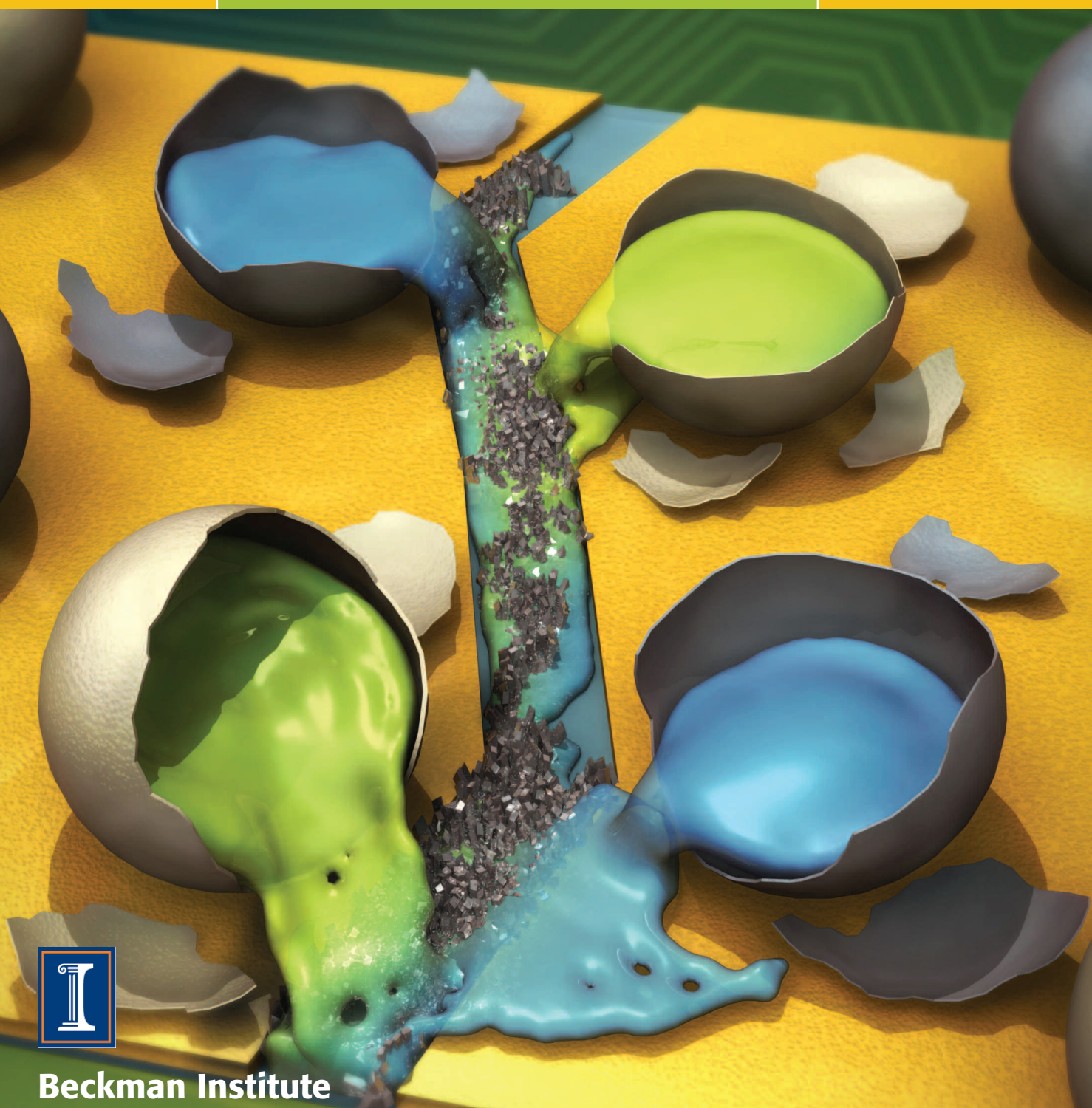
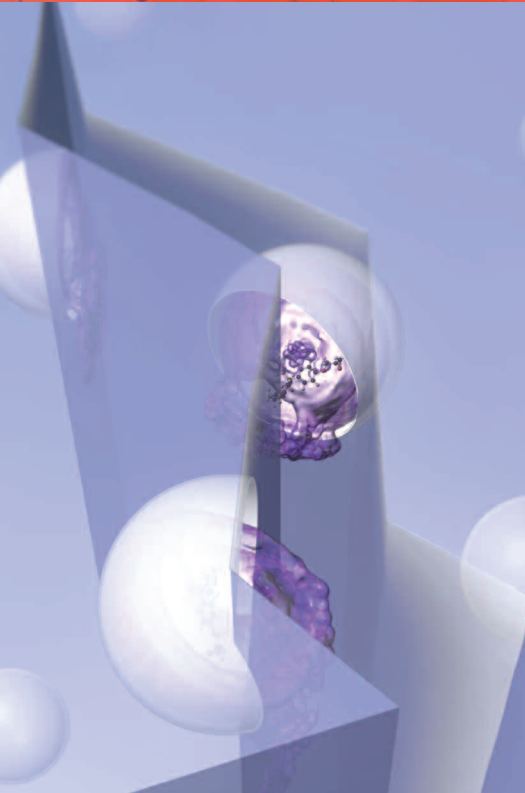
