Fabrication of Novel Functional Composite Forms for Filtration

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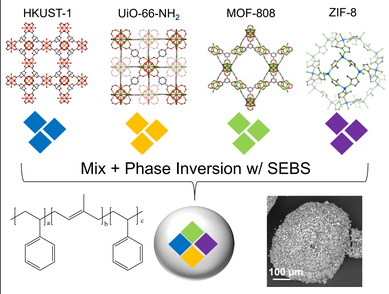
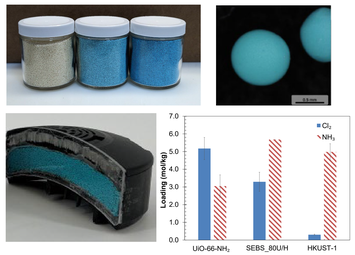
Objective: Develop revolutionary personal protective equipment utilizing polymer processing in conjunction with high activity metal-organic frameworks (MOFs)

Beads



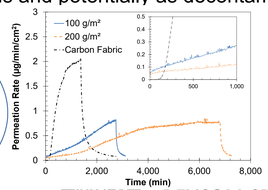
Phase inversion in non-solvents has been used to develop composite beads with mixtures of MOFs. Through appropriate choice of MOF, we can develop specialized or broad spectrum filters. A major advantage over impregnated carbon is that we can have different functionalities (i.e, acids, bases) physically separated into different MOF crystals but in the same bead, whereas in carbon the functionalities neutralize one another, reducing efficacy.

Formulations are being optimized for chemicals such as ammonia, chlorine, and sulfur dioxide for use in filters, and beads have been scaled to well over kg/day quantities with industry partners through the SBIR program. Prototype filters are being fabricated for evaluation. Additional polymers (i.e., polyimides and styrenic elastomers) are being inestigated to tune mechanical properties of the beads to minimize attrition.

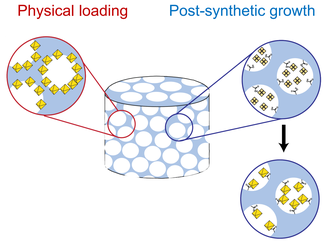


Images courtesy of Mainstream Engineering

Additional efforts are underway beyond filtration to utilize beads in protective suits as drop-in replacements for carbon beads and potentially as decontaminants. The detoxification provided by MOFs enhances protection and capabilities to the Warfighter. Enhancements over current materials have already been demonstrated.

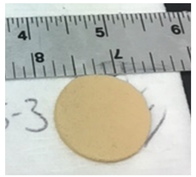


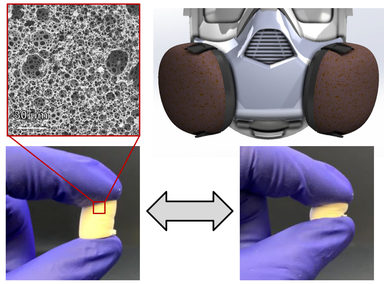
Foams



Foams are being developed using multiple techniques, including templating approaches to form high internal phase emulsions (HIPEs) with open cell structures. MOFs can be added during the polymerization of the foam, or functional groups can be incorporated into the foam for post-synthetic growth of MOFs to provide a uniform coating. The choice of polymer and processing technique dictates mechanical properties of the foam and can result in different use cases.

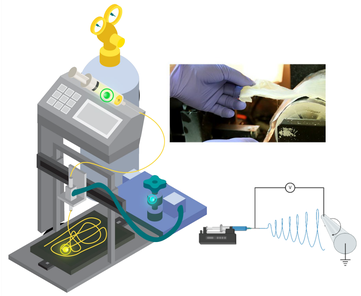
Harder foams from poly(styrene-*co*-ethylene-*ran*-butylene-*co*-styrene), SEBS, have been developed with DEVCOM ARL. These materials have shown the ability to adsorb and react with chemical warfare agents and chlorine. The ability to create shock-absorbing foams also lends to the development of helmet-lined filters to take "rubber off the face."





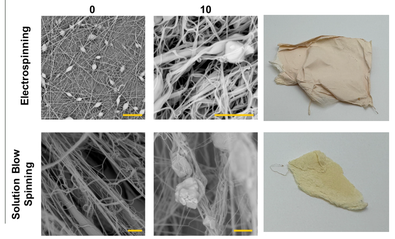
Alternatively, softer foams can be developed that can be depressed (or "squished"). This will allow for enhanced rifle sighting for the warfighter while maintaining high levels of protection. The ability to shape foams into novel forms also allows for new configurations. Finally, open celled foams incorporating MOFs may allow for combination gas/aerosol filters.

Fibers



MOFs are being integrated into fibers using multiple techniques, including electrospinning, solution blow spinning, and melt spinning. Each of these scalable techniques offers advantages and disadvantages, and the processing technique is important in determining how the MOF is integrated into/onto the fiber. Investigations are focused on structure-activity-processing relationships to understand composite activity as a function of processing technique.

Fibers have many potential uses for filtration. We can envision an "active" N95 or HEPA material that provides activity towards agent aerosols. Alternatively, low burden scarf-like concepts can be developed that provide escape level protection the Warfigher or low concentration level protection for Special Forces.



Scale bar is 10 µm.

Current investigations are focused on understanding optimal MOF incorporation strategies as well as optimizing piezoelectric effects, which can be used to harness energy in textiles and protective suits for a variety of applications, including photocatalysis and batteries. Scaling of these technologies will be conducted with partners such as NC State NWI.

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