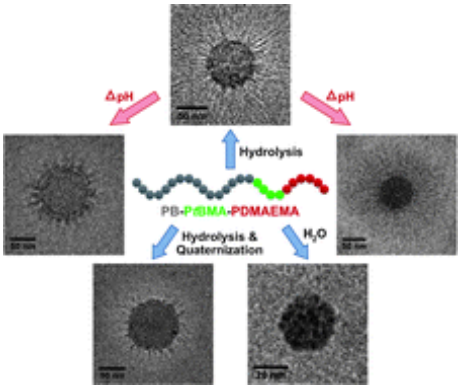
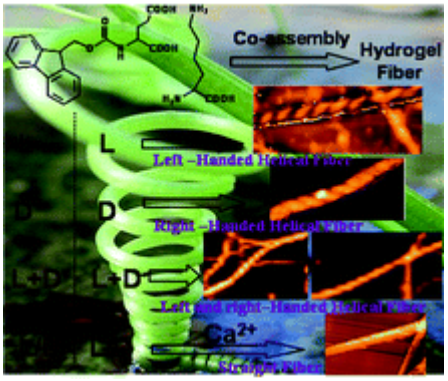
- Dual stimuli-responsive multicompartment micelles from triblock terpolymers with tunable hydrophilicity
  Betthausen, E.; Drechsler, M.; Förtsch, M.; Schacher, F. H.; Müller, A. H. E. *Soft Matter* **2011**, *7*, 8880-8891.
  Abstract:



A plethora of stimuli-responsive micellar aggregates with a compartmentalized shell can be formed in aqueous solution from ABC triblock terpolymers with tunable hydrophilicity. Polybutadiene-*block*-poly(*tert*-butyl methacrylate)-*block*-poly(2-(dimethylamino)ethyl methacrylate) (PB-*b*-P*t*BMA-*b*-PDMAEMA) and, after modifications by hydrolysis to poly(methacrylic acid) (PMAA) or quaternization to PDMAEMAq, PB-*b*-PMAA-*b*-PDMAEMAq terpolymers self-assemble in water, depending on pH and temperature. We demonstrate control over micellar shape, size, and charge *via* three different preparation pathways. Even more, the micelles are capable of undergoing rearrangements in both the shell and the corona in response to external stimuli like pH or salinity. In that way, different structures such as multicompartment, core–shell–corona or flower-like micelles were identified and characterized *via* cryogenic transmission electron microscopy (cryo-TEM) and dynamic light scattering (DLS). The presence of two oppositely charged polyelectrolyte blocks within the structures leads to the formation of intramicellar interpolyelectrolyte complexes (*im*-IPECs) in the shell of the particles. Surprisingly, the *im*-IPEC formed between PMAA and PDMAEMAq can be redissolved by changes in pH, even in the absence of additional salt.

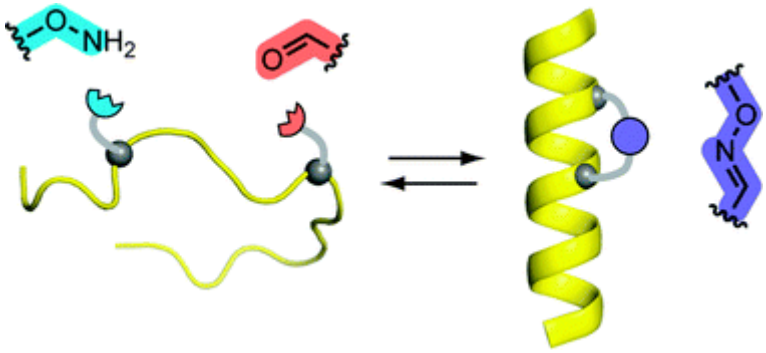
- Multicomponent hydrogels from enantiomeric amino acid derivatives: helical nanofibers, handedness and self-sorting
  Adhikari, B.; Nanda, J.; Banerjee, A. *Soft Matter* **2011**, *7*, 8913-8922.
  Abstract:



In this study, chiral helical nanofibers have been obtained from suitable, co-assembling, two oppositely charged amino acid based two component hydrogels. An equimolar mixture of an *N*-

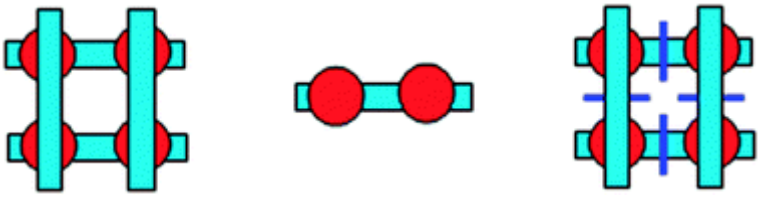
terminally protected amino acid Fmoc-(L/D)Glu (Fmoc: *N*-fluorenyl-9-methoxycarbonyl, Glu: glutamic acid) and (L/D)Lys (Lys: lysine) can co-assemble to form hydrogels. These hydrogels have been characterised using circular dichroism (CD), atomic force microscopy (AFM), transmission electron microscopy (TEM), X-ray powder diffraction, fluorescence spectroscopic and rheological studies. CD and AFM studies have been extensively used to examine the chiral/achiral nature of fibers obtained from different hydrogel systems. The equimolar mixture of two L-isomers, {Fmoc-(L)Glu + (L)Lys} in the assembled state, leads to the exclusive formation of left-handed helical nanofibers, whereas an equimolar mixture of two D-isomers, {Fmoc-(D)Glu + (D)Lys}, gives rise to right-handed helical nanofibers. The CD study of the gel obtained from the {Fmoc-(L)Glu + (L)Lys} system is exactly the mirror image of the CD signal obtained from the gel of the {Fmoc-(D)Glu + (D)Lys} system. These results suggest that the molecular chirality is being translated into the supramolecular helicity and the handedness of these fibers depends on the corresponding molecular chirality in the mixture of the two component system. Reversing the handedness of helical fibers is possible by using enantiomeric building blocks. Co-assembly of racemic and equimolar mixtures of all four components, *i.e.*, [{Fmoc-(L)Glu + (L)Lys} + {Fmoc-(D)Glu + (D)Lys}] can also form hydrogels. Interestingly, in this racemic mixture self-sorting has been observed with the presence of almost equal amount of left- and right-handed helical nanofibers. The equimolar mixture of Fmoc-(L)Glu and L-ornithine/L-arginine also produces hydrogel with left-handed helical fibers. Moreover, the straight fiber has been observed from the two component hydrogel {Fmoc-(L)Glu + (L)Lys} system in the presence of Ca^{2+}/Mg^{2+} ions. This indicates the straight nanofibers are obtained under suitable conditions and acid–base interaction is responsible for making the helical fibers at the nanoscale.

