# POLYMERIC MEMBRANES WITH ADAPTIVE DYNAMIC POROSITY FOR AIR FILTRATION OR SHELTER MATERIAL APPLICATIONS

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## ABSTRACT

This project involves the development of nano-porous polymeric membranes that incorporate a mechanism by which the morphology of the pores can be changed dynamically in response to an external stimulus. The use of these novel materials in membranes and fabrics would allow enhanced capabilities for addressing CB / COLPRO needs related to advanced air purification and shelter materials. In particular, successful development of the materials could allow for improvements in vapor separation, regeneration and self-decontamination as well as provide an added dimension that could be incorporated into engineered composites with further improved performance and / or additional functionality.

The initial goal of the effort is to demonstrate the viability of the concept by developing a material that can be activated after external sensors detect the presence of foreign agents. However, ultimately the goal is to develop a completely integrated adaptive membrane that senses CB agents and adjusts membrane porosity accordingly. A novel spectroelectrochemical platform will also be developed that will be used to demonstrate the proposed adaptive membrane concept. The platform will be integrated with the membrane materials and used to evaluate the permeabilities of the adaptive materials. Using the platform, methods for adaptive control of membrane switching also will be explored. The initial method that will be investigated for switching in the membranes will be thermal activation. After the feasibility of the concept is demonstrated, the emphasis will shift to electrical activation for switching.

The approach proposed for developing a new class of low-cost polymeric membranes with adaptive permeability is to employ polymer composites containing specially treated inert filler particles thoroughly dispersed in the polymer matrix. The inert particles may be either inorganic or polymeric. The particle size and size distribution of the filler will be controlled. By appropriate processing, the composites will be rendered porous due to formation of nanovoids at the particle-matrix interface. Membranes with switchable porosity are proposed which make use of a thin film of a liquid crystal elastomer (LCE) coated onto the particulate filler surfaces. LCE's undergo a large reversible change in dimension at the LC to isotropic phase transition. Also, they are conformable so that they will fill nanovoids of any arbitrary shape around the particles when they expand. Thus when the elastomer expands the pores are blocked and when the elastomer contracts the pores are unblocked or opened. The novel spectroelectrochemical platform will be used to demonstrate the proposed concept and evaluate the adaptive materials.

## OBJECTIVES

1) Fabricate nano-porous polymeric membranes (pores < 100nm) that incorporate a mechanism by which the pore morphology can be changed dynamically in response to an external stimulus.
2) Develop a spectroelectrochemical platform for triggering the dynamic change in porosity in order to demonstrate the concept and evaluate and optimize the adaptive materials.
3) The long-term objective is to develop a completely integrated adaptive membrane that senses CB agents and adjusts membrane porosity accordingly.

### Proposed Approach for Fabrication of Adaptive Materials

1) Disperse liquid crystal (LC) coated, inert filler particles of controlled size into a polymer matrix by conventional compounding methods.

| Filler particles | Polymeric Matrices |
|---|---|
| Polymeric | Polyethylene |
| Inorganic | Polypropylene |
| Biominerals | Polyethylene terepthalate |
| Nanotubes | |

2) Pretreat LC coated filler particles and stretch film during formation to create nanovoids between polymer matrix and filler particle.

### Mechanism for Changing Pore Morphology (1)

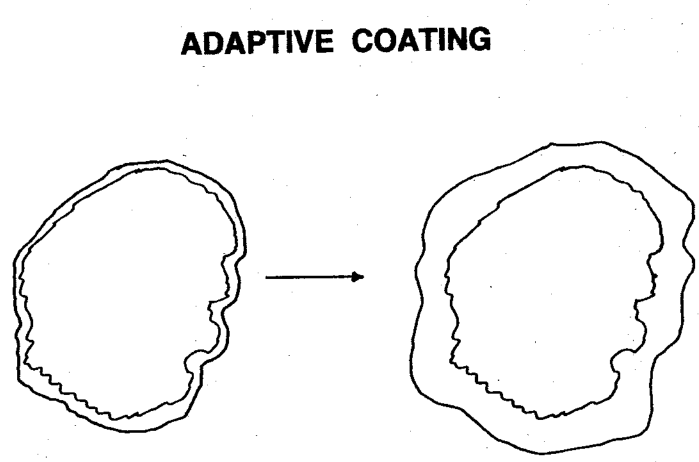


Figure 1. LC elastomer coating on solid particles expands at isotropic-LC phase transition. The expanded coating is compliant and fills micropores of any arbitrary shape around particles. Expansion and contraction is reversible.

