Fiscal Year:	FY 2021	**Task Last Updated:**	FY 11/29/2020
PI Name:	Yokoyama, Hiroshi Ph.D.		
Project Title:	Structure and Dynamics of Monodisperse Liquid Crystal Domains created on Suspended, Molecularly-Thin Smectic Films using Sub-Femtoliter Inkjet Technology		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	COMPLEX FLUIDS/SOFT MATTER--Complex Fluids		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	44242-0001	**Congressional District:**	13
Comments:			
Project Type:	Flight	**Solicitation / Funding Source:**	2015 NNH15ZTT002N MaterialsLab Open Science Campaigns for Experiments on the International Space Station
Start Date:	12/30/2016	**End Date:**	12/29/2021
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA GRC
Contact Monitor:	Hatch, Tyler	**Contact Phone:**	216.433.5073
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Flight Program:	ISS		
Flight Assignment:	Liquid Crystal Facility		
Key Personnel Changes/Previous PI:	November 2020 report: No change during this term.		
COI Name (Institution):	Emelyanenko, Alexander Ph.D. (Co-PI/ Lomonosov Moscow State University, Russia) Tabe, Yuka Ph.D. (Co-PI/ Waseda University, Japan)		
Grant/Contract No.:	NNX17AD68G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Liquid crystals are the unique state of matter in which the molecular order existing in the solid state can persist even in the flowing liquid state. Understanding the molecular interactions underlying the microscopic order is crucial for further development of better performing liquid crystals for industrial applications and also for elucidating the molecular mechanisms of a wide range of biological structures. The goal of this project is to study the evolution of microscopic islands of liquid crystals configured on a thin liquid crystal film in the microgravity environment. The islands are deposited on the film by means of a novel sub-femtoliter inkjet device in a prescribed configuration. The time dependent changes of configuration and the rotational motion of islands will reveal the hidden molecular action responsible for the liquid crystallinity. The research effort in 2019 has been focused on the two fronts: (1) Development to an automated film preparation system and an analytical tool for rapid mapping of the thickness distribution of the film, and (2) Improvement of the ultrafine inkjet device to allow better controlled deposition of droplets. The thickness of free standing films are quantized by the number of molecular layers and play a significant role in determining the structure and interaction of droplets and their structural evolution; for the Lehmann rotation, the sense and speed of rotation are known to undergo drastic change, and hence it is vital to characterize the film thickness in the first place. We have developed a novel approach for thickness measurement based on the color of the reflected light, not on the intensity of reflection, which has been used for decades as the standard technique. For 2D analysis of the film images, the color is a much more reliable variable than the intensity. We also developed an automated film preparation hardware that can be considered a prototype for the ultimate hardware for flight experiments. In 2017 and 2018, we demonstrated the feasibility of ultrafine inkjet technology based on electrostatic deposition. We refined the device by employing a reproducible electrochemical preparation method of sharp metallic needles. The hardware is equipped with fine positioning mechanisms to adjust the relative positions of the needle, the extraction electrode and the smectic film target.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The principal scientific objective of this flight experiment is to explore the hidden phenomena in free standing smectic liquid crystal films in the microgravity environment in which the capillarity-induced forces disappear. Generally, interactions of microscopic particles and islands freely suspended in two-dimensional liquid films are of central significance in a wide range of industrial fields ranging from oil and mineral recovery, food processing, pharmaceuticals, coating and wet processes, as well as in basic sciences dealing with protein-protein interactions in cell membranes to name a few. In Earth's gravitational field, intricate molecular interactions are often overwhelmed by capillarity forces and are hardly accessible in direct physical experimentations. Microgravity in space enables us to approach these phenomena such as Ostwald ripening, molecularly mediated island-island interactions and the Lehman rotation in liquid crystalline islands and films driven by the transmembrane molecular flow through the observation of configurational evolution of liquid crystalline islands on the smectic thin film. To prepare the required initial arrangement of islands, we develop and employ the sub-femtoliter inkjet deposition technology, which is integrated to an automated film preparation and observation hardware. Crucial for the liquid crystal science and technology is the understanding of intermolecular interactions responsible for the formation of liquid crystal phases. This space research aims to provide novel information that is hardly acquired from ground-based experiments.
Task Progress:	Liquid crystals are the unique state of matter in which the molecular order existing in the solid state can persist even in the flowing liquid state. Understanding the molecular interactions underlying the microscopic order is crucial for further development of better performing liquid crystals for industrial applications and also for elucidating the molecular mechanisms of a wide range of biological structures. The goal of this project is to study the evolution of microscopic islands of liquid crystals configured on a thin liquid crystal film in the microgravity environment. The islands are deposited on the film by means of a novel sub-femtoliter inkjet device in a prescribed configuration. The time dependent changes of configuration and the rotational motion of islands will reveal the hidden molecular action responsible for the liquid crystallinity. The research effort in 2020 has suffered seriously from the spread of COVID-19 infections across the nation since March. In particular, laboratory activities were almost entirely stopped through the rest of the year. We have therefore focused our research efforts on perfecting the thickness measurement method that was started last year. As is well known, the thickness of free-standing films is quantized by the number of molecular layers and plays a significant role in determining the structure and interaction of droplets and their structural evolution. In the Lehmann rotation, the sense and speed of rotation undergo drastic variation as the thickness changes. Rapid and precise determination of the thickness distribution over the free-standing film is critical for the analysis of the experimental observations. We have developed a novel approach for thickness measurement based on the quantitative analysis of color of the reflected light, not on the intensity of reflection, which has been used for decades as the standard technique. For 2D analysis of the film images, the color is a much more reliable and robust variable than the intensity. By using a state-of-the-art high-resolution camera, it became possible to determine the thickness of the film with an accuracy better than 1 nm over the entire range of interest from less than 10 nm up to several hundred nanometers.
Bibliography Type:	Description: (Last Updated: 12/04/2023)
Articles in Peer-reviewed Journals	Chen W, Yokoyama H. "Rapid thickness mapping of free-standing smectic films using colour information of reflected light." Liquid Crystals. 47. Published online: 28 Sep 2020. https://doi.org/10.1080/02678292.2020.1825843 , Sep-2020