Speaker:
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Title:
Extreme Microscopy: High-Resolution Imaging of Biological and Engineering Specimens at Extreme Conditions

Abstract:

Optical microscopy has been extensively applied to explore across a wide range of disciplines, e.g., microelectronics, biotechnology, mineralogy and agriculture. Recent decades, several improvements have been made to gain higher resolution, rapider image acquisition speed, or more sensitive detection. However, it is still challenging to apply an optical microscopy to record images and perform quantitative measurements of biological and engineering specimens at extreme conditions. For instance, the traditional fluorescence intensity-based method suffers from the difficulty of accurate measurement of oxygen levels in microfluidic devices or in living cells due to background fluorescence artefacts; current microscopes techniques lack of high enough spatiotemporal resolutions to investigate lipids dynamic molecular motion/interaction; existing optical microscope interferometers have serious limitations for measuring specimens in liquid media or aqueous environments directly, because of mismatch between optical path length and image path length in microscopy systems.

Here, to overcome the intrinsic difficulties aforementioned, three major microscopic techniques are invented to perform quantitative measurements under various spatiotemporal regimes on the specimens at extreme conditions. First, a widefield frequency domain fluorescence lifetime imaging microscopy (FD-FLIM) system was constructed and utilized to accurately characterize oxygen levels. Since lifetime-based measurements are independent of intensity variations, the calibration processes are amiable and the measured oxygen concentrations are more accurate. The FD-FLIM system is further integrated and controlled by a homemade code via Micro-Manager interface to improve the efficiency and the accuracy while rapidly assess the oxygen gradients in three dimensions. Second, using high-speed interferometric scattering (iSCAT) optical microscopy and small gold nanoparticles as labels, motion of single lipids is recorded via single-particle tracking with nanometer spatial precision and microsecond temporal resolution. By the technique, the nanoscopic substructures of the raft-mimetic membrane domains are revealed. Third, a newly-invented apparatus, “Self-Adjusting Liquid Linnik Interferometer (SALLI)”, has been fabricated to implement real-time whole field deformation measurement within liquid media. The deformation history and the material properties of thin film electrodes/battery cells during cycling are thus able to be experimentally determined.

It is important to note that novel microscopy techniques need much expertise in optics in order to generally cover diverse spatiotemporal regimes, i.e., from nanometer to micrometer in spatial precision and from microsecond to twice a week in temporal resolution. In my past research experiences, several samples including live cells, lipids labeled with nanoparticles, organoids cocultured with microbeads, dyed solution, dyed hydrogel, thin film electrodes, and commercial battery pouch cells have been successfully tested. We therefore believed that these microscopic techniques can greatly provide biomedical and agricultural scientists and engineers efficient tools to better understand physical properties of biological and engineering specimens naturally living in various extreme conditions.