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Towards self-assembling of organic photovoltaics

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Background

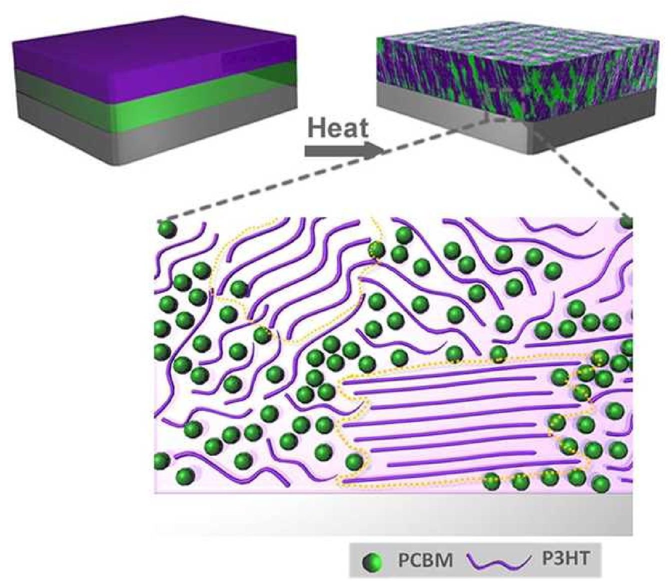
Organic photovoltaics (OPVs)

Organic photovoltaics have the potential to be more flexible, thinner, and more cost efficient than their inorganic counterparts. However, with the present OPV technology, performance has been limited due to low material stability, poor power conversion efficiency. Currently, research using bulk heterojunction (BHJ) photovoltaics has shown power conversion efficiencies approaching 10%, but more research must be done to understand the morphology of these solar cells in order to further optimize energy transport.

J. Nelson, Curr. Opin. Solid State Mater. Sci. 2002, 6, 87–95.

Fullerene-polymer photovoltaics

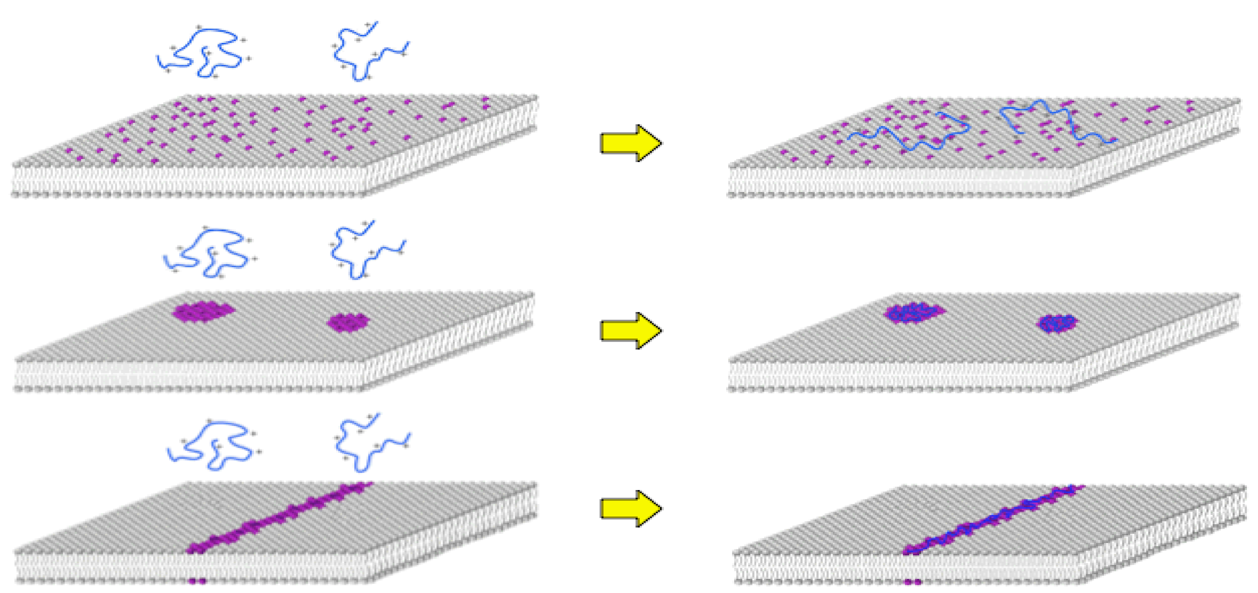
Currently, many OPVs are created using a blend of polymer and fullerene molecules in vertically stacked bilayers. The electron gradient between the two layers allows for the creation of energy by means of photons. However, unlike their inorganic counterparts, OPVs materials are dynamic rather than crystalline, which is problematic for maintaining the electron gradient.



