Contract No:

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Disclaimer:

Title of Project

Material Developments for 3D/4D Additive Manufacturing (AM) Technologies

Project Start and End Dates

Project Start Date: October 2019

Project End Date: September 2021

Project Highlight

Designed and created 3D/4D printed hydride materials via additive manufacturing that could be used as structural components for unmanned aerial vehicles (UAVs).

Project Team

Principal Investigator: Henry Sessions

Team Members: Patrick Ward, Zach Duca, and Simona Murph

Abstract

Additive Manufacturing (AM), or 3D printing, is a unique technology in which structurally complex objects can be easily manufactured. While AM allows for the creation of intricate 3D objects, these objects are inactive and motionless. With recent incorporation of a "pre-programmed functionality" to the 3D printed objects, a new concept has emerged, 4D printing. Specifically, the 4D printing technology enables a static 3D printed object to change its shape, functionality or property over time upon exposure to a specific stimulus such as heat, stress, light, pH, and moisture, etc. We designed and produced compact 3D/4D printable materials that can be used as (a) structural components of the unmanned aerial vehicles (UAVs), and (b) as hydrogen storage materials that supply hydrogen to a fuel cell to expand the operational reach, namely flight time, and endurance of the UAVs.

- **Objectives**
- Design and print 3D/4D hydride materials.
- Evaluate and optimize the 3D/4D printed hydride materials as hydrogen storage material.

REVIEWS AND APPROVALS

1. Authors:

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Name and Signature Date

2. Technical Review:

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Name and Signature Date

3. PI's Manager Signature:

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Name and Signature Date

4. Intellectual Property Review:

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publicly published in its current form.

SRNL Legal Signature

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Name and Signature

Introduction

Additive Manufacturing (AM), or 3D printing, is a unique technology in which structurally complex objects can be easily manufactured. While AM allows for the creation of intricate 3D objects, these objects are inactive and motionless. With recent incorporation of a "pre-programmed functionality" to the 3D printed objects, a new concept has emerged, 4D printing. Specifically, the 4D printing technology enables a static 3D printed object to change its shape, functionality or property over time upon exposure to a specific stimulus such as heat, stress, light, pH, and moisture, etc. One area of interest that can greatly benefit from the implementation of the 3D/4D printed objects is the field of unmanned aerial vehicles (UAV).

Unmanned aircraft systems (UASs) have experienced explosive growth in recent years and have proved to be an invaluable resource in military and first responders' missions, agricultural surveillance, deliveries, telecommunications, etc. In recent years, the need for improved UAS's operational reach and endurance has been echoed across all DOE's and DoD's levels of leadership. (Note: Operational reach is defined as the distance and duration across which a unit can successfully employ its capabilities).

The development and implementation of the 3D/4D hydride materials as structural components for hydrogen fuel cells operated UAV's proposed here will have a significant impact in expanding their operational reach and endurance. This project developed Smart/Enabling Tools, in the form of 3D/4D materials and components, that will enhance SRNL's drone and additive manufacturing programs while expanding SRNL's leadership role in scientific discovery and innovation. The research and development technologies addressed here will align with the SRNL's and DOE's and DOD's vision to encourage initiatives that will support national defense, and energy security programs.

Approach

- Design and produce a 3D/4D hydride materials via additive manufacturing technologies that could be used as parts of the unmanned aerial vehicles (UAV).
- 3D printing will be used to produce hydride foam materials (novel feeding stock materials) to create UAV parts, e.g. body, landing gear, and motor supports.
- 3D Printed materials will be characterized and evaluated as hydrogen storage material.

Accomplishments

- Designed and produced of a library of 3D/4D hydride-based materials that could be used as structural components of the unmanned aerial vehicles. Metal hydrides selection is based on decades of intensive and extensive explorations at SRNL in this field (Figure 1).
- Evaluated and characterized both hydrogen storage materials feeding stocks and 3D printed materials -isotherms, SEM, EDS, ICP-MS, EDS mapping, ICP-MS, UV-VIS, collected isotherms on selected feed stock & 3D printed hydride materials.
- Demonstrated for the first time that we can 3D print hydride materials for hydrogen storage capabilities. Preliminary measurements indicate small variation and responses in the hydride absorption kinetics.
- Developed a very unique automated, patent pending Sieverts apparatus at various temperatures available in our lab that can be used to collect isotherm measurements and evaluate the kinetics and thermodynamic behavior of hydride material at various temperatures and pressures;
- Feed stock and 3D printed materials were characterized before/after hydrogen loading (EDS/SEM/EDS mapping) to elucidate their properties and behavior.
- Hydrogen absorption isotherms adsorption and desorption kinetics capacity, thermodynamic were collected using the automated, patent pending Sieverts apparatus at various temperatures. Data collected will be used to compare the material capacity and plateau pressure for the 3D/4D printed samples.

