National Aeronautics and Space Administration

3D Printed Rocks for High-Fidelity Hydrothermal Vent Simulations

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Project Objective:

Evaluate the feasibility of producing a simulated compositional and physical analog of a hydrothermal vent entirely using binder jet additive manufacturing

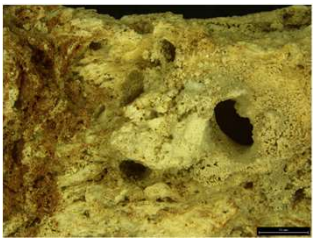
Motivation:

Hydrothermal vents are complex, porous structures which may exist at the water/rock interface of icy moons such as Europa and Enceladus; generate energy to support life & habitability; and may play a role in the origin of life. Efforts to simulate these systems rely on either taking samples from hydrothermal vents (resource intensive, and not analogous to other worlds), or synthesizing hydrothermal minerals or chimneys in lab (not structurally robust), and investigating them spectroscopically or electrochemically.

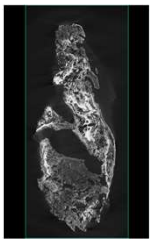
FY18/19 Results:

- X-Ray computed tomography (CT) analysis was used to understand internal void structure of a natural vent sample and help establish a "target" structure for 3-D printing experiments
- Targeted binder jet 3D printing experiments were carried out with commercially available natural olivine sand at the Ohio State University Center for Design and Manufacturing Excellence
- X-Ray CT analysis was completed on binder jet printed test coupons for comparison to natural vent materials
- Preliminary porosity and flow analysis suggests similar properties for natural and 3D printed structures
- Vent like porous morphologies were recreated in the 3D printed parts however there was a considerable amount of variability in printed test coupons even when using identical printing parameters. Variability was attributed to size and morphology of olivine sand procured which was not available in a more suitable size for binder jet printing

Natural vent sample

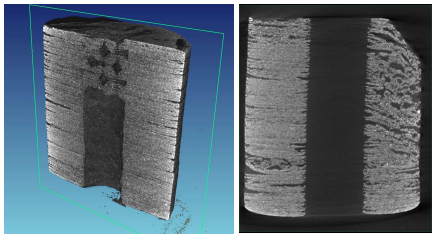


Natural vent sample detail view

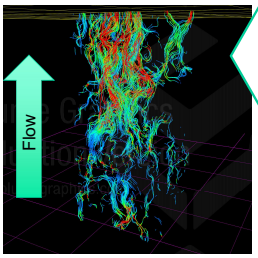


Natural vent sample X-Ray CT view

3D printed olivine sand coupons

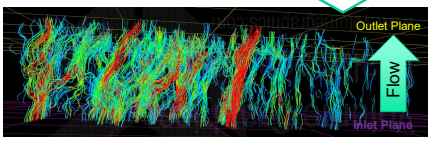


3D printed olivine sand X-Ray CT view



Flow analysis of natural sample

Flow analysis of 3D printed sample



Significance of Results

- These results demonstrate that 3-D printing porous structures using minerals relevant to Ocean Worlds is definitely feasible, but requires more work to perfect the technique. Stable structures were printed using the binder jet technique that displayed similar porosity and tortuosity to the natural vent samples, confirming that the geometry is achievable using additive manufacturing
- Future studies using this technique could incorporate different binders which may have a significant effect on the stability of the parts, as well as new minerals with different particles sizes, which may be more relevant to ocean worlds
- The techniques developed here to analyze and reconstruct the natural vent sample (namely CT scanning and CAD modeling) have helped to gain a better understanding of the natural samples already, and can be applied to future scientific studies on hydrothermal vents.

Acknowledgments: Binder jet printing experiments were carried out at the Ohio State University Center For Design and Manufacturing Excellence.

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