Treat, N. D.; Brady, M. A.; Smith, G.; Toney, M. F.; Kramer, E. J.; Hawker, C. J.; Chabinyc, M. L., Adv. Ener. Mater. 2011, 1, 82 - 89.

Research goal

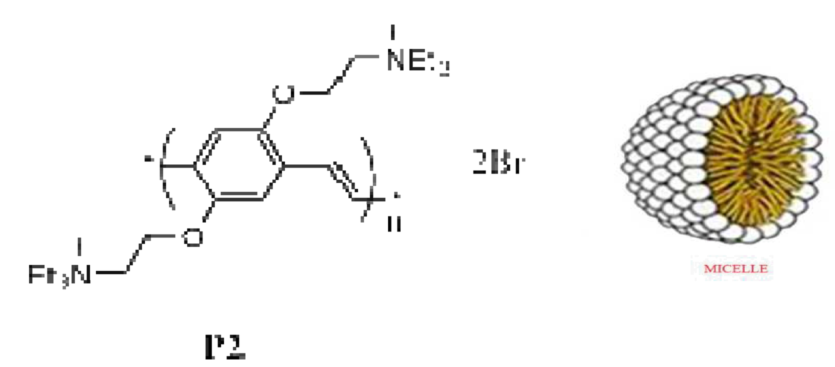
We are developing materials and methods to organize the conducting polymer and fullerene assemblies using self-organizing systems. Using lipid bilayers it may be possible to organize and orient the disparate materials using phase separation, charge interaction, and templated architectures.

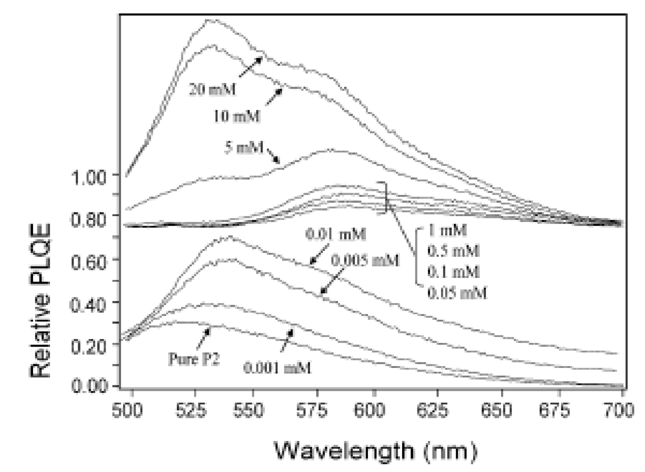


Results

Water-soluble polyphenylene vinylene (PPV)

Cationic PPV (P2) developed by Wang displayed enhanced fluorescence upon interaction with micelles as a result of enhanced structural order.

