Soft Matter:

A soft materials approach to functional bio-interfaces

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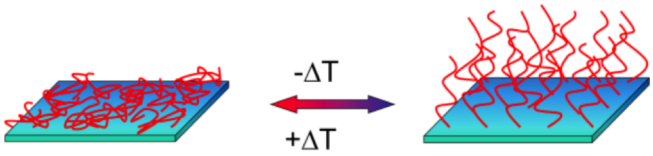
Taking a soft materials approach to materials science means using synthetic chemistry to create functional materials designed to elicit biological responses. Dr. Schaefer and his research group use this approach at interfaces to achieve membrane defouling, programmed cell release, surface immobilization of enzymes, and corrosion prevention. His group synthesizes surface-immobilized end-tethered polymers with the goal of understanding the relationship between synthetic chemistry, interface morphology, and performance.



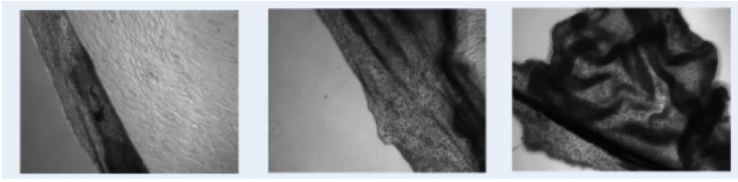
The thermal response of PNIPAm is used for membrane de-fouling and tissue engineering.

Membrane De-Fouling

Schaefer and his group grafted a polymer that responds to temperature changes on silicon wafers suitable for neutron reflectivity studies. By varying the graft density, the group controls the hydration characteristics of the films, which in turn controls biocompatibility. Denser grafts, they found, are less effective for de-fouling.

Regenerative Medicine

The group worked with heart surgeon, Prof. Yi-Gang Wang from UC Cardiovascular Diseases Center, on cell-sheet therapy for the repair of damaged heart tissue. They harvested connected cells as intact cell-sheets using a PNIPAm, a polymer that responds to temperature—allowing control of cellular attachment and detachment simply by changing the temperature. These cell sheets can then be used as epicardial tissue patches to restore function of the left ventricle.



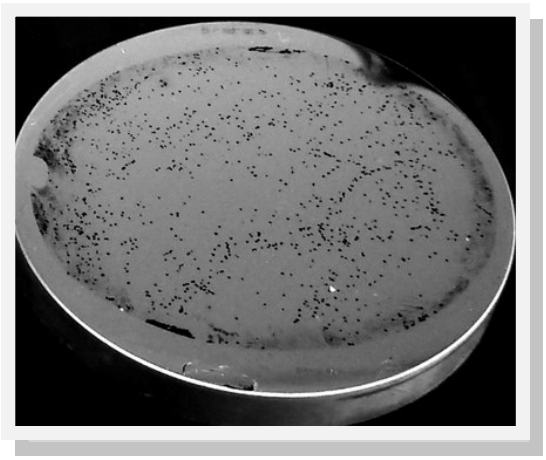
The release of a single cell sheet from a thermally-responsive polymer grafted on a glass microscope slide. The cell-sheet is peeling off the surface from left to right.

Microbially-Induced Degradation

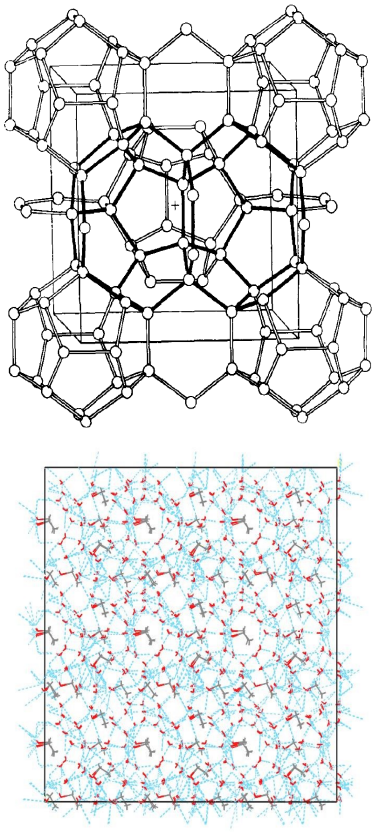
To minimize microbially-induced corrosion, Schaefer and his group worked with Dr. Wendy Goodson of the Air Force Research Laboratory to graft a copolymer made of a hydrophobic block at the metal surface and a hydrophilic, antibacterial block at the water interface. The hydrophobic block prevents water penetration to the metal and the hydrophilic block inhibits biofilm formation, the underlying cause of bio-corrosion.

Environmentally-Benign Anti-Corrosion Coatings

Elements such as iron and aluminum do not exist in nature as metals because the stable state is an oxide, commonly known as rust. Industry spends billions each year in corrosion control, trying to slow the inevitable return of refined metals back to their oxides. Schaefer and his group are studying the corrosion process of aluminum and steel that has been treated with a non-toxic, environmentally-friendly treatment, called Trivalent Chromium Process or TCP. Using neutron reflectivity, they found that water rapidly penetrates most metal-protective films, including TCP. In spite of water penetration the TCP film remains exceedingly protective. The corrosion rate on aluminum is less than 0.00005 in/y. By accelerating the corrosion rate electrochemically, however, TCP forms pits, a dangerous form of corrosion that can lead to rapid failure of the metal.



Electrochemically-induced pitting of aluminum deposited on a silicon wafer



Top: Schematic structure of clathrate I.
Bottom: Simulation of ethanol-water solution indicating a clathrate structure similar to top picture.

Physical Basis of Alcohol Perception

Although vodka is a reasonably pure mixture of alcohol and water, vodka brands show differences in appeal. Schaefer's group investigated the "vodka's molecular cocktails" (as Royal Society of Chemistry described the work) using the ^{1}H NMR, FT-IR and Raman spectroscopy. Component analysis shows that a clathrate-hydrate structure (similar to the cage-like morphology observed at low temperature) exists in all vodkas as well as ethanol-water solutions. The group defined a structurability parameter (SP), which determines the amount of such clathrates. SP thus measures the deviation of vodka from "clean" ethanol-water solutions. The researchers argue that the hydrate structure and its content are related to the perception of vodka. Perhaps when James Bond requires his vodka "shaken, not stirred" he is seeking a particular clathrate structure.