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The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

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RPPR Final Report
as of 01-Jun-2020

Agency Code:

Proposal Number: 73853CHRIP **Agreement Number: W911NF-19-1-0170**
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Final Report for Period Beginning 05-Mar-2019 and Ending 04-Mar-2020
Title: Double Helix SPINDLE Module for 3-D Super-resolution Imaging of Nanoscale Plasmon-enhanced Photocatalysis
Begin Performance Period: 05-Mar-2019 **End Performance Period:** 04-Mar-2020
Report Term: 0-Other
Submitted By: Peng Chen Email: pc252@cornell.edu
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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: **STEM Participants:**

Major Goals: The objective of this DURIP project is to acquire an add-on equipment module, “Double Helix SPINDLE,” to our existing optical microscope to enable 3-D single-molecule super-resolution fluorescence imaging, with nanometer resolution in x, y, and z dimensions so as to expand our study to catalysts with complex 3-D morphologies.

Accomplishments: Please see the uploaded file.

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: 2019Chemical Pioneer Award
2019 Joan Van der Waals Lecturer, University of Leiden
2019 Brian Bent Lecturer, Columbia University
2019 Keynote Lecture, 18th Beijing Conference and Exhibition on Instrumental Analysis
2019 Keynote Lecture, 16th Conference on Methods and Applications of Fluorescence (MAF 2019)
2019 Keynote Lecture, 5th International Conference on Energy Conversion and Storage (5th ICECS)
2019 Opening Keynote Lecture, International Bunsen Discussion Meeting on Probing Chemical Reactions by Single-molecule Spectroscopy
- Nano Research (Young Star Editor, 2019-)

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Peng Chen
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:

International Travel:
National Academy Member: N
Other Collaborators:

This DURIP grant enabled us to acquire an add-on equipment module, “Double Helix SPINDLE,” to our existing optical microscope to enable 3-D single-molecule super-resolution fluorescence imaging, with nanometer resolution in x, y, and z dimensions, beyond our original 2-D imaging of comparable resolution. This would allow us to study reactions on catalyst particles with complex 3-D morphologies, such as those semiconductor particles with truncated bipyramidal morphologies and those with additional plasmonic particles deposited on top. This double Helix module has been purchased, installed on our microscope for single-molecule super-resolution imaging, tested and calibrated for x/y/z single-molecule localization to ~20 nm precision.

Although powerful in resolving single-molecule targets in 3D with high resolution, it comes with additional complications technically. First, as this module is added in the detection path and the module contains a phase mask and multiple lens for light collimation and refocus, the overall light throughput is decreased, compromising some detection sensitivity in single-molecule imaging. Second, due to the double helix point spread function, the image of a single molecule appears as two lobes with different alignments for different z positions, as compared with a single Gaussian-shaped image in typical 2-D imaging. This difference in image properties made our home-written MATLAB code unsuitable for automated data processing, which are absolutely necessary because a typical day of experiments in our lab generates tens to hundreds of thousands of images. On the other hand, the ImageJ plug in that was provided by the vendor has very limited automation function and not open source for revision. We need a graduate student or postdoc, who is an excellent computer programmer and also has a project focused on 3-D imaging to justify devoting sufficient time to work out another 3-D version of our home-written codes.

Scientifically, the catalysts that our research focuses on either are flat in geometry (e.g., metal nanoplates or nanorods) or have 3-D morphology that has sufficient symmetry for which 2-D projection will provide sufficient information on overall 3-D positions. Therefore, experiments utilizing this 3-D resolution has been slow to come to be priority, as most of scientific questions we are trying to answer can be addressed in 2-D imaging. One direction that likely will require 3-D super-resolution imaging is the study of plasmonic nanoparticles supported on 3-D semiconductor particles, in which the plasmonic nanoparticles could be located at any position on the 3-D particle without much symmetry. But our current research funded by ARO RCS has now been directed toward a high priority direction: cooperative ligand adsorption on single nanocatalysts mapped by COMPEITS imaging. Another possible direction is to use this 3-D imaging to enable tracking single protein molecules in single bacterial cells, which could possibly benefit our research of metal efflux complexes in bacteria, part of which funded by ARO Microbiology Program.