing for development of microfluidic samples
- Obtain baseline dynamics for use in computational fluid dynamics modelling
- Validate hydrophobic coating process
- Characterize flooding behavior of printed gas diffusion layers



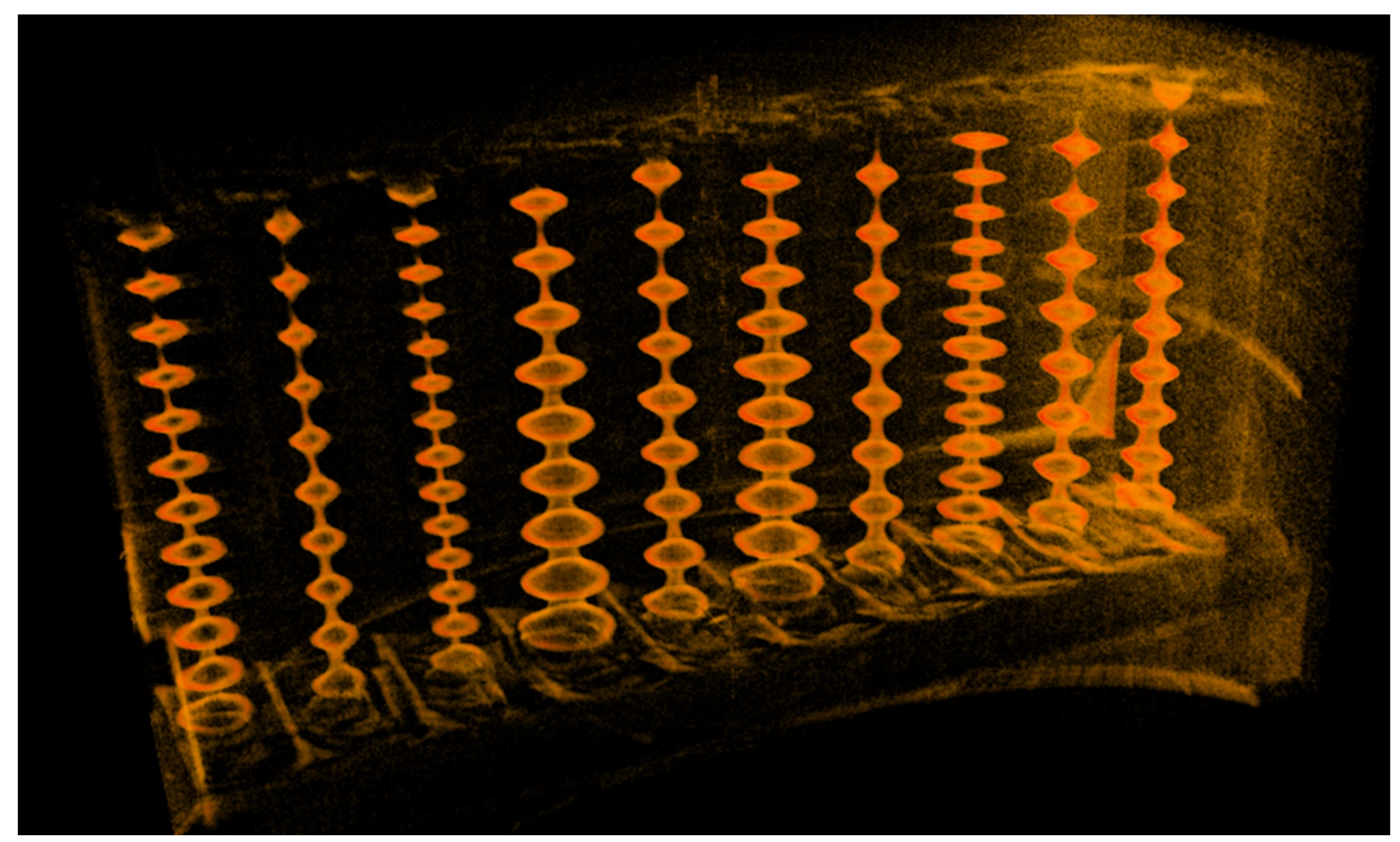
Printed samples, approximately the size of a poppy seed.
Left: 3D sample
Right: 2D sample



