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14. ABSTRACT
Crosby and Emrick purchased the Advanced Imaging and Micromanipulation system, capable of high-speed, high resolution image acquisition (AIM-FAST). This instrument system is built on a ZEISS Axiovert Observer 7 optical microscope, equipped with a piezoelectric scanning stage, a Hamamatsu ORCA 7 imaging system, and an Eppendorf micromanipulation and microinjection platform. This device is designed especially for mechanical measurements of mesostructured materials, including the hierarchical mesostructures, called "mesoscale polymers", which we have developed through support from the Army Research Office (ARO/W911NF-14-1-0185) MSPs are

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Report Title

Final Report: Advanced Imaging and Micromanipulation System for High-Speed Characterization of Multifunctional, Hierarchical Structures (AIM-FAST)

ABSTRACT

Crosby and Emrick purchased the Advanced Imaging and Micromanipulation system, capable of high-speed, high resolution image acquisition (AIM-FAST). This instrument system is built on a ZEISS Axiovert Observer 7 optical microscope, equipped with a piezoelectric scanning stage, a Hamamatsu ORCA 7 imaging system, and an Eppendorf micromanipulation and microinjection platform. This device is designed especially for mechanical measurements of mesostructured materials, including the hierarchical mesostructures, called "mesoscale polymers", which we have developed through support from the Army Research Office (ARO/W911NF-14-1-0185) MSPs are created with unique geometries, such as helices or grid-like sheets, which can dynamically change over a broad range of relevant length and time scales. AIM-FAST enables the structural, mechanical, and electrical property characterization of our MSP library. Furthermore, through laboratory training and coursework, AIM-FAST will provide a great opportunity to train future engineers and scientists on the intricacies of micro- and nanoscale manipulation, high speed imaging, as well as how small scale structure property relationships translate to macroscale materials performance.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Crosby, Alfred J	0.00	No
Emrick, Todd	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**2**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See Attachment

Technology Transfer

Mesoscale Polymers (MSP), specifically helical forms, as developed with ARO Grant W911NF-14-1-0185 by Crosby and Emrick, provide exceptional opportunities in the control of mechanical properties in advanced, soft materials composites. To quantify and demonstrate these mechanical properties, the AIM-FAST instrument purchased with these provided DURIP funds has been critical. Over the past 6 months since completing the setup of the AIM-FAST instrument, we have collected images, videos, and mechanical property measurements that have been shared with visiting industrial scientists from Exxon-Mobil, Kuraray, and BASF to help develop future industrial collaborations based on MSP. Furthermore, Crosby attended a Strategic Planning Workshop at the Army Research Laboratory focused on materials for automonous vehicles and shared the capabilities that MSP can provide for new soft materials in this application.

Final Report for ARO Grant W911NF-15-1-0367

Title: Advanced Imaging and Micromanipulation System for High-Speed Characterization of Multifunctional, Hierarchical Structures (AIM-FAST)

PI: Alfred J. Crosby, Todd Emrick

Organization: Polymer Science & Engineering Department, University of Massachusetts Amherst

Abstract

With DURIP funds, Crosby and Emrick purchased the Advanced Imaging and Micromanipulation system for high-speed, high-resolution image acquisition (AIM-FAST). This instrument system is built on a ZEISS Axiovert Observer 7 optical microscope, equipped with a piezoelectric scanning stage, a Hamamatsu ORCA 7 imaging system, and an Eppendorf micromanipulation and microinjection platform. The device is ideally-suited for mechanical measurements of mesostructured materials, including the "mesoscale polymers" (MSP) developed by Crosby and Emrick under support of the Army Research Office (ARO/W911NF-14-1-0185). MSPs fabrication processes give access to unique mesoscale geometries, such as helices or grid-like sheets, which can dynamically change over a broad range of length and time scales. AIM-FAST enables the structural, mechanical, and electrical property characterization of our MSP library. Furthermore, through laboratory training and coursework, AIM-FAST will train future engineers and scientists on the intricacies of micro- and nanoscale manipulation, high speed imaging, and how small scale structure property relationships translate to macroscale materials performance.