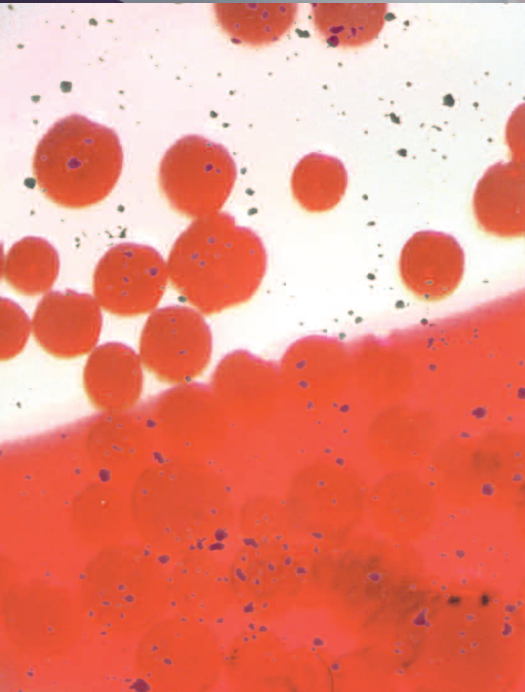
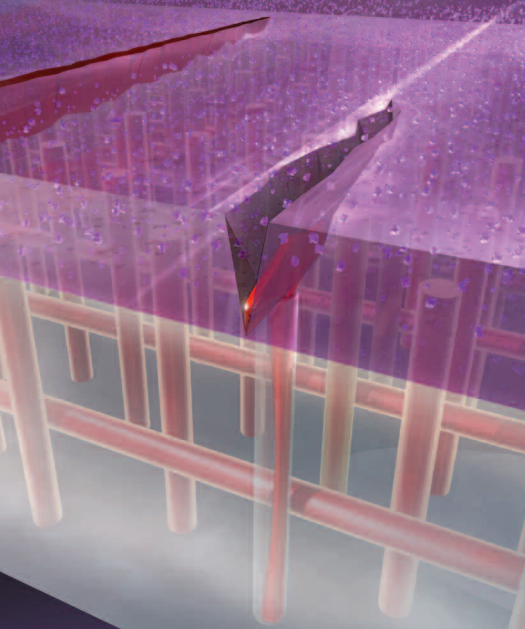


