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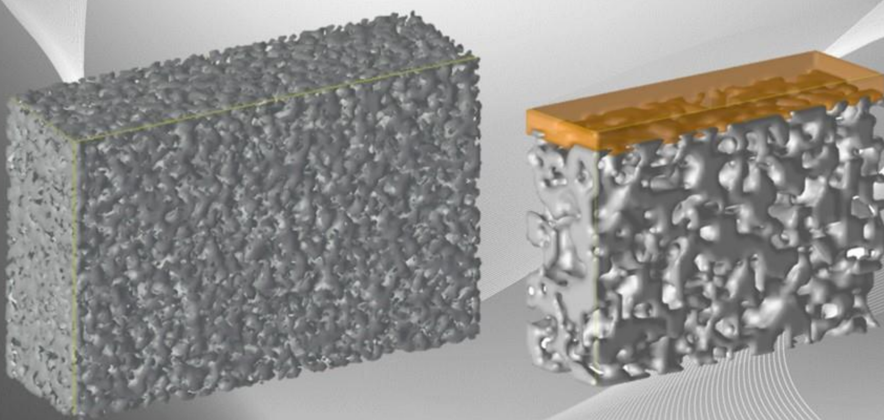
SBIR/STTR SUCCESS



The strong and flexible MWI porous metal structure can be coated with a thin ceramic layer to reduce surface pore size from 200 nm to 20 nm.

MOLECULE WORKS INC.

Synthetic membranes are a well-known technology with wide applications in air and water filtration, and molecular separations in industrial plants. Although the current market is served by several experienced companies, Molecule Works Inc. (MWI), a startup based in Washington State, is commercializing an innovative line of membrane products, which offer higher performance than conventional polymer- and ceramic-based membranes. MWI membranes are based on the fundamental inventions and understandings that were obtained at Pacific Northwest National Laboratory (PNNL) through scientific research that started in 2008, and on subsequent critical scale-up developments in MWI's pilot-scale facilities that have enabled manufacturing at competitive prices.

FACTS

PHASE III SUCCESS
While working on a Phase II SBIR project, MWI has received a $3.8M DOE-share award from the Advanced Manufacturing Office.

IMPACT
MWI has reduced process cost to competitively manufacture a specialty membrane product with customizable functionality.

DOE PROGRAM OFFICE
Bioenergy Technologies Office (BETO); Energy Efficiency & Renewable Energy (EERE).

www.moleculeworks.com

At the heart of MWI's products are 3 PNNL inventions: thin porous metal sheet, thin-sheet zeolite membrane, and cassette-type membrane module. Dr. Wei Liu, the scientist who led the PNNL team to pioneer these technologies, joined MWI in 2016, following a path that well illustrates the challenges and opportunities many R&D-heavy startups encounter in their business development. The interest of Dr. Liu in membranes started prior to his PNNL career, when he was a senior research engineer at Amoco Oil Company (BP) in the late 1990s. Back then, membranes were not commonly used in the refining and petrochemical industry, but Dr. Liu realized the need for novel membrane material structures that could survive high temperatures in the highly reactive hydrocarbon environments. After eight years of developing ceramic monolith-based reactor and membrane technologies at Corning Incorporated, his broad scientific curiosity and technology interests led Dr. Liu to accept a strategic hire position at PNNL, where he was given freedom to pursuing research topics relevant to energy and environmental technologies. At PNNL, through support from several DOE programs, including the Advanced Research Projects Agency-Energy (ARPA-E), Dr. Liu's team developed and patented the thin micro-porous nickel alloy sheets – a new membrane technology platform, which is the foundational invention enabling several types of membranes MWI is currently commercializing.

Much stronger and chemically stable than polymers, the porous metal sheet can be made thin enough (20-200 microns) to greatly reduce material cost and minimize flow resistance, thereby enhancing throughput and productivity. A key feature, the uniform pore size over a range of 100-1000 nanometers, determines the membrane functionality by enabling micro-filtration of bacteria, viruses and/or unwanted particulates down to 100 nm from air and water.

The membrane functionality is tailored by depositing metal-oxide coatings on the metal sheet's surface, resulting in smaller and chemically selective pores for separation of smaller particulates and molecules. Among those metal oxide coatings is zeolite – a special type of metal oxide with well-defined porous structures of 0.3 to 0.8 nm in diameter. These thin-sheet zeolite membranes were made possible by a second proprietary technology, which ensures the structural integrity of ceramic and metal oxide films deposited on the porous metal substrate in spite of very different thermo-mechanical properties of the two kinds of materials.