- Promoting peptide α-helix formation with dynamic covalent oxime side-chain cross-links
  Haney, C. M.; Loch, M. T.; Seth Horne, W. *Chem. Commun.* **2011**, *47*, 10915-10917.
  Abstract:



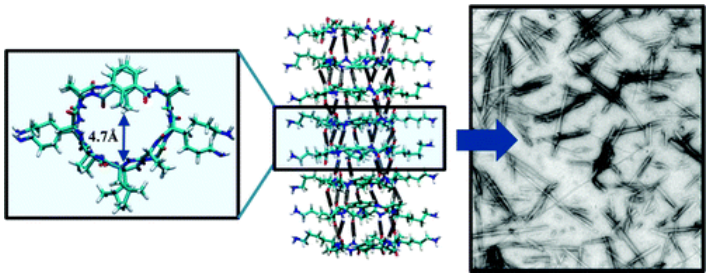
Covalent side-chain cross-linking has been shown to be a viable strategy to control peptide folding. We report here that an oxime side-chain linkage can elicit α-helical folds from peptides in aqueous solution. The bio-orthogonal bridge is formed rapidly under neutral buffered conditions, and the resulting cyclic oximes are capable of dynamic covalent exchange.

- Modulation of self-assembly and magnetism of Cu(II) grids in solution
  Parizel, N.; Ramírez, J.; Burg, C.; Choua, S.; Bernard, M.; Gambarelli, S.; Maurel, V.; Brelot, L.; Lehn, J.-M.; Turek, P.; Stadler, A.-M. *Chem. Commun.* **2011**, *47*, 10951-10953.
  Abstract:



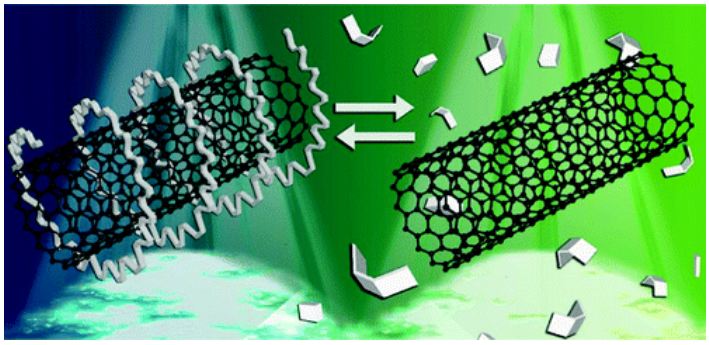
Depending on the Cu(II)/ligand molar ratio, a pyrimidine-based ligand generates a tetranuclear grid (1/1) or a dinuclear stick (2/1). EPR, MS and visible spectroscopy studies suggest that dilution produces partial dissociation of the grid in solution. Replacement of 2-H-pyrimidine by a 2-phenyl-triazine unit prevents the dissociation of the grid. All these factors influence the magnetic properties of the architectures herein involved.

- Processable Cyclic Peptide Nanotubes with Tunable Interiors
  Hourani, R.; Zhang, C.; van der Weegen, R.; Ruiz, L.; Li, C.; Keten, S.; Helms, B. A.; Xu, T. *J. Am. Chem. Soc.* **2011**, *133*, 15296-15299.
  Abstract:



A facile route to generate cyclic peptide nanotubes with tunable interiors is presented. By incorporating 3-amino-2-methylbenzoic acid in the d,l-alternating primary sequence of a cyclic peptide, a functional group can be presented in the interior of the nanotubes without compromising the formation of high aspect ratio nanotubes. The new design of such a cyclic peptide also enables one to modulate the nanotube growth process to be compatible with the polymer processing window without compromising the formation of high aspect ratio nanotubes, thus opening a viable approach toward molecularly defined porous membranes.

