

# Superconductors Enable Lower Cost MRI Systems

## NASA Technology

The future looks bright, light, and green—especially where aircraft are concerned. The division of NASA's Fundamental Aeronautics Program called the Subsonic Fixed Wing Project is aiming to reach new heights by 2025–2035, improving the efficiency and environmental impact of air travel by developing new capabilities for cleaner, quieter, and more fuel efficient aircraft.

One of the many ways NASA plans to reach its aviation goals is by combining new aircraft configurations with an advanced turboelectric distributed propulsion

(TeDP) system. Jeff Trudell, an engineer at Glenn Research Center, says, "The TeDP system consists of gas turbines generating electricity to power a large number of distributed motor-driven fans embedded into the airframe." The combined effect increases the effective bypass ratio and reduces drag to meet future goals.

"While room temperature components may help reduce emissions and noise in a TeDP system, cryogenic superconducting electric motors and generators are essential to reduce fuel burn," says Trudell. Superconductors provide significantly higher current densities and smaller and lighter designs than room temperature equivalents.

Superconductors are also able to conduct direct current without resistance (loss of energy) below a critical temperature and applied field. Unfortunately, alternating current (AC) losses represent the major part of the heat load and depend on the frequency of the current and applied field. A refrigeration system is necessary to remove the losses and its weight increases with decreasing temperature.

In 2001, a material called magnesium diboride ( $MgB_2$ ) was discovered to be superconducting. The challenge, however, has been learning to manufacture  $MgB_2$  inexpensively and in long lengths to wind into large coils while meeting the application requirements.

## Technology Transfer

For more than a decade, Hyper Tech Research, a Columbus, Ohio-based company, has been working on the development of  $MgB_2$  superconducting wire. According to Mike Tomsic, president of Hyper Tech, "When  $MgB_2$  came along, we were excited because the transition temperature was twice as high as any known intermetallic superconductor at the time. We saw the potential for many applications."

Early in the development process, the company received funding from Glenn Research Center's Small Business Innovation Research (SBIR) program to investigate  $MgB_2$  for motors and generators for turboelectric aircraft propulsion systems. Hyper Tech also worked with Glenn on the process of making very fine superconducting filaments to reduce AC losses.

"Hyper Tech designed and fabricated a set of four  $MgB_2$  rotor coil packs for a superconducting generator," says Trudell. "The advantages of using  $MgB_2$  wire and coils developed by Hyper Tech include low cost and density, the ability to be easily configured in any critical current as a round wire, and the low AC loss potential."

While further development is required before  $MgB_2$  can be used for NASA applications, Tomsic says the



These aircraft concepts are designed to burn less fuel and expel fewer emissions. For a deeper look at NASA's Fundamental Aeronautics Program, scan this code.

NASA projects have helped Hyper Tech to advance  $MgB_2$  to a point where it can be used for commercial products.

“At the time we made the coils for NASA, they were probably the longest length  $MgB_2$  wires and highest performing  $MgB_2$  coils anyone had made in the world,” says Tomsic.

## Benefits

Several years after its initial work with Glenn, Hyper Tech now builds superconducting coils and has patented a process for manufacturing  $MgB_2$  superconducting wire in many different diameters and lengths. Through collaboration with various research organizations, Hyper Tech continues to increase the performance of  $MgB_2$  wire. Tomsic says the company has obtained funding to do demonstrations and has sold wires and coils to companies for their own developmental products. “Instead of just making the wire, we are developing subsystem prototypes along with our customers,” he says.

Hyper Tech has received funding from the National Institutes of Health, the Department of Energy, the National Institute of Standards and Technology, and the State of Ohio, and has been cooperating with major companies to apply  $MgB_2$  superconducting wire to magnetic resonance imaging (MRI) devices. These devices are used in medical facilities to make images of organs and structures inside the body. Most MRIs generate a strong magnetic field using superconductors, which allow for the highest-quality imaging.

By using  $MgB_2$  superconducting wire for MRI background coils, the company hopes to help MRI producers drive down the cost of MRIs. “That’s the number one application for  $MgB_2$  wire,” says Tomsic.

Tomsic explains that MRIs currently use niobium titanium superconductors that are cooled in a bath of liquid helium. The liquid helium helps prevent magnet quenches where the magnet increases in temperature due to local overheating and can cause damage. Some MRI machines experience the issue more often than others. “The problem is that liquid helium is in short supply,” says Tomsic. “By 2017–2018, it is predicted that the demand will exceed the supply. For many customers,



After Hyper Tech Research advanced superconducting wire for NASA, the company started applying the same wire to magnetic resonance imaging (MRI) devices to reduce the cost of MRI systems.

the cost of helium has tripled in the last five years, and is expected to keep increasing.”

The MRI industry is looking to convert to conduction cooled magnets, which would transfer heat from the superconductor coil to copper links to a refrigerator to remove the heat from the magnet, describes Tomsic. “This would eliminate the large helium bath,” he says. “We have programs with Siemens and General Electric working on developing replacement magnets for their existing MRI background magnets.”

Getting  $MgB_2$  wire into MRIs will make  $MgB_2$  wire more economical for other power applications like superconducting fault current limiters (SFCL). SFCLs use superconductors to limit electrical surges before they exceed a circuit breaker capacity. According to Tomsic, SFCLs can be advantageous when adding renewable energy like wind and solar to the grid, which can cause fault currents that exceed the breaker capacity. Many companies, including Hyper Tech, are working on the technology to develop and manufacture low cost SFCLs.

Presently, Hyper Tech is working on a British-government-funded program to make wires and coils for FCLs. “Hyper Tech and our collaborators have the potential to come up with a low cost fault current limiter. Full size distribution voltage SFCLs are scheduled to be on the grid in the next two years or less.”

In the last couple of years, there has been interest in lightweight generators for offshore wind power. “We have had great interest from Asia, Europe, and the US,” says Tomsic. “The potential  $MgB_2$  wire market for offshore wind could be greater than the MRI wire market.”

Since 2003, the company has grown from 8 to 27 employees, with 16 employees involved with  $MgB_2$  superconductor wire activity. The company has also increased its revenue from approximately \$1 million to \$5.4 million, with \$3 million from work on  $MgB_2$  superconductor wires and coils.

Even though  $MgB_2$  wire is not yet employed in aircraft or wind turbines, it promises a bright future with lighter, greener, low-cost technologies. ❖