Finally, a third invention allows for the thin membranes to be assembled in a cassette-type membrane module designed to achieve high surface area packing density, minimize pressure drop, and perform *in-situ* cleaning.

For Dr. Liu, the decision to leave PNNL was not easy and came after a group of friends who had just co-founded MWI and were familiar with Dr. Liu's research findings, licensed the technology from PNNL with the intent of commercializing it. At this point, it became clear that scaling up PNNL's technology required additional and different R&D focused primarily on cost reductions in raw materials and parts, equipment, and manufacturing processes. Although less appealing to a scientist, due to the low potential for scientific publications, this type of R&D is as involved as laboratory research and absolutely critical for a technology to mature and acquire market readiness.

Dr. Liu joined MWI because he felt uniquely positioned to undertake the scale-up challenge. He not only had a deep knowledge and technical insights of the technology's fundamentals, but he was also passionate about transferring his research results to the market, which meant finding innovative ways to reduce manufacturing costs without sacrificing performance. This endeavor led Dr. Liu and the MWI team to produce new intellectual property on the manufacturing processes and application products.

MWI operations started with a seed investment from private investors and an ARPA-E grant. Subsequently, in 2018, MWI was awarded a Phase I DOE SBIR grant for applying its high throughput membrane technology to dewatering of micro-algal cultures. While working on the Phase II of the same award, MWI was able to leverage the R&D conducted within the SBIR to secure $3.8M in follow-on funds from DOE in the form of a DOE cost-share award supported by the Advanced Manufacturing Office (AMO) with the objective to improve industry drying processes through water-molecular separation to strengthen domestic manufacturing competitiveness.

One key to MWI’s success in securing post-SBIR funding has been the focus on scaling up the membrane module through pilot-scale field tests at an ethanol plant. This effort has allowed MWI to effectively differentiate its technology from other companies’ product offerings. MWI’s strategy has been to identify a few application areas where the developed membrane technology could be employed with a strong value proposition. Progress in one application area feeds into the others and contributes to advance the core manufacturing technologies towards high-volume production and commercialization.

One area in which MWI’s technology brings value is air dehumidification, which involves the HVAC market and was pursued with support from ARPA-E. The ARPA-E, AMO, and SBIR projects are all based on the thin porous metal sheet and cassette-type module designs to address application needs of different water removal processes by putting a membrane film of specific functionality on the porous metal sheet. Through the SBIR project, MWI made critical improvements to the membrane module designs and the porous metal sheet manufacturing process. These results are now the starting point for the R&D that will be conducted during the AMO project.

A usable membrane technology has three levels of components: the membrane, the membrane module and an application-specific system in which the module fits. The membrane is the core of the membrane system and process, like a central processing unit (CPU) in computers. MWI’s business model involves manufacturing the membranes in house, outsourcing the production of membrane module components and forming alliances with companies to design and market the system. As Mr. Mitch Odinak, Chief Commercial Officer of MWI explains, “the alliances can take multiple forms. An example is a selling relationship, in which the partnering company buys the product and place it on the market using its existing customer channels. Other forms are a joint equity venture, or a licensing arrangement. The option we will adopt will not be predetermined but will vary, depending on the specific application.”

Continuing to discuss MWI’s business model, Mr. Odinak points out that while some startups are asset-light and can attract venture capital quickly, others like MWI require building sophisticated machinery and extensive customer testing before achieving sales. For the latter companies, Federal grants and contracts are essential to de-risk the technology and get ready for manufacturing. Because one single Government grant is often not sufficient to bridge the gap to commercialization, Federal investment opportunities should be chosen carefully, aiming at building a portfolio of projects with different timelines and objectives. According to Mr. Odinak, “the SBIR program enables shorter projects with near term sales opportunity, while larger grants like those from ARPA-E, for example, focus on longer term projects, which might lead to larger sale opportunities."

Mr. Odinak views the SBIR as an efficient program to bridge the gap between Federal grants and private funding because SBIR grants allow a startup company to maintain freedom in the R&D process, and, even more importantly, to retain the rights to intellectual property, which is the foundation for a company to achieve revenues.

MWI shows us that even when operating in a large and established market, through innovative R&D and business planning, a startup can sufficiently reduce costs to transform a specialty, high-performance technology into a competitive product.

Written by Claudia Cantoni, Commercialization Program Manager, DOE SBIR/STTR, April 2020.