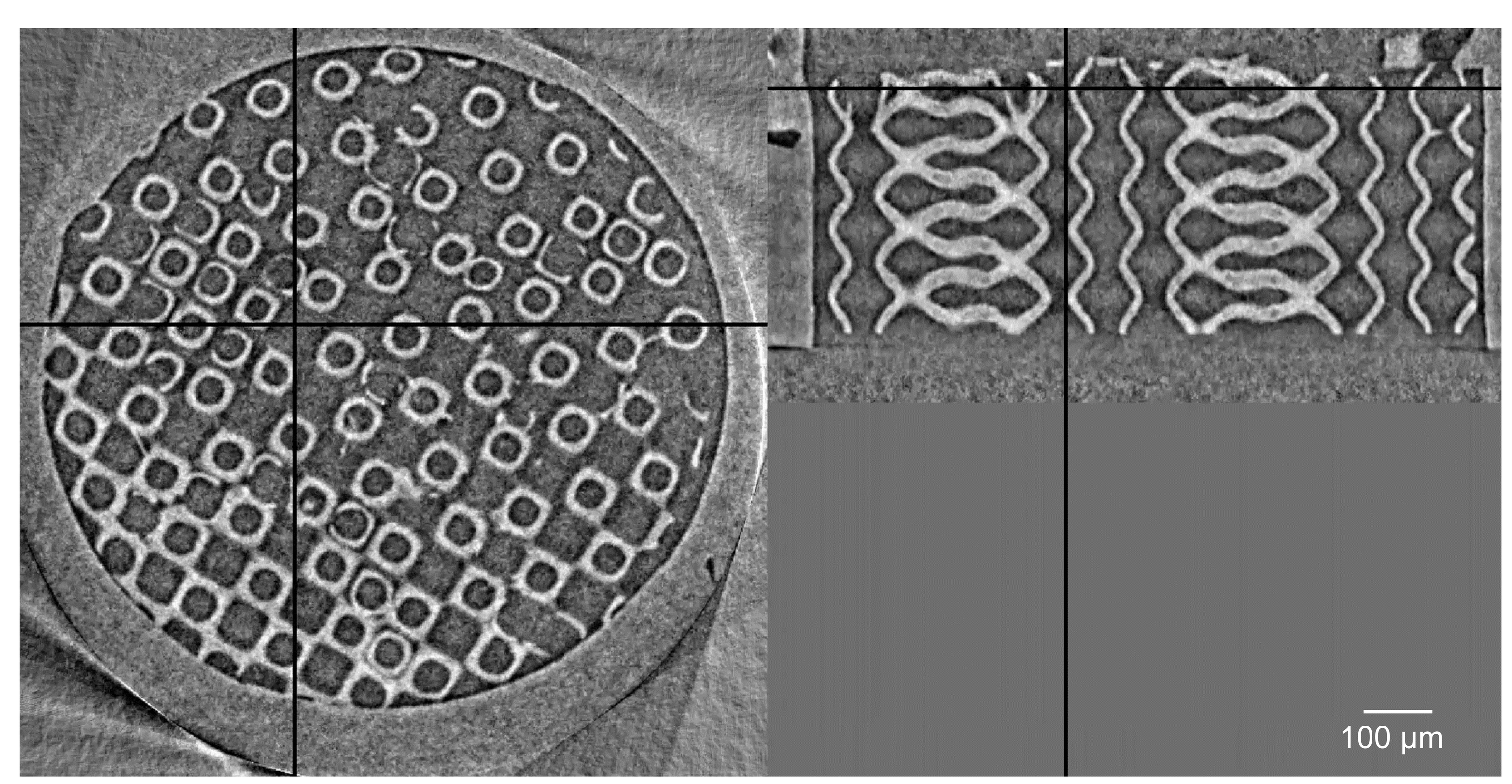
High Energy X-ray Imaging



A 2D sample exhibiting flooding behavior, 8X speed.



3D reconstruction of the above sample to evaluate print quality



A low-framerate screen capture of a 3D sample during real-time XCT reconstruction. Visible are two slices of the sample and rapid flooding. Actual capture was at 433 fps, with an X-ray energy of 30 keV

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Methods

Microfluidic samples were fabricated via two-photon polymerization

- **0.6 micron resolution**
- 1600 µm diameter prints, 750 µm in height
- Printed onto material-matched additively manufactured substrates with microfluidic fitting interface

Water introduced via **pressure driven flow**, in the 20-100 mBar range, resulting in 1-3 uL/min flow rates

- Dynamic solid-fluid interactions captured with high energy X-ray imaging
- CT scans on all samples to validate prints against CAD models
- Radiography for *in operando* testing of 2D samples
- CT for *in operando* testing of 3D samples
- Pressure and flow data synced with X-ray imaging to produce

Results

- Additively manufactured microfluidic structures were **dimensionally accurate** and **highly reproducible**
- Straight microfluidic channels were used to validate hydrophobic coating efficacy as well as create a geometrically simple design for computational fluid dynamic simulation software. **Experimental results agree with preliminary CFD simulation data**.
- In general, **2D samples with hydrophobic coatings flooded at higher pressures** compared to uncoated, approximately 50 mBar for uncoated and 100 mBar for coated
- Analysis of 3D samples is ongoing, however **uncoated geometries of all types flooded completely** compared to coated which exhibited partial flooding at the same pressure

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