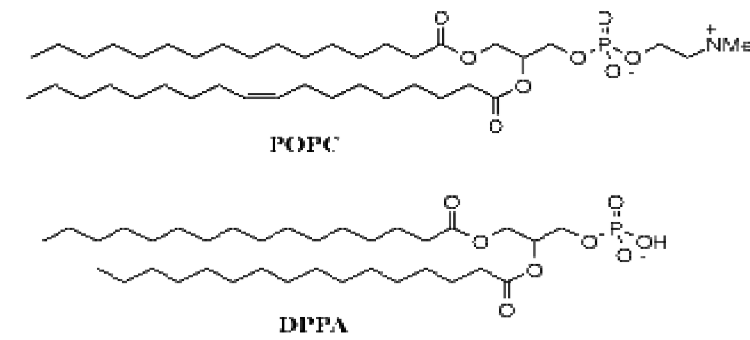


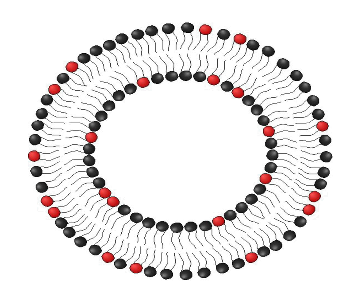


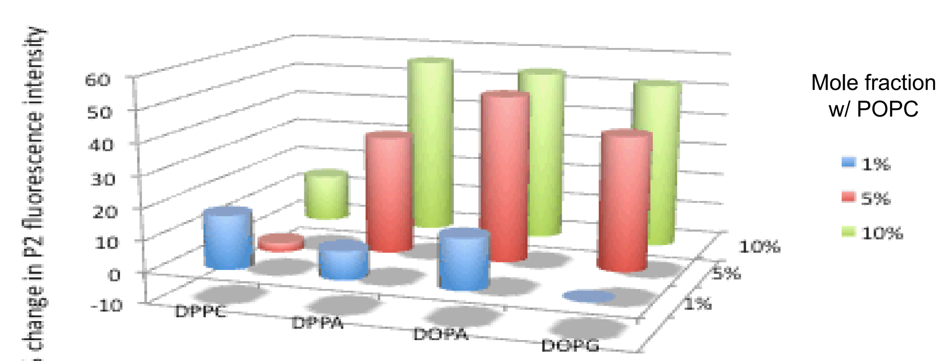
Treger, J. S.; Ma, V. Y.; Gao, Y.; Wang, C.-C.; Wang, H.-L.; Johal, M. S. J. Phys. Chem. B 2008, 112, 760 - 763.

Phase separation and charge interaction with giant vesicles

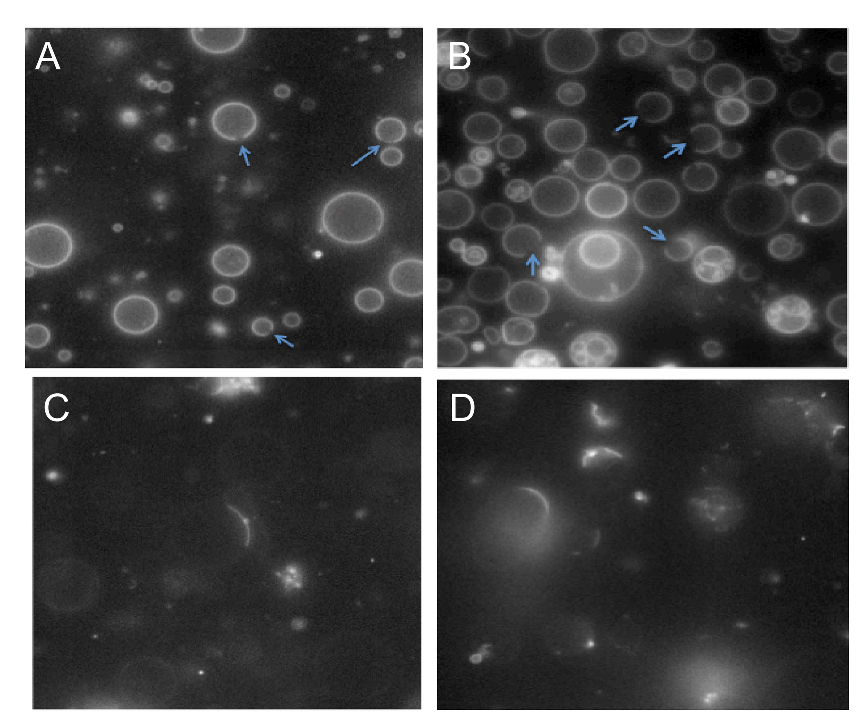
We studied the effect of phase separation in lipid membranes on the assembly and fluorescence of P2. Bilayers with randomly dispersed negative charge (DOPA/POPC, DOPG/POPC) enhanced fluorescence of P2 by >50%. For phase separated membranes (DPPA/POPC), domains enriched with negatively charge DPPA selectively bound P2.