Future Directions

- Technology integration of UAV's components with the aircraft and maturation.

FY 2021 Peer-reviewed/Non-peer reviewed Publications

- Efficient Thermal Processes using Alternating Electromagnetic Field for Methodical and Selective Release of Hydrogen Isotopes, Energy & Fuels Special Issue, 2021; Selected as the cover art; SRNL – corresponding and first author.

Intellectual Property

- Structural Components for UAVs Made of 3D/4D Printable Materials - U.S. Patent Application
- Automatic Gas Absorption-Desorption Apparatus - U.S. Patent Application

Total Number of Post-Doctoral Researchers

Zachary Duca – SRNL

Include all images, charts and figures with captions, as shown below.

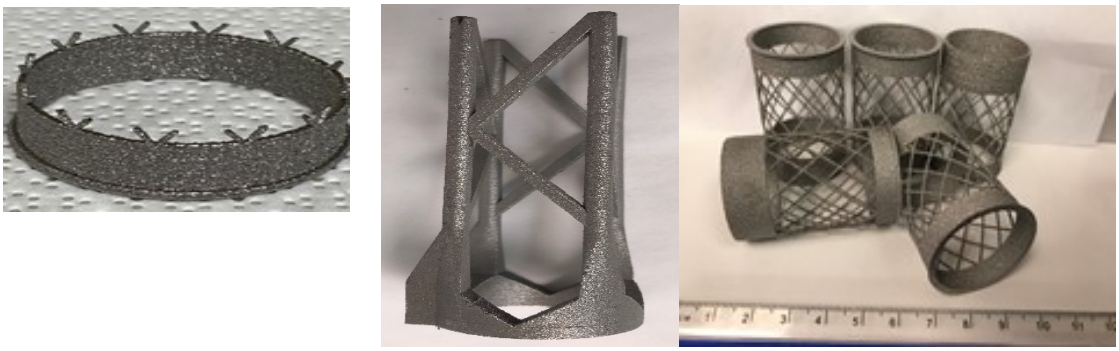

Figure 1: 3D/4D printed metal hydride objects.

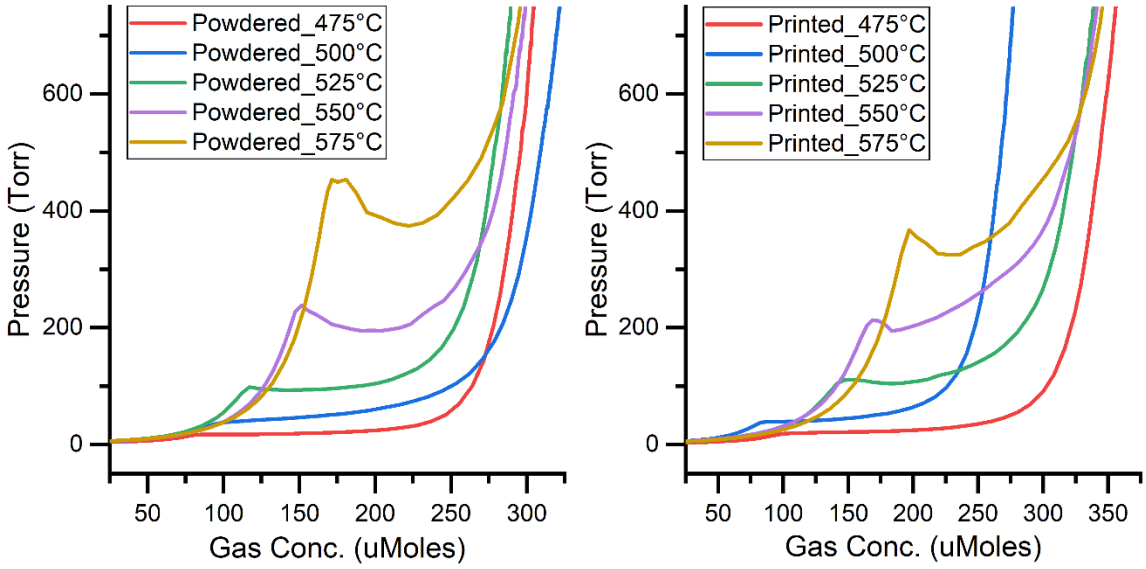

Figure 2: Hydrogen absorption isotherm absorption on powdered (left) and printed (right) hydride alloy.