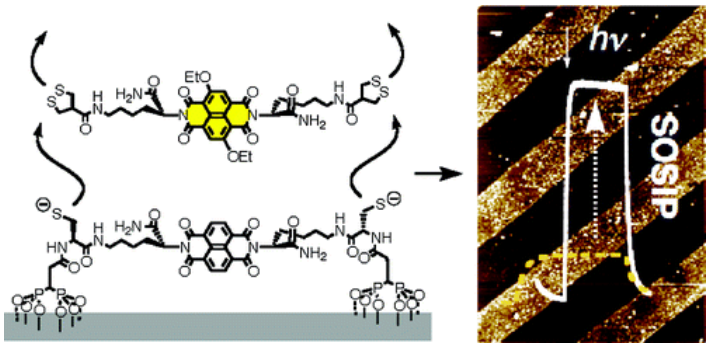
- Modular Engineering of H-Bonded Supramolecular Polymers for Reversible Functionalization of Carbon Nanotubes
  Llanes-Pallas, A.; Yoosaf, K.; Traboulsi, H.; Mohanraj, J.; Seldrum, T.; Dumont, J.; Minoia, A.; Lazzaroni, R.; Armaroli, N.; Bonifazi, D. *J. Am. Chem. Soc.* **2011**, *133*, 15412-15424.
  Abstract:



A H-bond-driven, noncovalent, reversible solubilization/functionalization of multiwalled carbon nanotubes (MWCNTs) in apolar organic solvents ($CHCl_3$, CH_2Cl_2, and toluene) has been accomplished

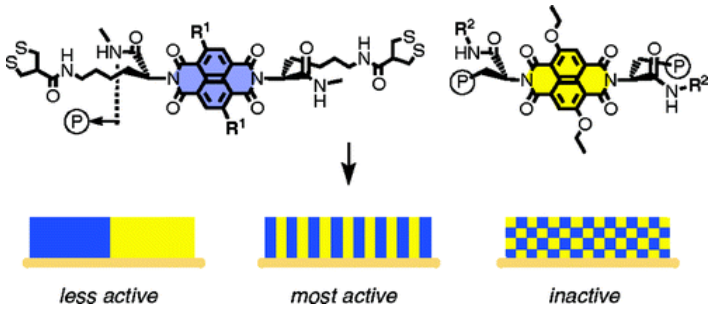
through a dynamic combination of self-assembly and self-organization processes leading to the formation of supramolecular polymers, which enfold around the outer wall of the MWCNTs. To this end, a library of phenylacetylene molecular scaffolds with complementary recognition sites at their extremities has been synthesized. They exhibit triple parallel H-bonds between the NH–N–NH (DAD) functions of 2,6-di(acetylamino)pyridine and the CO–NH–CO (ADA) imidic groups of uracil derivatives. These residues are placed at 180° relative to each other (linear systems) or at 60°/120° (angular modules), in order to tune their ability of wrapping around MWCNTs. Molecular Dynamics (MD) simulations showed that the formation of the hybrid assembly **MWCNT•[X•Y]$_n$** (where **X** = **1a** or **1b** -DAD- and **Y** = **2**, **3**, or **4** -ADA-) is attributed to π–π and CH–π interactions between the graphitic walls of the carbon materials and the oligophenyleneethynylene polymer backbones along with its alkyl groups, respectively. Addition of polar or protic solvents, such as DMSO or MeOH, causes the disruption of the H-bonds with partial detachment of the polymer from the CNTs, followed by precipitation. Taking advantage of the chromophoric and luminescence properties of the molecular subunits, the solubilization/precipitation processes have been monitored by UV–vis absorption and luminescence spectroscopies. All hybrid MWCNTs–polymer materials have been also structurally characterized via thermogravimetric analysis (TGA), transmission electron microscopy (TEM), atomic force microscopy (AFM), scanning tunneling microscopy (STM), and X-ray photoelectron spectroscopy (XPS).

- Self-Organizing Surface-Initiated Polymerization: Facile Access to Complex Functional Systems
  Sakai, N.; Lista, M.; Kel, O.; Sakurai, S.-i.; Emery, D.; Mareda, J.; Vauthey, E.; Matile, S. *J. Am. Chem. Soc.* **2011**, *133*, 15224–15227.
  Abstract:



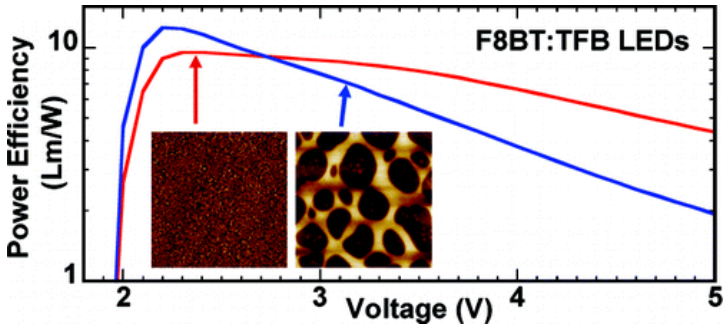
Facile access to complex systems is crucial to generate the functional materials of the future. Herein, we report self-organizing surface-initiated polymerization (SOSIP) as a user-friendly method to create ordered as well as oriented functional systems on transparent oxide surfaces. In SOSIP, self-organization of monomers and ring-opening disulfide exchange polymerization are combined to ensure the controlled growth of the polymer from the surface. This approach provides rapid access to thick films with smooth, reactivatable surfaces and long-range order with few defects and high precision, including panchromatic photosystems with oriented four-component redox gradients. The activity of SOSIP architectures is clearly better than that of disordered controls.

