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SMS Wins Two $125,000 NASA SBIR Phase I Awards

Solid Material Solutions (SMS) has been awarded funding for two SBIR Phase I proposals it submitted to NASA. One is for the development of Bi2212 superconductors for motors to be used in aero propulsion, and the other is for a low current superconducting coil operating above 15 K. The SBIR contracts last for 6 months with a maximum funding of $125,000.

Proposal Aims to Develop HTS Bi2212 Airplane Motor

The first proposal, entitled "Bi2212 Superconductors for High-Power Density Motors for Aero Propulsion," aims to develop an all-HTS lightweight high-power motor. In the design, the motor's stator coils are wound with low loss, transposed cables comprised of strong, low loss, small-diameter Bi2212 wires.

The motor is intended for use in future hybrid aircraft such as envisioned in NASA's N3-X plan for a turboelectric distributed propulsion power aircraft. Such aircraft will require all-superconducting electric motors and generators in order to achieve power densities in excess of 10 kW/kg.

Unlike in a DC rotor the stator must operate in AC mode, for example to 0.5 T at 120 Hz, making it impossible to use wide HTS tapes due to their high losses in transient fields. Such motors require HTS in narrow wire, fine-filament form and cabled into a low-loss transposed form.

The small-diameter Bi2212 wires to be used in the motor have fine filaments with enhanced matrix resistances between them. They also have the axial twist necessary for low loss in transient fields, while providing the operating J_c and strength at above 20 K for achieving >10 kW/kg specific power.

"The wire for the stator will be the smallest that is practically possible," said Alexander Otto, co-Founder of SMS. "In the Phase 1 project, wires down to about 0.2 mm will be fabricated and tested. The target operating J_c will be determined by motor design work, with a useful threshold expected at 2 kA/cm^2."

Bi2212 Motor: Phase I Includes Four Steps

The current Phase I project includes four steps. The first step is development of a baseline design for an all-superconducting, strong Bi2212 wire-based machine. The second step involves fabricating Bi2212-based wire and cabled conductor samples, after which their properties will be tested including I_c at up to 40 K and in fields from 0 to 5 T. The final step will involve applying the results to develop a basic Bi2212-based conductor, stator, and motor design that incorporates features for attaining target AC loss levels and meeting all other key requirements.

"Since late July, our efforts have been directed at completing the first two steps," said Otto. "Our team is currently analyzing different novel motor design options and features.

"AC loss levels must enable the motor to operate with high efficiency, for example >99%. The required strength will be established by specific motor design and operating conditions such as rotational frequency. The Bi2212 low-loss conductor will be manufacturable in long lengths similar to 1G tape and LTS wires and cables."

Second Proposal to Develop SC Coil for Magnetic Cooling

The second proposal, entitled "Compact, Low Current Superconductor Coil Operating Above 15 K for Magnetic Cooling," aims to develop a compact, low current coil wound with a very fine Bi2212 wire that draws about 6 A and generates in excess of 4 T while operating at up to 25 K. Bi2212 provides an HTS option for achieving these properties such that the cooling system exceeds the capabilities provided by present LTS-based adiabatic magnetic refrigeration (ADR) coils.

ADR can achieve superior efficiency with fewer moving parts than compressor-refrigerators, making it the choice for space-based instruments that require cooling to the sub-Kelvin range. The low operating current required for space-based usage, the high operating J_c needed to keep weight and size down, as well as the benefits of higher operating temperatures provide an opportunity for a Bi2212-based system to outperform current ADR systems.

"This Bi2212 coil will match present LTS coil operating J_c at a 2.5 times higher operating temperature," said Otto. "The Phase 1 specifications are for a wire with 6 to 12 A operating current, with J_c and operating temperature exceeding 300 A/mm^2 at 15 K in a 4 T field."

Team Working to Design, Fabricate Bi2212-based Fine Wire

The project's first step involves the design and fabrication of prototype Bi2212-based fine wire. Based on the results, longer lengths will be produced at best design and mode conditions, followed by testing to validate scalability. As a final step, the research team will wind and test a subscale test coil with similar bore sizes to the LTS-based coils in order to demonstrate the basic feasibility of fabricating an ADR-style coil with the Bi2212 wire.

"Since late July, efforts have been directed at completing the first step of the project," said Otto. "Subscale test coils will be fabricated with hundred-meter wire lengths and tested in the final month of the project."

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Otto also compared the required specifications for the wire being developed for the high-density motor and the ADR coil: "Although both the motor and ADR wires are small in diameter, their internal designs differ because they target different operating conditions. ADR wire is centered on a small and precise operating current with a high J_c in slowly ramped fields, whereas stator wire and cable are centered on achieving features for very low loss in rapidly ramped AC fields at lower operating J_c and weaker fields."

SMS Develops Commercial HTS Bi2212 Wire, Cables, and Coils

Founded in 2012 by Alexander Otto and Linda Saraco, SMS is working to realize strong round and rectangular Bi2212 wires and their low-loss cabled and coiled forms. SMS currently develops and manufactures prototype long lengths of strong rectangular 2212 wire, while also developing and scaling up its strong, standard-diameter wire capability with considerable support from the DOE. SMS has also developed transposed cabling for its Bi2212 wires, as well as prototype small-coil winding and reaction capability.

"SMS Bi2212 wires are three times stronger than prior Bi2212 wires, with similar strength to high-strength 1G tape products," said Otto. "They can also be tailored to meet many specific strength specifications.

"Bi2212-based wires can provide a useful Jc to several-fold beyond the 20 T field and 10 K temperature limits of commercial LTS wires and without the piece length, AC loss, transposed cabling, and other limitations of HTS tapes. Among HTS options, only Bi2212 can be processed to attain useful J_c's in wire and cable forms that are similar to commercial LTS designs."

SMS Reinforces Wire with Superalloy

Otto added that SMS was able to improve the characteristics of its Bi2212 wire by reinforcing them with a superalloy: "The key breakthrough at SMS is an approach for applying a thin superalloy reinforcement to a wide variety of Bi2212 wires in such a way that enables the formation of Bi2212 with a usefully high J_c at standard reaction conditions. An even higher J_c [is attainable] by applying the breakthrough pressure heat treatment pioneered at Florida State University."

In addition to the NASA SBIRs, SMS has an ongoing program that is co-funded by a development grant from the National Institutes of Health and that is developing persistent current, rectangular wire-based Bi2212 coils with superconducting joints. The relative simplicity and scalability of the Bi2212 wire process in comparison to 1G tape suggests that a similar effort to scale up the production of Bi2212 wires could result in much longer piece lengths, possibly in excess of 5 km, and with a higher yield and at lower cost. ❍