Scientific Progress

Mesostructured materials are being developed and studied at an increasingly rapid pace due to the unique combination of properties that can be produced and actively tuned in mesoscale composite materials. One particularly enabling example of such materials are mesoscale polymers (MSP) developed by Crosby and Emrick through the support of the Army Research Office (ARO/W911NF-14-1-0185). MSPs represent a platform technology that provides strategies and methods for fabricating mesoscale structures from nanoscale components, which can subsequently be integrated into secondary structures, e.g. helices or 2-D fabric-like grids. Fluorescence images of example structures are shown in Figure 1. Crosby and Emrick have constructed elementary devices to initiate the

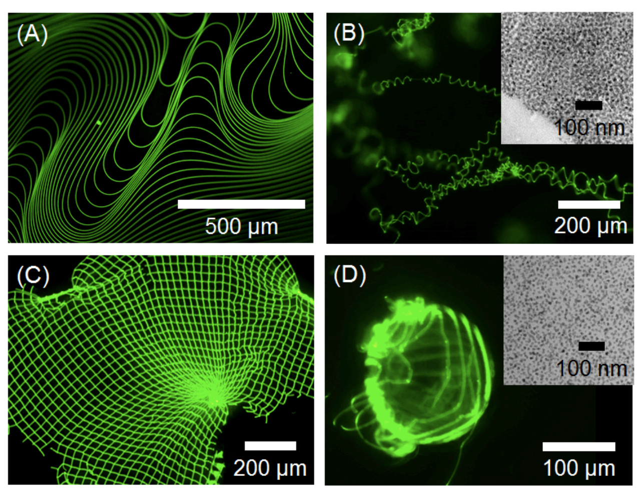

Figure 1: MSP structures fabricated from polymer-functionalized semiconductor nanoparticles. (A) Flexible ribbons, (B) helical ribbons, (C) grid-like sheets, and (D) ribbon-encapsulated droplets. TEM insets: (B) Edge of a CdSe QD ribbon (~70% inorganic) and (D) a polymer-coated CdSe QD ribbon (~30% inorganic).

structural, mechanical, and electrical properties of MSPs; however, these devices and their measurements are limited in the time and spatial scale that can be investigated. Accordingly, Crosby and Emrick proposed the acquisition of an Advanced Imaging and Micromanipulation System for High-Speed Characterization of Multifunctional, Hierarchical Structures (AIM-FAST).

The AIM-FAST advanced measurement system is comprised of a ZEISS Axiovert Observer 7 optical microscope, a piezoelectric x-y scanning stage, a Hamamatsu ORCA 7 high speed imaging system, and an Eppendorf micromanipulation and microinjection platform. The system is controlled by Zeiss software, which enables high resolution, high speed imaging of large structures *with precision x-y-z positioning*. These components were assembled on a vibration isolation table and integrated with custom-fabricated chambers and manipulator tools to provide direct manipulation and characterization of MSPs. Images of the assembled AIM-FAST system

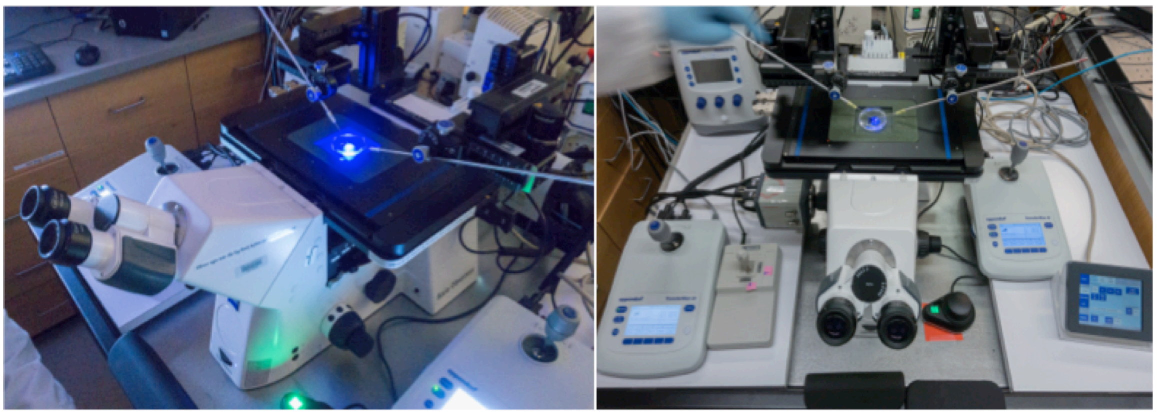

Figure 1. Images of the AIM-FAST system in the Crosby laboratory with a specimen of PMMA MSP ribbons being imaged and stretched.

in the Crosby laboratory are provided in Figure 1.

For MSP characterization, the AIM-FAST system provides numerous advantageous functions. First, as MSPs are released into fluid environments, their flexibility, small size scale, and low density provide challenges for acquiring static, high resolution images of their structural shape in different configurations. With AIM-FAST, a user can identify MSPs at a lower magnification objective, secure the MSP with one or two micromanipulator attachment tools, then control the relative position of the micromanipulator tools to deform the MSPs into desired configurations. In this device configuration, imaging at higher magnifications kis achieved without undesired vibrations or drift in the fluid environment. Furthermore, using custom manipulator tools, such as the carbon fibers shown in Figure 2, we can measure the deflection of the carbon fiber to determine the force exerted on the MSP structure in different configurations. Most importantly, these measurements can be made at various levels of spatial resolution and at significantly greater speeds than previously permitted. For example, we have used this capability to record the recoil of MSP helices after stretching them to failure, thus enabling a new, systematic experimental method for measuring the dynamics of helix formation.

