Contract No:

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Title of Project

Patterning of magneto-optical nanomaterials

Project Start and End Dates

Project Start Date: October 2020

Project End Date: September 2021

Project Highlight

Developed a versatile and automatic mesoscale patterning technology that provides precise and consistent control and special arrangement of functional nanomaterials.

Project Team

Principal Investigator: Paul Beaumont

Team Members: Henry Sessions, Simona Murph

Abstract

Patterning of colloidal particles in precisely organized architectures has attracted intense research interest for decades. This is due to their potential applications in flexible electronics, magnetic and optical devices, sensors, biotechnology, communications, etc. However, creation of mesoscale assemblies at commercial scales have received less attention. The mesoscale systems reside between the micro- and macroscopic scales, with length dimensions from ≈ 100 µm to 5 mm. By leveraging decades of experimental and theoretical research in nanomaterial fields, we were able to precisely create and control the placement of nanoscale materials, allowing us to create mesoscale materials. We developed a versatile and automatic mesoscale patterning technology (via SEM-FIB and 3D printing) that provides precise and consistent control and special arrangement of functional nanomaterials. The versatility of the strategy is demonstrated by patterning nanoparticles with different dimensions, shapes and compositions, tethered with various functionalities and subjected to different external stimuli.

Objectives

- Fabrication of novel magneto-optical nanomaterials of various sizes, shapes, and compositions.
- Developed novel large scale (mesoscale) patterning approaches.

REVIEWS AND APPROVALS **Signatures on file**

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

Patterning of colloidal particles in precisely organized architectures has attracted intense research interest for decades. This is due to their potential applications in flexible electronics, magnetic and optical devices, sensors, biotechnology, communications, etc.

The most common surface patterning techniques, including nanoimprinting, nanografting, or a combination of nanolithography techniques coupled with chemical approaches, generating micrometer and submicrometer-sized architectures. Unfortunately, these approaches either lack the required surface coverage or a specialized and costly print/stamp technology is necessary in achieving the patterning of nanoparticle arrays on surfaces. However, creation of mesoscale assemblies at commercial scales have received less attention. The mesoscale systems reside between the micro- and macroscopic scales, with length dimensions from ≈ 100 µm to 5 mm.

By leveraging decades of experimental and theoretical research in nanomaterial fields, we were able to precisely create and control the placement of nanoscale materials, allowing us to create mesoscale materials. The key to the production of mesoscale systems is through the tailoring a nanomaterials' chemical functionality as a way of controlling and tuning their molecular interactions and at their interfaces in ways that can be used to couple materials together to develop new capabilities and architectures.

Approach

We developed a versatile mesoscale patterning technology that provide precise and consistent control and special arrangement of functional nanomaterials. The versatility of the strategy was demonstrated by patterning nanoparticles with different dimensions, shapes and compositions, tethered with various functionalities and subjected to different external stimuli.

Accomplishments

- Mesoscale patterning was achieved by a series of novel procedures:
    - Nanomaterials produced by our automated flow-throughput domain process (AFTDP) recently developed by us, aka nano-additive manufacturing approach, were printed on various surfaces through reliable surface functionalization/ patterning approaches (Figure 1).

- The Zeiss Crossbeam 550 Scanning Electron Microscope-Focused Ion Beam (SEM-FIB) was used for creation of unique patterned architectures (Figure 2): circles, zigzag lines, etc. on metal deposited substrates. Dimensions and architectures can be easily tailored from nano to micron scale dimensions.
- Acquired and constructed a 3D printer stage capable of 20 nm movements, “steps” that permits controlled manipulation of the printing process; The resolution of the printer could also be adjusted in developed software to accommodate the picomotor resolution as well as the print head resolution. Developed LabVIEW software interface to manually control the picomotor printer stage (Figure 3).

Future Directions

A multifactorial experimental design will be used in the future for 3D additive printing of advanced nanomaterials and explore the correlation between the processing parameters that govern both production and printing.

FY 2021 Peer-reviewed/Non-peer reviewed Publications

Two manuscripts are in preparation for publication in peer-reviewed journals.

Intellectual Property

- One patent application was filled with the US Patent and Trademark Office: Systems and methods for manufacturing nano-scale materials; Application # 16892711/2020.