Self-Healing Materials Research



Beckman Institute

FOR ADVANCED SCIENCE AND TECHNOLOGY



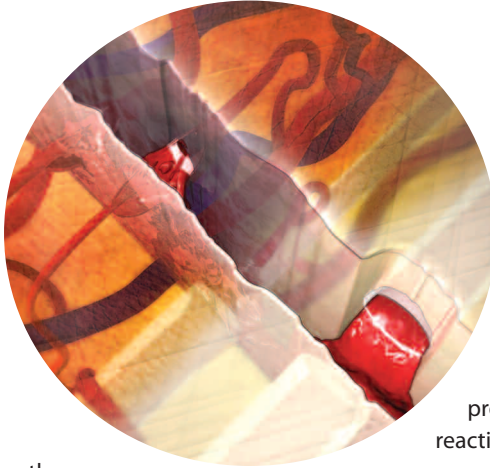
Self-Healing Materials Research

Efforts to create autonomic, or self-healing, materials have become a fast-growing line of research, in large part due to advancements made by Beckman Institute researchers.

In 2001, Beckman faculty members Nancy Sottos, Jeff Moore, and Scott White published a paper in *Nature* magazine detailing their breakthrough work that demonstrated for the first time self-healing in an engineered materials system. The paper drew worldwide attention in newspapers, journals, and websites and earned a front page story in the *Washington Post*.

Inspired by biological processes in which damage triggers an autonomic healing response, their work has used encapsulated microcapsules and microvascular networks as methods for generating self-healing in a polymer material and, in a recent research line, in electrical energy storage systems, including batteries. Since the *Nature* paper first appeared in 2001, numerous advances have been made by Beckman researchers, including developing methods that are more practical and cost-effective than the original approach, developing systems that are able to repair multiple cracks, and the introduction of mechanochemical approaches to self-healing. Potential applications could include materials that self-repair damage on coatings such as those applied to airplane fuselages or bridges, and batteries for electrical vehicles.

In exciting new research lines, work at Beckman is creating self-healing capacities for electronics. In one, **Jeff Moore** and **Paul Braun** led a project that used microcapsules containing unfunctionalized single-walled carbon nanotubes (CNTs) that, when ruptured, released the CNTs and formed a bridge between two probe tips, completing the circuit and restoring the current. In another line led by **Moore, Nancy Sottos,** and **Scott White,** microcapsule methods employ healing agents that are released when the capsules are ruptured in response to damage, restoring conductivity within 40 microseconds. The technology is being developed for use in a wide range of energy storage systems, including batteries, and can easily be integrated into existing manufacturing methods.



Nancy Sottos, Jeff Moore, and **Scott White** have developed microvascular composites that improved the microcapsule concept (in which the healing agent was consumed) through an interconnected delivery network of microchannels that provide for multiple self-healing reactions.

Jeff Moore led a project that used mechano-chemical transduction (turning mechanical energy into chemical energy) to create self-healing polymer composites. Using a mechanically active polymer incorporating a molecular unit called a mechanophore to drive and control a chemical reaction, a new method – mechanical force – for doing chemistry and creating self-healing materials was developed.

In an advance for microvascular self-healing systems, **Nancy Sottos** and **Scott White** demonstrated that an active pumping capability for pressurized delivery of liquid healing agents in those systems significantly improves the degree of healing compared with capillary force methods that are currently being used to deliver healing agents. Based on the same principle of fluid flow in biological vascular systems, the active pumping method improves the degree of mechanical recovery, and the continuous flow of healing agents from dynamic pumping extends the repeatability of the self-healing response.

Paul Braun and his research group collaborate with **Nancy Sottos** on self-healing of nano-cracks in polymers and composites and, within **Moore's** mechanochemistry multi-university project, are investigating optical techniques for detection of mechanophore activation in bulk polymers and at interfaces in composite materials.

Philippe Geubelle's Computational Mechanics group contributes computational design aspects to the development of autonomous materials systems. Geubelle's group has created computational analysis and optimization tools for materials with embedded microvascular networks to be used in self-healing and self-cooling material systems.