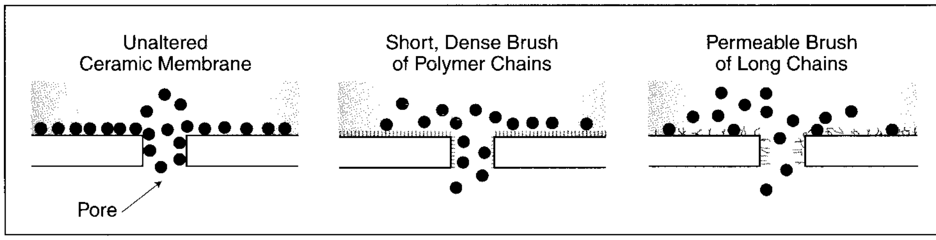
Initiatives
IN ENVIRONMENTAL TECHNOLOGY INVESTMENT

Special Pull-Out Section in this Issue

A publication of WPI, a not-for-profit organization
VOLUME 6 • WINTER 1999

Creating a better membrane with ceramic-polymer composites

An Environmental Management Science Program project is developing and testing new tougher membranes that selectively separate and concentrate a target species, often present in dilute solution. These robust membranes made of ceramic-supported polymers (CSP) have the potential to perform difficult liquid-phase separations while consuming less energy than conventional distillation and extraction.



Graft polymerization modifies the pore surface of ceramic membranes.

Scientists at the University of California at Los Angeles have been working to advance the ability to "tailor design" a new class of tougher, task-specific CSP membranes for remediation applications, recovery and recycle, effluent treatment, and replacement of some energy-intensive separation processes. Led by UCLA's Yoram Cohen, researchers are developing chemically modified ceramic membranes for the treatment of oil-in-water emulsions and for the pervaporation removal of volatile organics from aqueous systems.

It gets hairy!

CSP membranes are fabricated by modifying the pore surface of a ceramic membrane support by a graft polymerization process. The process consists of activating the membrane surface with alkoxy vinyl silanes onto which vinyl monomers are added through free-radical graft polymerization, resulting in a thin surface layer of terminally anchored polymer chains. Reaction conditions are selected based on knowledge of the graft polymerization kinetics for the specific polymer/substrate system. The resulting CSP membrane is a composite structure whose mechanical strength and thermal stability are provided by the ceramic support and whose selectivity is determined by the covalently bonded polymer brush layer. What's unique about the CSP membrane, says Cohen, is that "the polymer membrane phase can be completely swollen by the solvent or permeate without a loss of membrane functionality. This is a clear advantage over current polymer membranes, whose performance degrades in harsh solvent conditions and high temperatures."

Synthesizing the membrane requires controlling the polymer surface graft yield and the length of the resulting terminally anchored surface chains by careful surface activation and control of the graft polymerization reaction. One prototype membrane featured highly hydrophilic polyvinylpyrrolidone (PVP) on a silica substrate. Because of its affinity for water (it is completely water soluble), the PVP brush layer expanded while preferentially allowing the passage of water over oil and improving separation performance.

Pervaporation removes organic contaminants

Another promising application of CSP membranes involves pervaporation, in which organic pollutants are removed from dilute aqueous waste by selective partitioning (solvation) into and diffusion through a polymeric membrane, followed by recovery as condensed vapor on the permeate side.
Composite polymer membranes have high selectivities but lack physical stability and are chemically vulnerable to various industrial solvents. Conversely, ceramic membranes have excellent structural integrity and high chemical and thermal resistance but poor selectivity and a limited selection of pore sizes. By modifying the surface of a ceramic substrate with a polymeric active layer, CSP membranes use the strengths of each approach to overcome the weaknesses of the other.

(See *Creating a better membrane* page 5, after insert)

New EMSP projects address subsurface cleanup problems

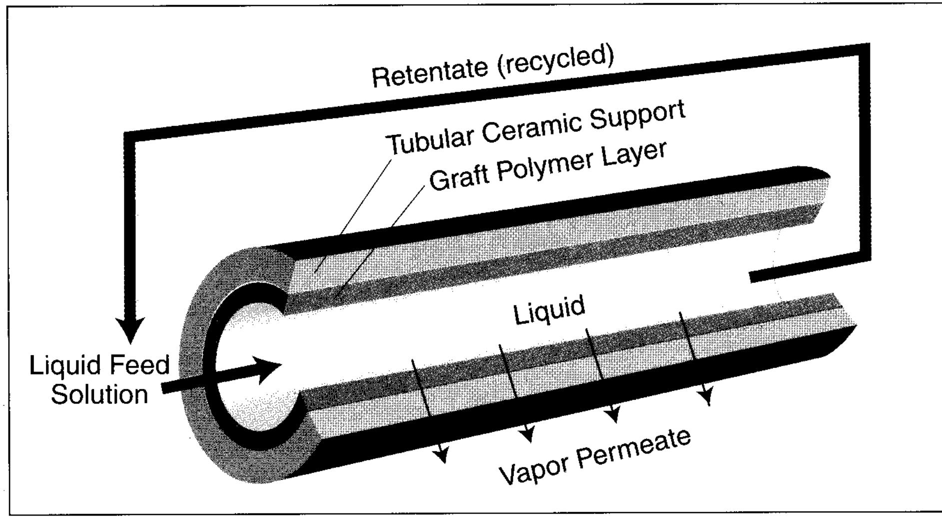
In September DOE Under Secretary of Energy Ernest Moniz announced funding totaling over $25 million for 31 new research projects tackling complex subsurface contamination problems. This is the fourth year of grants and other awards made under the department's Environmental Management Science Program, established by Congress in fiscal year 1996.

Many of the projects are collaborations among researchers at 20 universities, eight DOE labs, and three other research institutions. Nine projects will develop characterization and monitoring technologies to better understand the location and specific chemical nature of the contaminants; eight projects will help develop cost-effective, environmentally benign methods to remove radioactive contaminants from polluted sites; and 14 projects will study contaminant fate and transport to better understand how contaminants interact with and migrate through the soil and groundwater.

A complete list of the projects, including funding and research summaries, is available on EMSP's Web site at http://emsp.em.doe.gov.

Creating a better membrane *from page 4*

A series of studies showed that polyvinyl acetate CSP membranes can separate and recover trichloroethylene (TCE), chloroform, and methyl tertiary butyl ether from aqueous solutions. Membrane pervaporation performance proved to be independent of solute concentration and period of usage and limited only by the feed-side concentration boundary layer. Experiments also found that the enrichment factor increased with increasing polymer graft yield. The enrichment factor for separation of TCE and chloroform from water varied from 69 to 150.



In pervaporation, polutants diffuse through the membrane as vapor.

The CSP membranes are ready for testing and scale-up for field applications. CSP membranes could be adapted for large-scale applications using available arrays of tubular membranes or a multichannel membrane assembly. Continuing research is focused on exploring a higher range of polymer surface densities and different choices of grafted polymer, more fully understanding the mechanism of CSP pervaporation, and optimizing the membranes for increased selectivity. Cohen says the ultimate goal is to "develop a membrane technology that can be used for organic-organic separations to replace energy-intensive separation processes like distillation and those using solvents for extraction. Clearly such replacements will be selective, but the benefit of pollution prevention would be immense."

For contact and other additional information, see the Web site of UCLA's Polymer and Separations Research Laboratory at http://www.polysep.ucla.edu.

Initiatives in Environmental Technology Investment
WPI
2000 Kraft Drive • Suite 1000
Blacksburg, VA 24060-6373