- Lateral Self-Sorting on Surfaces: A Practical Approach to Double-Channel Photosystems
  Lista, M.; Areephong, J.; Sakai, N.; Matile, S. *J. Am. Chem. Soc.* **2011**, *133*, 15228–15231.
  Abstract:



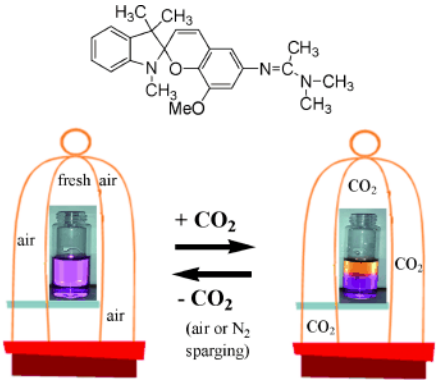
We report that self-sorting during self-organizing surface-initiated copolymerization (co-SOSIP) provides facile access to oriented multicomponent architectures. Alternate lateral and uniform axial self-sorting into formal supramolecular n/p-heterojunction photosystems is found to generate up to 40 times more photocurrent. More or less topological matching gives rise to alternate axial self-sorting into inactive charge-transfer complexes or uniform lateral sorting into the less active macrodomains, respectively. Experimental support for self-repair during co-SOSIP is reported. Initiators on the surface are shown to serve as templates for the self-sorting into multichannel architectures of freely variable composition.

- Phase-Separated Thin Film Structures for Efficient Polymer Blend Light-Emitting Diodes
  Yim, K.-H.; Doherty, W. J.; Salaneck, W. R.; Murphy, C. E.; Friend, R. H.; Kim, J.-S. *Nano Lett.* **2010**, *10*, 385–392.
  Abstract:



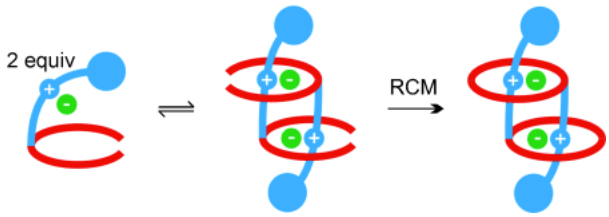
We report laterally and vertically phase-separated thin film structures in conjugated polymer blends created by polymer molecular weight variation. We find that micrometer-scale lateral phase separation is critical in achieving high initial device efficiency of light-emitting diodes, whereas improved balance of charge carrier mobilities and film thickness uniformity are important in maintaining high efficiency at high voltages. The optoelectronic properties of these blend thin films and devices are strongly influenced by the polymer chain order/disorder and the interface state formed at polymer/polymer heterojunctions.

- Spiropyran–Amidine: A Molecular Canary for Visual Detection of Carbon Dioxide Gas
  Darwish, T. A.; Evans, R. A.; James, M.; Hanley, T. L. *Chem. Eur. J.* **2011**, *17*, 11399-11404.
  Abstract:



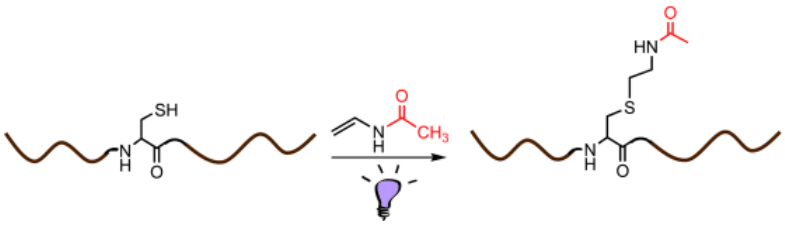
Molecular canary: Spiropyran substituted with an amidine group (SP–Am; see scheme) is a sensitive reversible colorimetric CO_2 probe and can function as a molecular canary. Aqueous alcohol solutions containing Sp–Am are purple and on addition of low levels of CO_2 gas become yellow. The purple colour is rapidly recovered when CO_2 is removed from the solution by inert gas or air sparging, or slowly when allowed to stand uncovered.

- A Janus [2]Rotaxane Synthesized by Using an Anion-Templated Clipping Methodology
  Evans, N. H.; Beer, P. D. *Chem. Eur. J* **2011**, *17*, 10542-10546.
  Abstract:



Clipping a Janus rotaxane: The synthesis of a novel anion-templated Janus [2]rotaxane species consisting of pyridinium chloride axle and isophthalamide macrocyclic components is reported. This represents a rare example of the synthesis of a Janus [2]rotaxane by using a “clipping” methodology.

- A Direct Method for Site-Specific Protein Acetylation
  Li, F.; Allahverdi, A.; Yang, R.; Lua, G. B. J.; Zhang, X.; Cao, Y.; Korolev, N.; Nordenskiöld, L.; Liu, C. F. *Angew. Chem. Int. Ed.* **2011**, *50,* 9611-9614.
  Abstract:

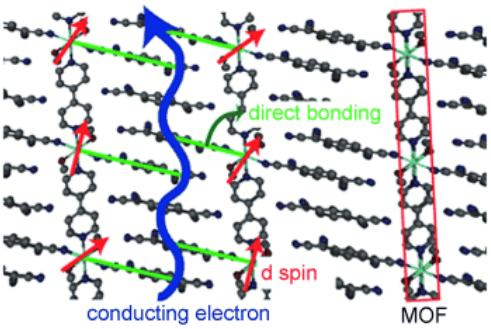


Radicals at work: Radical-mediated thiol-ene addition of the thiol group of Cys to *N*-vinylacetamide gives acetyl-thialysine (KSAc), a near-perfect mimic of acetyl-lysine (see picture). The reaction is highly efficient with near quantitative conversion obtained in short reaction times. The generated KSAc is functionally identical or similar to its native counterpart.

