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Development of Elastomeric Selectively Permeable Membranes for Chemical/Biological Protective Clothing

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ABSTRACT

NSC and its industry partners have developed selectively permeable membranes (SPM) that allow selective diffusion of water molecules for evaporative cooling while providing protection against chemical/biological (CB) agent threats with minimum heat stress, weight, and bulkiness. These membranes are proven effective barriers to chemical agents, but they are non-elastomeric; therefore cannot be used in making conformable clothing systems, which is sought for in advanced material development programs such as the Advanced Integrated Warfighter Protection program that supports the Objective Force Warrior (OFW) future program. This paper reports on the development of an elastomeric SPM (eSPM), compare its water vapor transport, CB barrier, and physical properties to that of the SPMs, and the current chemical protective garment in use.

INTRODUCTION

Fabrics containing elastomeric barriers such as butyl rubber provide excellent protection from chemical warfare agents, but wearers can use the clothing only intermittently due to rapid onset of heat stress, motion restriction, and weight.[1] Activated carbon-based, air permeable fabric systems, such as the US Army Battle-Dress Overgarment (BDO) [MIL-S-43926], the US Marine Corps Saratoga Overgarment (Saratoga®) [MIL-S-29461], and other chemical and biological (CB) protective uniforms in use by military forces worldwide provide the individual soldier chemical warfare agent protection for an extended period of use. However, these fabric systems are also heavy, bulky, and subject the soldiers to heat stress under high workload and in battlefield conditions. NSC has developed new selectively permeable membranes (SPM) in collaboration with the membrane industries such as W.R. Grace & Co., Compact Membrane Systems, Membrane Technology Research, Inc., Akzo Nobel Faser AG, and W.L. Gore & Associates, Inc to allow selective diffusion of water molecules (Figure 1) for evaporative cooling while providing protection against CB agent threats with minimum heat stress, weight, and bulkiness.[2]

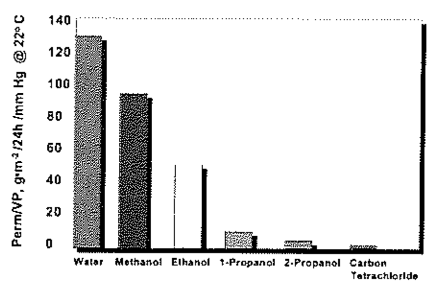

Figure 1. Permeation/Saturated Vapor Pressure of a Typical Selectively Permeable Material

These membranes are related to those used worldwide by the chemical industry for carrying out gas separations, in the purification of water by reverse osmosis, and in medical applications.[3, 4] Although, these membrane are proven effective barriers to chemical agents (Table 1), they are non-elastomeric; therefore not stretchable. They cannot be used in making conformable clothing systems, which are sought for in advanced material development programs such as the Advanced Integrated Warfighter Protection program and the Future Warrior program.

TEST RESULTS AND DISCUSSIONS

Dermal penetration of chemical warfare agents is rapid and could be lethal (mustard skin permeability rate is 2 cm/min and that of nerve agent is 0.1 cm/min.) While biological agents do not penetrate the skin, they could adsorb on to clothing or gloves in high concentrations to spread the extensive environmental bio-contamination.

Besides, the entry of infection through cuts, abrasions and bruises on the skin poses a percutaneous threat as serious as inhalation.

Chemical Agent	Material	Thickness (Mil)	Breakthrough Time (min)
HD	LDPE	4	15-20
HD	LDPE	20	240
HD	Vinyl	20	210
HD	*ICET 81-77-03A*	*8-12*	*> 48hr*
HD	*ICET 81-77-01B*	*8-12*	*> 48hr*
GB	LDPE	20	80
GB	LDPE	40	385
GB	Neoprene	60	180
GB	Vinyl	30	300
GB	Vinyl	50	660
GGB GB	Butyl Rubber	25	660
GB	ICET 81-57-02	8-12	>48hr
GB	ICET 81-57-02	8-12	>48hr

Table 1. Relative CW Agent Test Results (Performed by Geomet Technologies, Inc.)

E-SPMs provide passive physical barrier to significantly retarding or stopping the diffusion of the CW agents and other solvent molecules. They will also provide reactive barrier properties. In the event some diffusion of CW agents occurs through the surface layers, the polymer matrix provides catalysts that enhance the hydrolysis of the chemical weapons. It also provides an active biocidal barrier. The surface of the material provides a "kill zone" for Anthrax and other microorganisms and provides a continuous contact biocidal activity (Figure 2).

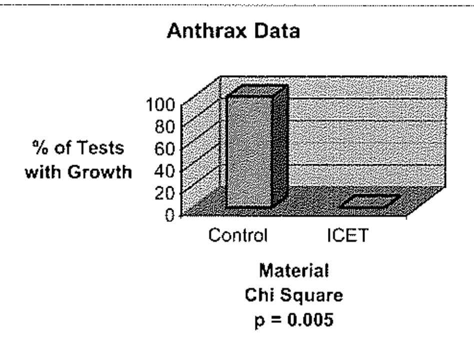

Figure 2. Anthrax Kill-Rate (Performed by Army ECBC/A. Turesky)

The samples were tested to determine moisture vapor transport (MVT) properties, barrier properties against chemical simulants using in-house test methods, and surety chemical agents (Table 1), and their physical properties. Selected membranes were coated onto fabrics in order to have a durable material system, and the properties of the lab-size laminates were determined. MVT properties were determined using a novel dynamic moisture permeation cell (DMPC) developed at NRDEC.[5] E-SPMs produced by ICET, Inc. and others will be discussed.

Barrier properties against a variety of liquid and vapor chemical challenges were determined under various humidity levels using a membrane permeation instrument. Natick developed this test to study steady state and dynamic organic vapor transport through films, fabrics, and membranes.[6] The significance of the e-SPM concept, material composition, processes, and performance, including key properties of these and other fabrics--physical properties, barrier properties, and moisture vapor transport properties—are presented.

CONCLUSIONS

The eSPM material development continues at NSC with the collaboration of ICET, Inc. and other industry partners. It is anticipated that this novel approach to chemical and biological protective clothing will serve as a viable means of increasing comfort and reducing heat stress in CB clothing, and eSPM is the second-generation SPM material.

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