SBIR·STTR America's Seed Fund

U.S. DEPARTMENT OF ENERGY | SBIR/STTR Programs Office

Many materials are processed in the liquid state to produce a variety of structures and properties, including high performance optical and laser glasses, defect-free single crystals for the semiconductor industry, nanocomposite alloys for lighter weight and improved strength, and amorphous pharmaceuticals. Understanding the short-lived metastable states formed in liquids, particularly at high temperature, is critical for producing desired properties in energy conversion materials, or to model the behavior of nuclear fuels to optimize safety. However, the study of materials in extreme conditions is hampered by the container. A perfectly inert container does not exist in nature; therefore, sample interaction

FACTS

PHASE III SUCCESS
MDI has achieved a $1.03M ROI for a technology developed through a DOE SBIR grant.

IMPACT
Employing acoustic levitation combined with aerodynamic forces, MDI's groundbreaking technology makes it possible to study materials in extreme conditions without interference from the container.

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with the hot container's walls often sabotages experiments by introducing contamination and other spurious effects. Materials Development, Inc. (MDI) has a solution to the container problem that is brilliant and technically complex at the same time: eliminating the container!

This is achieved by combining acoustic and aerodynamic "levitation" forces to allow even dense liquid materials to "float" at temperatures as high as 3500 °C. An example is shown in the figure above which illustrates an advanced hybrid levitator for work with materials in extreme conditions. The advanced sample environment can be integrated with neutron or x-ray beamlines to probe a material's structure *in-situ* or used in the laboratory in conjunction with laser beam heating and optical diagnostics to investigate process-property-structure relationships in a wide variety of materials.

MDI was founded in 2006 by Rick Weber, who previously directed the Glass Products Division at Containerless Research, Inc. (CRI). Weber earned his Ph.D. at Imperial College London, developing aerospace alloys. He moved to the U.S. and worked with a company developing advanced instruments for NASA flight experiments. He realized that the non-contact processing tools that he was helping to develop could be used for processing advanced glasses. Weber and two colleagues spun off CRI, which was sold when a new glass technology developed using containerless processing was commercialized.

When MDI was founded, the Advanced Photon Source (APS) at Argonne National Laboratory (ANL) was ramping up operations, providing perfect timing to develop collaborations with scientists interested in using synchrotron light to analyze the structure of molten materials free from container interference. Personal communications at conferences led to collaborations with ANL and later Oak Ridge National Laboratory (ORNL) scientists. The work has resulted in a patent on containerless materials processing. "We worked initially as APS users and then with other users at beam lines to integrate our sample environment with the facility's instruments. This process has led to a 'turn-key product that is easy to operate for a wide range of materials and conditions," explained Weber.

Neutron and synchrotron scattering techniques have contributed to improvements in materials that are crucial for economic growth, such as magnetic recording and data storage media, medical and turbine materials. MDI's innovative sample environment solutions for beam lines are accelerating future advances in the processing of optical and functional glasses, semiconductor crystals and high-performance structural materials.

A Department of Energy (DOE) Phase II SBIR award to MDI that was completed in 2015 resulted in the development of an aerodynamic sample levitation system with laser beam heating. This was integrated with the Nanoscale-Ordered Materials Diffractometer (NOMAD) instrument at the Spallation Neutron Source (SNS) operating at ORNL. A specially developed instrument was optimized for work at Sector 6 ID-D at APS, where users can also investigate materials over a range of length scales from atomic to mid-range ordering in near real time. The work led to a commercial instrument for the niche market of processing and studying materials in extreme conditions. Today, an additional DOE Phase II award, which has expanded MDI's core technology to enhance experimental environments, has already provided an ROI of $1.03M in sales alone, with more in the pipeline.

In addition to sales, the SBIR grants have other commercialization outcomes, for example job creation. Thanks in part to the SBIR funds, MDI has hired and trained full-time scientific and technical staff and built a highly skilled team with know-how and specialized knowledge. Experiments at beamlines have included work with about 20 graduate students. By working at MDI to optimize sample synthesis and levitation conditions, graduate students have been able to interact effectively with the APS and the SNS teams during the beamline experiments. Several graduate students have gone on to research careers. Some have entered academic positions and bought instruments from MDI for use in their own research programs. This has helped to expand the market for instruments as well as helping to train the next generation of researchers.

The work with DOE has resulted in more than 100 peer reviewed publications. In addition to being an important metric of success, publications have helped DOE user facilities recruit new users. These were attracted in part by the opportunity to use MDI's sample environments for extreme condition experiments that had not been possible before. "The impressive aspect of MDI's R&D is the number of high-profile scientific publications that acknowledge SBIR support" states Dr. Thiyaga P. Thiyagarajan, the DOE program manager for the SBIR project at the SNS. It is important to realize that although not as quantifiable as cash returns, student training and publications are impactful outcomes of federal investment in R&D, and both ultimately contribute to our national economy, security and workforce.

MDI is an excellent example among startups providing R&D services and niche scientific instruments, which have become profitable by establishing a long-term business relationship with DOE. Weber views the SBIR as a program that serves the mission of DOE well by providing funds that are necessary for small businesses to develop the types of innovative technologies needed by the agency. MDI is expanding into new commercial and industrial markets. To this end, being awarded a Phase II helps to establish MDI's technical credentials with both customers and potential investors.

MDI is currently working with business consultants to help broaden its market sectors and exposure as well as reaching out to new customers.

Written by Claudia Cantoni, Commercialization Program Manager, DOE SBIR/STTR, March 2021.