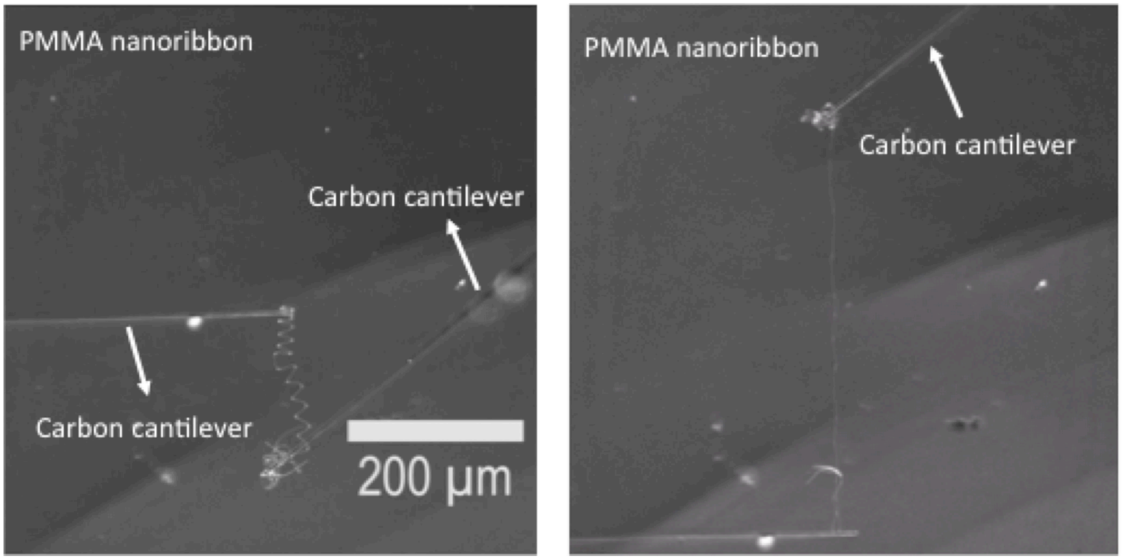

Figure 2. Left: Image taken on AIM-FAST of a PMMA MSP nanoribbon helix attached to two carbon fiber cantilevers held by the Eppendorf micromanipulators. Right: The same PMMA MSP nanoribbon shown in the image on left now stretched by moving the micromanipulator tools to a increased separation distance.

In addition to precise characterization of MSPs, we anticipate that AIM-FAST will enable new measurements for a large variety of DOD-related projects at the University of Massachusetts Amherst and throughout Five College system. For example, since the installation of AIM-FAST, researchers in the Crosby research group have used this instrument to implement cavitation rheology on small scale biological tissues, such as spheroids (Figure 3). Researchers in the Emrick research group have also used AIM-FAST to image the transition of MSP nanoribbons exposed to different solvent environments and to understand their morphological transitions. We expect numerous researchers to take advantage of the AIM-FAST system, and the infrastructure for training and instrument scheduling is established to easily accommodate this use.

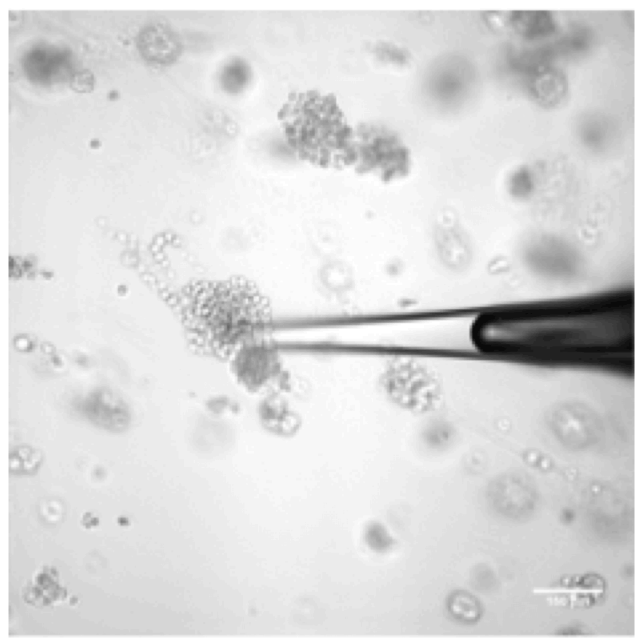

Figure 3. Image of glass micropipette inserted into a spheroid of cells on AIM-FAST. Pressure of injection of saline measured to determine mechanical properties of spheroid using cavitation rheology.