- Highly Conducting Coordination Polymers Based on Infinite M(4,4′-bpy) Chains Flanked by Regular Stacks of Non-Integer TCNQ Radicals

Rivas, M. B.; Ota, A.; Reinheimer, E.; Prosvirin, A.; Martinez, J. V.; Dunbar, K. R. *Angew. Chem., Int. Ed.* **2011**, *50,* 9703-9707.

Abstract:

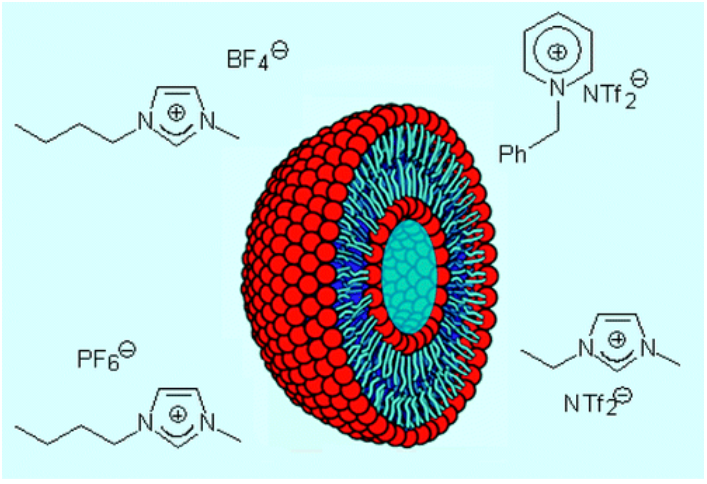


All coordinated: Highly conducting coordination polymers of the type [M(4,4′-bpy)(η1-TCNQ)$_2$(CH$_3$OH)$_2$]TCNQ (M=Mn, Zn) have been realized by using TCNQ (7,7,8,8-tetracyanoquinodimethane) as a building block (see picture). Regularly spaced stacks of TCNQ are connected to a MnII–4,4′-bipyridine spine by two η1-TCNQ ligands involved in a stacked column with free TCNQ radicals.

- Vesicles in Ionic Liquids

  Gayet, F.; Marty, J.-D.; Brulet, A.; Lauth-de Viguerie, N. *Langmuir* **2011**, *27*, 9706-9710.

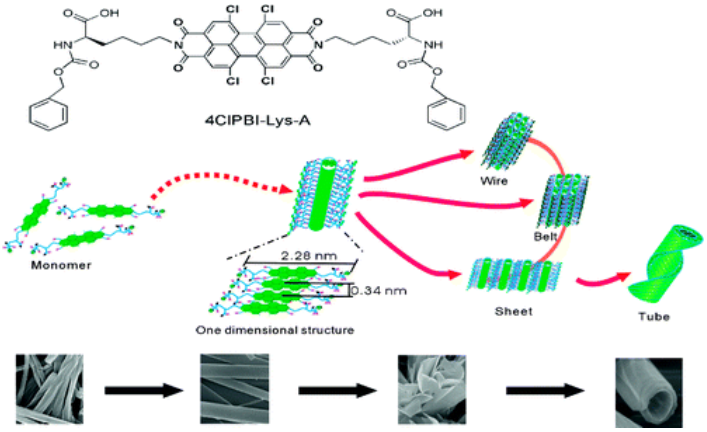
  Abstract:



The formation of vesicles from 1,2-dipalmitoyl-*sn*-glycero-3-phosphatidylcholine (DPPC) in several room-temperature ionic liquids, namely, 1-butyl-3-methylimidazolium tetrafluoroborate (BmimBF$_4$), 1-butyl-3-methylimidazolium hexafluorophosphate (BmimPF$_6$), 1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide (EmimNTf$_2$), and *N*-benzylpyridinium bis(trifluoromethylsulfonyl)imide (BnPyNTf$_2$), as well as in a water/BmimBF$_4$ mixture, was investigated. In pure ionic liquids, observations by staining transmission electron microscopy demonstrated clearly the formation of spherical structures with diameters of 200–400 nm. The morphological characteristics of these vesicles in ionic liquids, in particular, the membrane thicknesses, were first investigated by small-angle neutron scattering measurements. The mean bilayer thickness was found to be ~63 ± 1 Å in a deuterated ionic liquid (BnPyNTf$_2$-*d*). This value was similar to that observed in water. The effect of ILs on the modification of the phase physical properties of multilamellar vesicles (MLVs) was then investigated by differential scanning calorimetry. In pure IL as in water, DPPC exhibited an endothermic pretransition followed by the

