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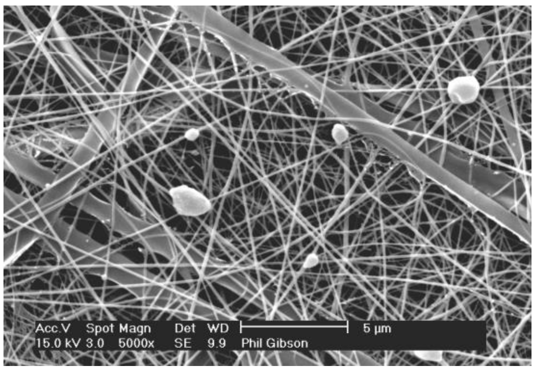
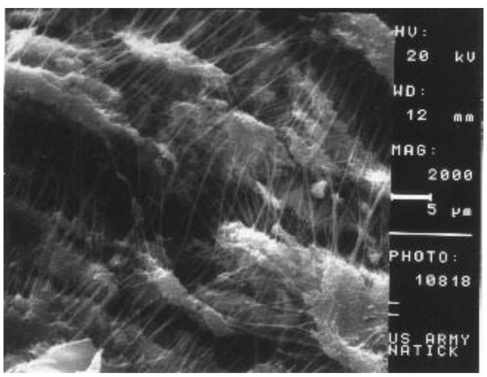
Can Protective Garments be Wearable Filters?

Protective garments for medical, civilian safety and military applications range from disposable lightweight fabrics to multilayered fabrics and laminated barrier materials, depending upon the nature of the contamination that threatens the wearer. Usually, only full barrier garments, such as the Level A liquid splash protective garments provide full protection from aerosols, and this is due to their air impermeability. An interesting question is whether it is possible to provide both high air permeability for comfort and a high level of aerosol protection in a garment. Is it possible?

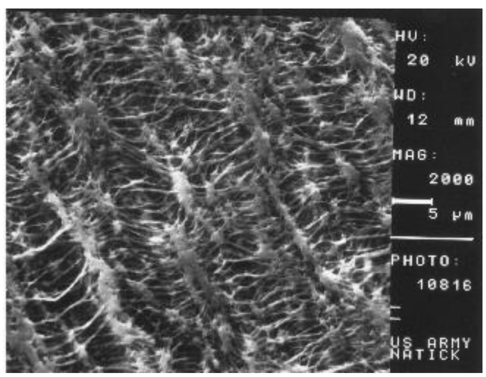
Typical air permeable woven fabrics provide very little aerosol protection, while nonwoven fabrics of similar weight can filter out more airborne particles by virtue of their random pore size and fiber size distributions, and their potential for electrostatic charging to increase filtration efficiency. Combinations of layers of protective fabrics, containing nonwoven materials, adsorptive layers such as carbon, and rugged fabrics for overall garment durability will increase aerosol protection. However, the most effective way to eliminate aerosol penetration without suffering a penalty of high air resistance and high garment weight is to incorporate a microporous membrane consisting of ultrafine or nanosized fibers, such as the material shown in the figure below.



Electrospun Membrane



Expanded PTFE Membrane 1



Expanded PTFE Membrane 2

Figure 1. Various fibrous membranes that can be used with cover fabrics.

The incorporation of a fibrous microporous membrane by lamination to a cover fabric increases filtration efficiency from 80% for the base fabric to over 99% for a membrane-backed fabric, without significantly increasing resistance to air flow. The finer the mean membrane fiber diameter, the better the filtration efficiency and air flow. Shown in the table below, the air flow resistance and the aerosol filtration efficiency can be adjusted independently. Membrane 1 minimal effect on the air flow resistance of the base fabric and increases filtration efficiency to 97%. An electrospun nylon layer can be applied at different thicknesses to the fabric – this example reduces air flow but achieves 99% filtration. Membrane 2 increases air flow resistance to unacceptable levels for a comfortable fabric but provides full aerosol protection. The data in this table suggests that there is a middle ground and the structure of the membrane can be optimized with respect to the factors that affect air flow (pore size and thickness) and the factors that affect aerosol protection (fiber size and charge).

Table 1. Pore Size, Air Permeability and Aerosol Filtration of Fabric and Membranes

Sample	Frazier Air Permeability (ft^3/min-ft^2) @ 5 inches water	Pore Size (μm)	Aerosol Filtration Efficiency (%)
Shell Fabric Alone	7.0	>20.0	79
Membrane 1	5.58	2.106	97
Electrospun Membrane	3.70	1.89	99
Membrane 2	0.11	0.209	99.99

Textile developers can laminate these ultrafine fibrous membranes to traditional textiles, but technical challenges have to be overcome to increase the durability of the laminated fabrics in sewing, while in use, and during washing. This is an important area and materials development, textile assembly and performance assessment for “wearable filters” of the future will be underway for some time to come.

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Keywords
Filtration Media
Membranes
Aerosol Filtration