National Aeronautics and Space Administration

Robust, Additively Manufactured Ceramic Micro Gas Chromatography Columns

Principal Investigator: Samad Firdosy (357); Co-Investigators: Marianne Gonzalez (353), Margie Homer (353), Valeria Lopez (353), Robert Dillon (357), Richard Kidd (389)

Program: FY21 R&TD Innovative Spontaneous Concepts

Objective

The objective of this work was to evaluate the feasibility for fabricating an enclosed micro gas chromatography (uGC) column using ceramic 3D printing processes

Background

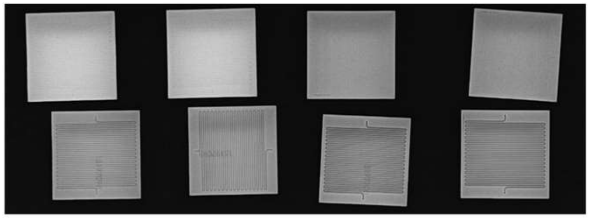
The current state of the art fabrication method for micro gas chromatography (uGC) column structures involves multiple steps including traditional photolithography processes to etch micro channels in silicon substrates, bonding processes to enclose/seal the channels and pressurized flow for application of stationary phase coatings. The inherently poor, glass-like mechanical behavior of silicon (extremely low ductility and toughness) and required face plate bonding to seal channels imposes geometric limitations (i.e. channels can only be fabricated in 2D), limits robustness (e.g. shock and vibe associated with planetary exploration) while sacrificing potential device performance. Subsequent integration of the uGC with related devices (e.g., valves, mass spectrometer (MS) chips, ect.) necessitates additional components for packaging, increasing system complexity, and often requires using materials with disparate thermal expansion. High resolution ceramic 3D printing processes offer the potential to fabricate enclosed column structures with considerable geometric flexibility for incorporating long channel lengths and integrated packaging for additional components.

Significance/Benefits to JPL and NASA

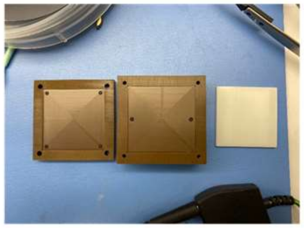
The concept of an enclosed micro-GC column which is integrated with respective packaging for incorporation valves, concentrators, etc, and printed via ink jet based ceramic using yttria stabilized zirconia or aluminum oxide. Multiple GC columns may be printed within monolithic structures enabling robust GC column structures with enhanced performance. Engineering ceramics (e.g. alumina and zirconia) have considerably improved mechanical properties and toughness compared to traditional silicon based materials. Additive manufacturing allows for GCs that are typically built in layers to be built in one piece with considerable geometric freedom. This opens the opportunity to fabricate GCs of longer lengths, in addition to being able to miniaturize other concepts like two dimensional chromatography (GCxGC). GCxGC allows for high resolution separation due to two columns with different stationary phases.

Approach and Results

Enclosed 0.2 mm x 1 m long channel 3D printed in zirconia

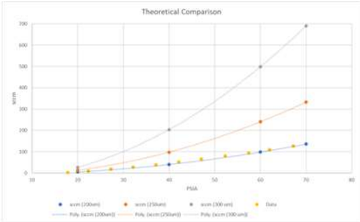


X-ray radiographs of (starting from top left and moving clockwise) pair of 0.05mm columns, pair of extended length columns, pair of 0.3 mm columns and pair of 0.5mm columns



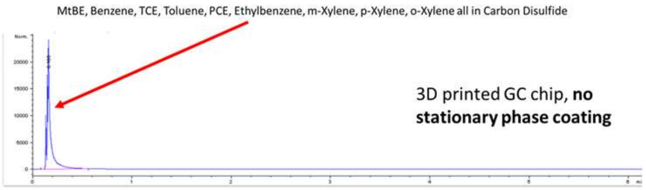
Flow test fixture and 3D printed column

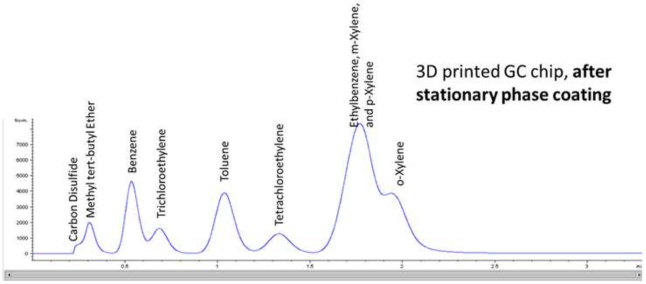
Assembled and instrumented flow test fixture



Flow vs. inlet pressure for 0.2mm x 1m long channel compared to prediction. Actual channel cross-section dimensions are 0.05-0.1mm smaller than CAD dimensions

3D printed column flow testing and radiographic examination





Separation performance of a 3D printed ceramic GC chip with and without subsequent stationary phase coating

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: Samad.A.Firdosy@jpl.nasa.gov

Clearance Number:
RPC/JPL Task Number: R21242