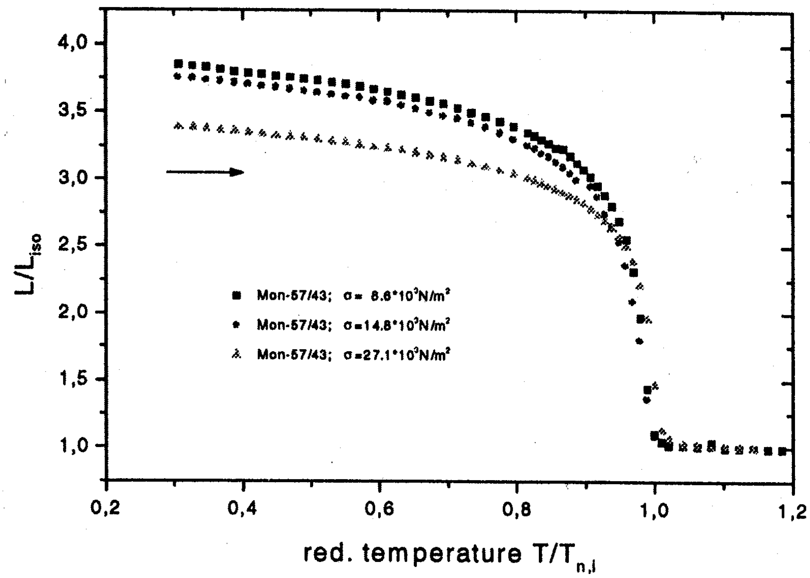


Figure 2. Thermoelastic behavior of LCE Mon-57-43 from [ 8 ]. Data show that within a narrow temperature region in the vicinity of $T_{n,i}$ the sample elongates by a factor of >3.

Possible Switching Modes Include:

1) Thermal
2) Electrical
3) Magnetic
4) Piezoelectric

Spectroelectrochemical Evaluation Platform / Probe

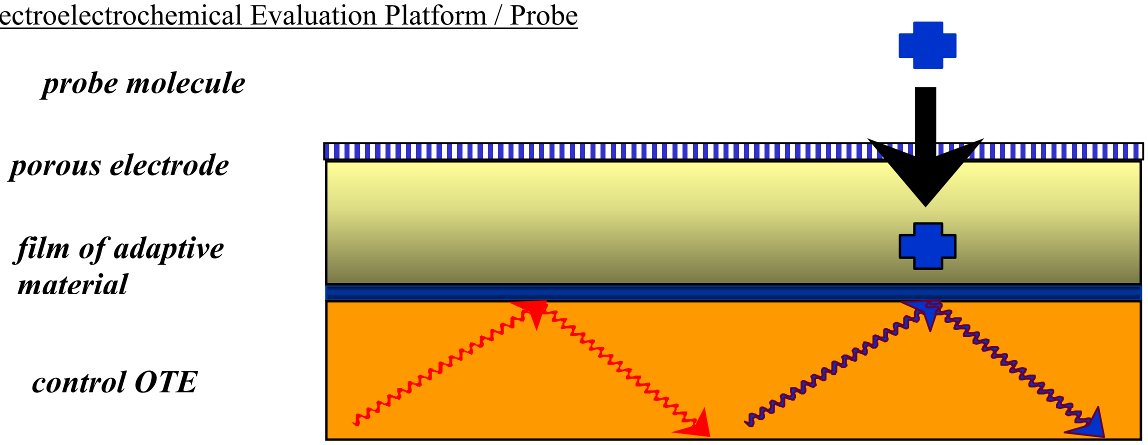


Figure 3: Spectroelectrochemical materials probe. Probe cross-section: three phases consisting of optically transparent control electrode, adaptive material to be studied, micromesh control electrode, and sample containing probe molecules. Propagated light (blue) is diminished by evanescent field interaction with probe molecules that penetrate into the film from the sample above.

Potential Advantages and Applications of Proposed Adaptive Materials:

1) Low Cost
2) Active Vapor Phase Molecular Filtration
3) Enables More Efficient Filter Regeneration
4) Enables Improved Self-Decontamination
5) New Engineered Composites