Dynamics of Phospholipid Membrane Composite Nanomaterials

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Scientific Thrust Area: Soft, Biological and Composite Nanomaterials Thrust

Proposal Title: Silica-Phospholipid Membrane Nanocomposites: Synthesis and Characterization of Robust Biological Transport Systems (G. P. Lopez)

Research Achievement:

Interactions at the bio-nano interface have exciting potential in the next generation of technological advances. At the cellular level, lipid membranes, composed mainly of lipids and proteins, create the barrier at which interaction between the biological and non-biological world take place. Membranes exist not only as barriers, but are also key components of cellular activity. For example, they allow for creation of potential gradients, allowing for processes such as energy production to occur, and also serve as sites for cellular target recognition. Lipid membrane model systems have become popular for investigating biological membrane structure and function. These assemblies have the advantage of compositional and environmental control, allowing for investigation of membrane properties that can often be difficult to assess in cellular systems. Interaction of these assemblies with synthetic substrates, including nanostructured materials, has already exhibited potential in creating new bio-synthetic architectures as well as in providing information on cellular responses to the non-biological world. Presented are examples from CINT user collaborations and CINT thrust efforts that utilize membrane assemblies to investigate biological phenomena and develop new methods towards understanding membrane properties and processes.

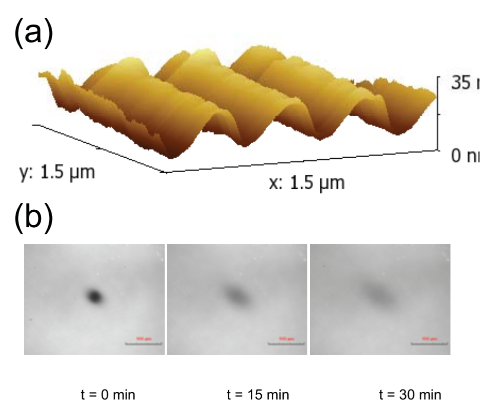

Figure 1. Lipid Membrane Assemblies (LMA) on nanostructured surface. (a) AFM of LMA on nanostructured surface. (b) Images of fluorescence recovery after photobleaching of LMAs on nanostructured surface.

Research that focuses on the morphology and dynamics of lipid bilayer assemblies on nanostructured surfaces will be shown. Using atomic force microscopy and quantitative fluorescence microscopy, we have shown that the bilayer assemblies conform to the underlying nanostructured substrate and display apparent anisotropic diffusion (Figure 1). Simulations indicate that lipid diffusion on the surfaces is homogeneous and consistent with isotropic diffusion along the periodic surface, however over macroscopic scales diffusion appears anisotropic due to the nanostructured surface.

Thus, we demonstrate how quantitative analysis of dynamics probed by larger-scale fluorescence imaging can yield information on nanoscale thin-film morphology.

Further, we will describe research focusing on mechanisms underlying biological and health effects of nanomaterials. Cellular lipid membranes represent the physical barrier between the cell and the external environment, and thus serve as a point of interaction of foreign particles, such as fullerenes, with the cell. In this study, we used in situ atomic force microscopy (AFM) and fluorescence spectroscopy to visualize the interaction of a systematically functionalized series of fullerenes with both THP-1 cellular membrane fragments and lipid bilayer assemblies (LBA) of various compositions. Results suggest various mechanisms in which fullerenes may interact with membrane architectures and elicit responses (Figure 2). Results were evaluated as a function of fullerene physical, chemical and electrical properties, providing input toward developing predictive models for biological effects of nanomaterials.

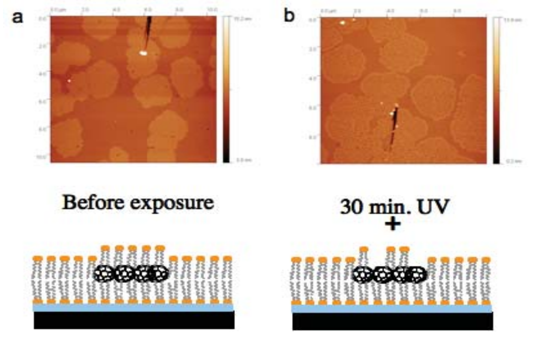

Figure 2. Fullerene incorporation into POPC LBA. (a) incorporation of fullerene into LBA interior with aggregation. (b) UV-exposed enhanced LBA damage localized to areas of fullerene incorporation.

Lastly, a novel strategy for silica encapsulation and stabilization of membrane components will be described. The described method is simple, controllable and non-toxic to biological structures. Various membrane components, both biological and bio-inspired that have been successfully encapsulated and exhibited stability over days to months will be described. This research represents a significant advancement in our ability to stabilize biological structures under various conditions and will have significant impact in biosensing, drug delivery and biophysical research.

Future Work:

Research will continue to explore dynamics of membrane composite nanomaterials. We will exploit the stability and maintenance of biological activity in robust materials to develop integrated composite systems that mimic biological activity such as active transport and signal propagation. Further, platforms will be developed for investigation of membrane dynamics and organization using a variety of biophysical techniques.

Associated Publications:

J. Werner, G.A. Montaño, A Zurek, A. Garcia, E. Akhadov, G.L Lopez, A.P. Shreve. (2009) *Formation and characterization of a supported phospholipid membrane on a periodic nanotextured substrate.* Langmuir 25(5):2986-2993.

R. Martin, H.-L. Wang, S. Iyer, G.A. Montaño, J.S. Martinez, A.P. Shreve, Y. Bao, C.-C. Wang, Z. Chang, Y. Gao, J. Gao, R. Iyer, . (2009) *Impact of physicochemical properties of engineered fullerenes on key biological responses* Toxicology and Appl. Pharmacology 234:58-67.