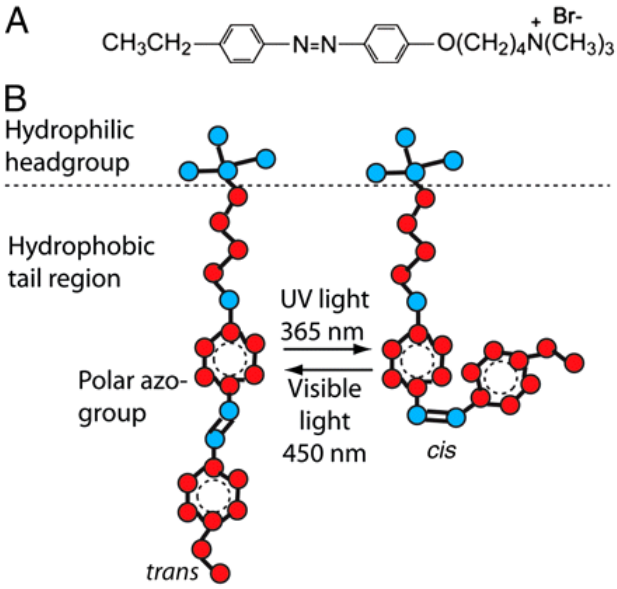
main transition. These transition temperatures and the associated enthalpies in ILs were higher than those in water because of a reduction of the electrostatic repulsion between zwitterionic head groups. To better understand the effect of ionic liquid on the formation of multilamellar vesicles, mixtures of $BmimBF_4$ and water, which are miscible in all proportions, were analyzed ($BmimBF_4$/water ratio from 0% to 100%). SANS and DSC experiments demonstrated that the bilayer structure and stability were strongly modified by the IL content. Moreover, matching SANS experiments showed that $BmimBF_4$ molecules prefer to be located inside the DPPC membrane rather than in water.

- Fine-Tuned Nanostructures Assembled from l-Lysine-Functionalized Perylene Bisimides
  Sun, Y.; He, C.; Sun, K.; Li, Y.; Dong, H.; Wang, Z.; Li, Z. *Langmuir* **2011**, *27*, 11364-11371.
  Abstract:



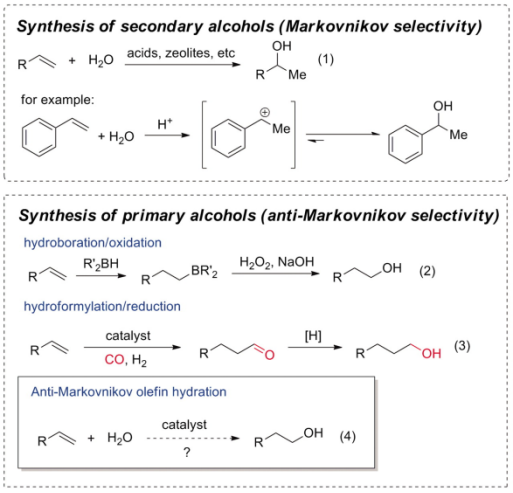
Controllable nanostructures with tunable dimensions were obtained via self-assembly of CBZ-l-lysine-functionalized tetrachloroperylene bisimides (4ClPBI-Lys). Depending on the nature of substitute, solvent polarity, and sample concentration, 4ClPBI-Lys could form nanosphere, nanowire, nanobelt, and nanosheet, which were found to have different degree of molecular ordering. The effects of substitution position with respect to l-lysine on 4ClPBI were also explored in terms of assembly nanostructures. Hydrogen bonding was important to promote formation of long-range ordering. The nanostructures of different assemblies were characterized using SEM, TEM, XRD, UV–vis, and FTIR spectroscopy. For each obtained supramolecular assembly, we also found that the molecular packing motif ultimately determined the corresponding devices' electronic properties.

- General hydrophobic interaction potential for surfactant/lipid bilayers from direct force measurements between light-modulated bilayers
  Donaldson, Jr., S. H.; Lee, Jr., C. T.; Chmelka, B. F.; Israelachvili, J. N. *Proc. Nat. Acad. Sci.* **2011**, *108*, 15699-15704.
  Abstract:



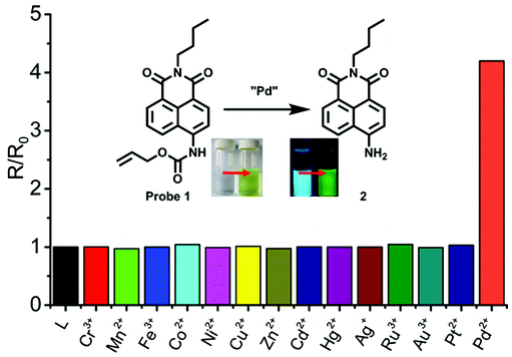
We establish and quantify correlations among the molecular structures, interaction forces, and physical processes associated with light-responsive self-assembled surfactant monolayers or bilayers at interfaces. Using the surface forces apparatus (SFA), the interaction forces between adsorbed monolayers and bilayers of an azobenzene-functionalized surfactant can be drastically and controllably altered by light-induced conversion of *trans* and *cis* molecular conformations. These reversible conformation changes affect significantly the shape of the molecules, especially in the hydrophobic region, which induces dramatic transformations of molecular packing in self-assembled structures, causing corresponding modulation of electrostatic double layer, steric hydration, and hydrophobic interactions. For bilayers, the isomerization from *trans* to *cis* exposes more hydrophobic groups, making the *cis* bilayers more hydrophobic, which lowers the activation energy barrier for (hemi)fusion. A quantitative and general model is derived for the interaction potential of charged bilayers that includes the electrostatic double-layer force of the Derjaguin–Landau–Verwey–Overbeek theory, attractive hydrophobic interactions, and repulsive steric-hydration forces. The model quantitatively accounts for the elastic strains, deformations, long-range forces, energy maxima, adhesion minima, as well as the instability (when it exists) as two bilayers breakthrough and (hemi)fuse. These results have several important implications, including quantitative and qualitative understanding of the hydrophobic interaction, which is furthermore shown to be a nonadditive interaction.