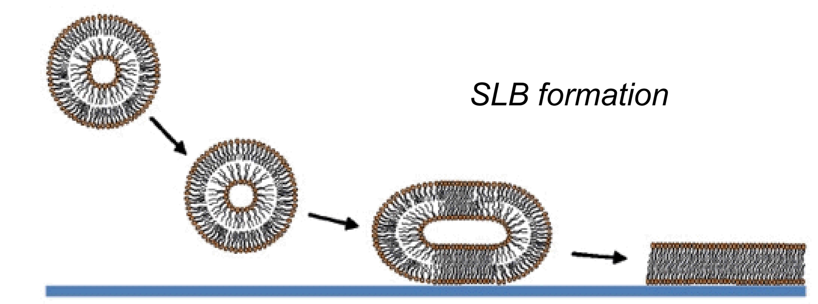
P2 fluorescence intensity increases upon adsorption to negatively charged lipids for both randomly dispersed (DOPA, DOPG) and phase separated (DPPA) containing membranes.



Giant vesicles of A) 5% DPPA/POPC and B) 10% DPPA/POPC labeled with BODIPY 530/550 HPC show phase separated domains (dark regions) rich in gel phase DPPA (TRITC filter). Bottom images, observed with GFP filter, show P2 selectively adsorbs to domains on membrane for C) 5% DPPA/POPC and D) 10% DPPA/POPC ([P2] = 10 μM).

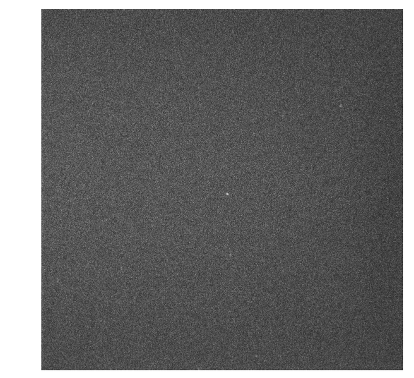
Supported lipid bilayers (SLB)

We employ SLBs to aid in our understanding of the polymer/membrane interaction. SLBs form via vesicle fusion of small unilamellar vesicles (SUVs) with a glass surface. By using different compositions of lipids in the bilayer we can create domain architectures that facilitate selective polymer affinity. We plan to experiment on several different lipids in order to create clear domains.