Acknowledgements

- Michael Brown, Dalton Hare, Henry Ajo, Ray Belliveau.

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

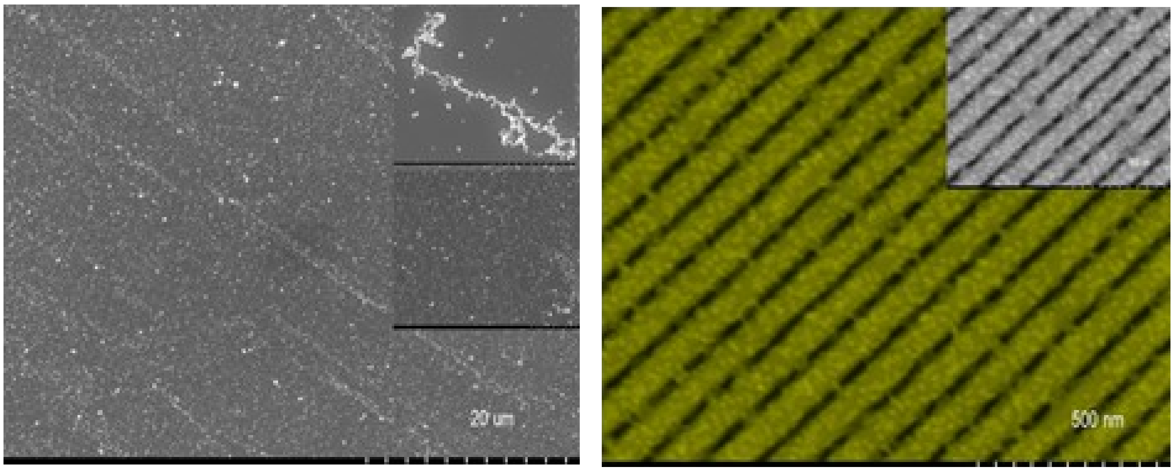

Figure 1: Mesoscale assemblies' nanoarchitectures (left) FexOy-based nanomaterials patterned on magnetic medium and (right) gold nanostructures patterned on FIB created patterns.

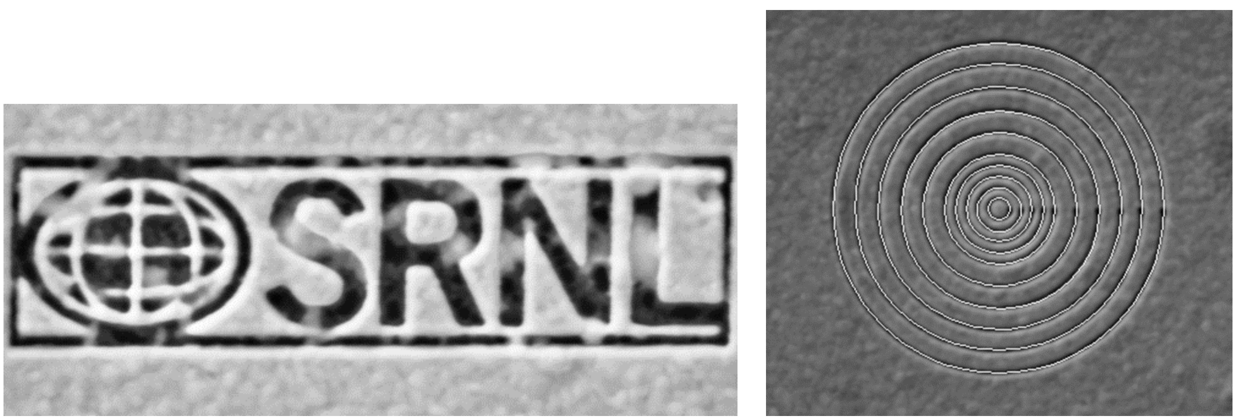

Figure 2: SEM-FIB patterning: (left) SRNL logo of outer dimensions 4.2 microns long by 1.1 microns tall; (right) Concentric circles with tailored dimensions.

Figure 3: Print preview of material printed with a 3D printer created with a head resolution of 30 nm.