- Primary Alcohols from Terminal Olefins: Formal Anti-Markovnikov Hydration via Triple Relay Catalysis
  Dong, G.; Teo, P.; Wickens, Z. K.; Grubbs, R. H. *Science* **2011**, *333*, 1609-1612.
  Abstract:



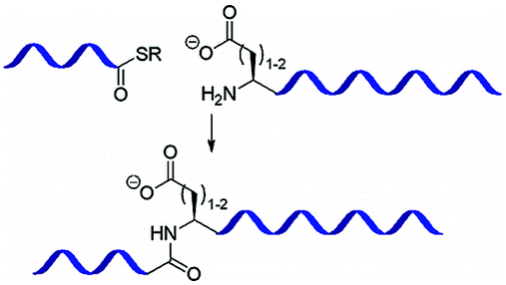
Alcohol synthesis is critical to the chemical and pharmaceutical industries. The addition of water across olefins to form primary alcohols (anti-Markovnikov olefin hydration) would be a broadly useful reaction but has largely proven elusive; an indirect hydroboration/oxidation sequence requiring stoichiometric borane and oxidant is currently the most practical methodology. Here, we report a more direct approach with the use of a triple relay catalysis system that couples palladium-catalyzed oxidation, acid-catalyzed hydrolysis, and ruthenium-catalyzed reduction cycles. Aryl-substituted terminal olefins are converted to primary alcohols by net reaction with water in good yield and excellent regioselectivity.

- A Colorimetric and Ratiometric Fluorescent Probe for Palladium
  Jiang, J.; Jiang, H.; Liu, W.; Tang, X.; Zhou, X.; Liu, W.; Liu, R. *Org. Lett.* **2011**, *13*, 4922–4925.
  Abstract:



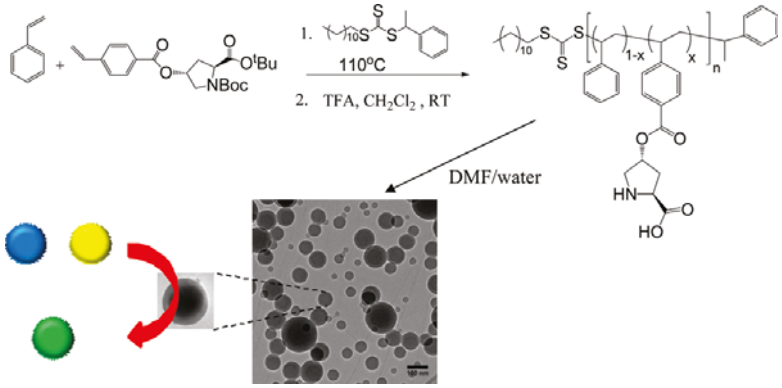
A colorimetric and ratiometric fluorescent probe for the palladium species has been developed based on the Pd0-catalyzed cleavage of an allyoxycarbonyl group of amines under mild conditions. The probe displays a highly sensitive and selective response with significant changes in both color (from colorless to jade-green) and fluorescence (from blue to green), through the ICT process.

- Peptide Ligations Accelerated by *N*-Terminal Aspartate and Glutamate Residues
  Thomas, G. L.; Hsieh, Y. S. Y.; Chun, C. K. Y.; Cai, Z.-L.; Reimers, J. R.; Payne, R. J. *Org. Lett.* **2011**, *13*, 4770–4773.
  Abstract:



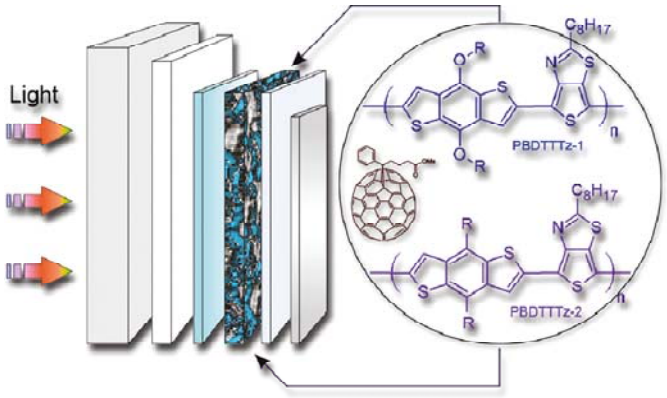
A novel application of intramolecular base catalysis confers enhanced reaction rates for aminolysis ligations between peptide thioesters and peptides bearing N-terminal aspartate or glutamate residues. The broad scope of this process and its application in the total synthesis of the diabetes drug exenatide is demonstrated.

- L-Proline Functionalized Polymers Prepared by RAFT Polymerization and their Assemblies as supported Organocatalyst
  Lu, A.; Smart, T.; Epps, T. III; Longbottom, D. *Macromolecules* **2011, *44*,** 7233-7241.
  Abstract:



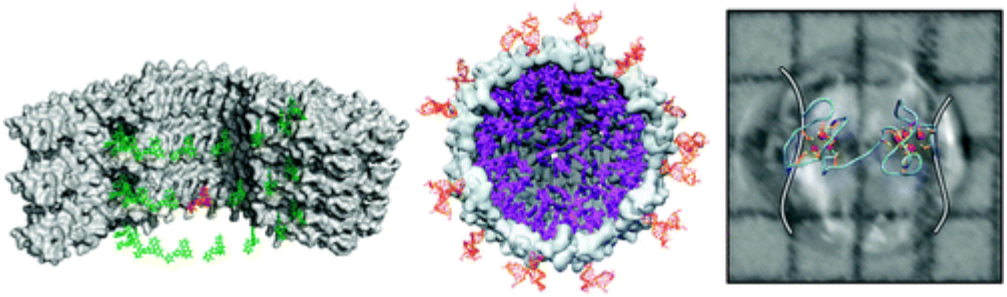
We have prepared a range of well-defined copolymers of styrene and L-proline functionalized styrene (5-11 kDa) using reversible additionfragmentation chain transfer (RAFT) polymerization techniques and explored their use in supported catalysis. Upon deprotection of the L-proline functionalities, the solution self-assembly of these copolymers was investigated in mixed solvent systems. The resulting assemblies were characterized by dynamic light scattering, transmission electron microscopy (on graphene oxide substrates, along with cryo-TEM and tomography), and scanning electron microscopy. The application of these functional assemblies as supported catalysts for the aldol condensation reaction was explored using cyclohexanone and 4-nitrobenzaldehyde. The rate and selectivity of solution catalysis in our self-assembled system were comparable to those of L-proline, and a significant advantage of our system was that the polymer support could be utilized at lower catalyst loadings with comparable activity and also could be recycled a number of times while maintaining activity and selectivity.

- Synthesis and Characterization of New Poly(thieno[3,4-d]thiazole) derivatives for Photovoltaic applications
  Allard, N.; Beaupré, S.; Aïch, B.; Najari, A.; Tao, Y.; Leclerc, M. *Macromolecules* **2011**, *44*, 7184-7187.
  Abstract:



We report the synthesis of new push-pull conjugated polymers for bulk heterojunction solar cells based on benzo[1,2-b:4,5-b0]dithiophene (push) and thieno[3,4-d]thiazole (TTz) (pull) derivatives. Stille polycondensation between distannyl-BDT derivatives with 4,6-dibromo-2-octylthieno[3,4d]thiazole led to two alternating copolymers, namely PBDTTTz-1 and PBDTTTz-2, which have a bandgap of 1.8 and 1.7 eV, respectively. Both copolymers are stable in air with HOMO energy level of -5.3 eV for PBDTTTz-1 and -5.4 eV for PBDTTTz-2. Both copolymers have been tested in bulk heterojunction solar cells, and preliminary results (without any optimization process) show promising power conversion efficiency of 1.4% for PBDTTTz-1 and 1.7% for PBDTTTz-2.

- Using Synthetically Modified Proteins to Make New Materials
  Witus, L. S.; Francis, M. B. *Acc. Chem. Res.* **2011**, *44*, 774–783.
  Abstract:



self-assembling light harvesting systems | targeted vehicles for drug and imaging agent delivery | protein-based hydrogels for water remediation

The uniquely diverse structures and functions of proteins offer many exciting opportunities for creating new materials with advanced properties. Exploiting these capabilities requires a set of versatile chemical reactions that can attach nonnatural groups to specific locations on protein surfaces. Over the years, we and others have developed a series of new techniques for protein bioconjugation, with a particular emphasis on achieving high site selectivity and yield. Using these reactions, we have been able to prepare a number of new materials with functions that depend on both the natural and the synthetic components. In this Account, we discuss our progress in protein bioconjugation over the past decade, focusing on three distinct projects.
We first consider our work to harness sunlight artificially by mimicking features of the photosynthetic apparatus, with its beautifully integrated system of chromophores, electron transfer groups, and catalytic centers. Central to these photosystems are light-harvesting antennae having hundreds of precisely aligned chromophores with positions that are dictated by the proteins within the arrays. Our approach to generating similar arrangements involves the self-assembly of tobacco mosaic virus coat proteins bearing synthetic chromophore groups. These systems offer efficient light collection,

are easy to prepare, and can be used to build complex photocatalytic systems through the modification of multiple sites on the protein surfaces.

We then discuss protein-based carriers that can deliver drugs and imaging agents to diseased tissues. The nanoscale agents we have built for this purpose are based on the hollow protein shell of bacteriophage MS2. These 27 nm capsids have 32 pores, which allow the entry of relatively large organic molecules into the protein shell without requiring disassembly. Our group has developed a series of chemical strategies that can install dyes, radiolabels, MRI contrast agents, and anticancer drugs on the inside surface of these capsids. We have also developed methods to decorate the external surfaces with binders for specific proteins on cancer cells.

As a third research area, our group has developed protein–polymer hybrid materials for water remediation. To reduce the toxicity of heavy metals in living cells, Nature has evolved metallothioneins, which are sulfur-rich polypeptides that bind mercury, cadmium, and other toxic ions at sub-parts-per-billion concentrations. Unfortunately, these proteins are very difficult to incorporate into polymers, largely because typical protein modification reactions target the very cysteine, lysine, and carboxylate-containing residues that are required for their proper function. To address this challenge, we developed a new way to attach these (and many other) proteins to polymer chains by expressing them as part of an N- and C-terminal modification “cassette”. The resulting materials retain their selectivity and can remove trace amounts of toxic metal ions from ocean water.

Each of these examples has presented a new set of protein bioconjugation challenges that have been met through the development of new reaction methodology. Future progress in the generation of protein-based materials will require scalable synthetic techniques with improved yields and selectivities, inexpensive purification methods for bioconjugates, and theoretical and dynamical treatments for designing new materials through protein self-assembly.

- Bioconjugation *via* azide–Staudinger ligation: an overview
  Schilling, C. I.; Jung, N.; Biskup, M.; Schepers, U.; Bräse, S. *Chem. Soc. Rev.*, **2011**, *40*, 4840-4871.
  Abstract:

Bioconjugation techniques using organic azides are compared in this *critical review*. A particular focus is on chemical ligation reactions and their application to chemical biology (179 references).