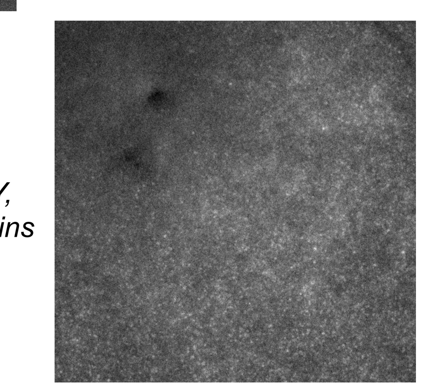


SLB formation

http://popups.ulg.ac.be/Base/docannexe/image/6568/img-11.jpg



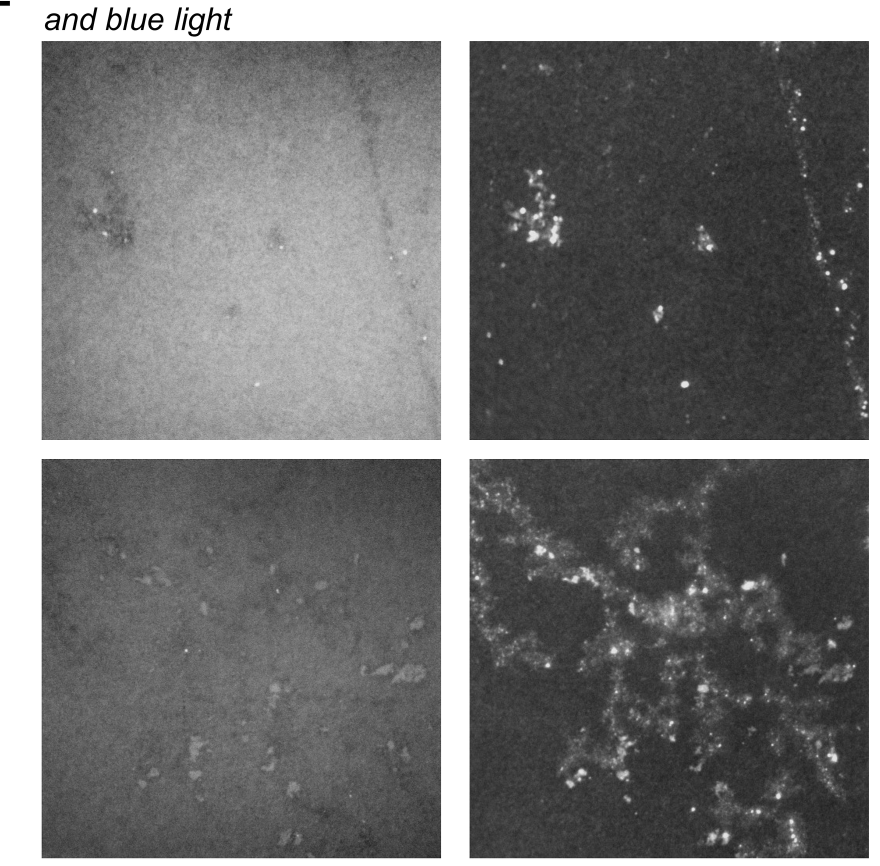
SLB of 20% DPPG, 0.03% BODIPY, and 59.9% POPC - no domains seen



SLB of 20% DSPC, 20% cholesterol, 0.03% BODIPY, and 59.9% DPHPC - domains

P2 binding of SLB domains

SLB of 20% DSPC, 89.9% POPC, 0.03% BODIPY in green and blue light

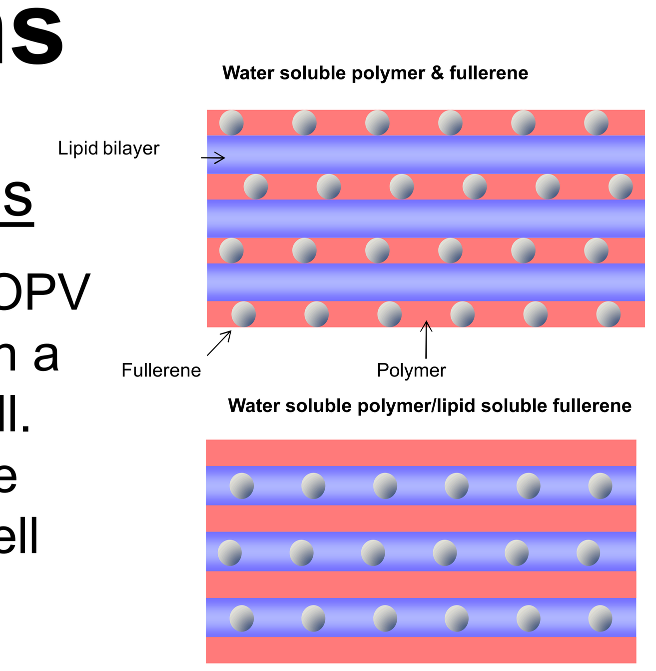


After forming the SLB, P2 was added. BODIPY responds to wavelengths in the green spectra, and will often bind to the lipid disordered (POPC) regions. P2 responds to wavelengths in the blue spectra, and was able to bind specifically to DSPC domains. In the future, we will run these experiments with negatively charged lipids (DOPA, DOPG) as well as phase separated membranes (DPPA).

Future plans

Structural order with lipid membranes

Our goal is the creation of a more organized OPV structure, which will allow electrons to travel in a proficient manner through the photovoltaic cell. Further research will allow us to determine the most effective lipids for domain creation as well as P2 binding.



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