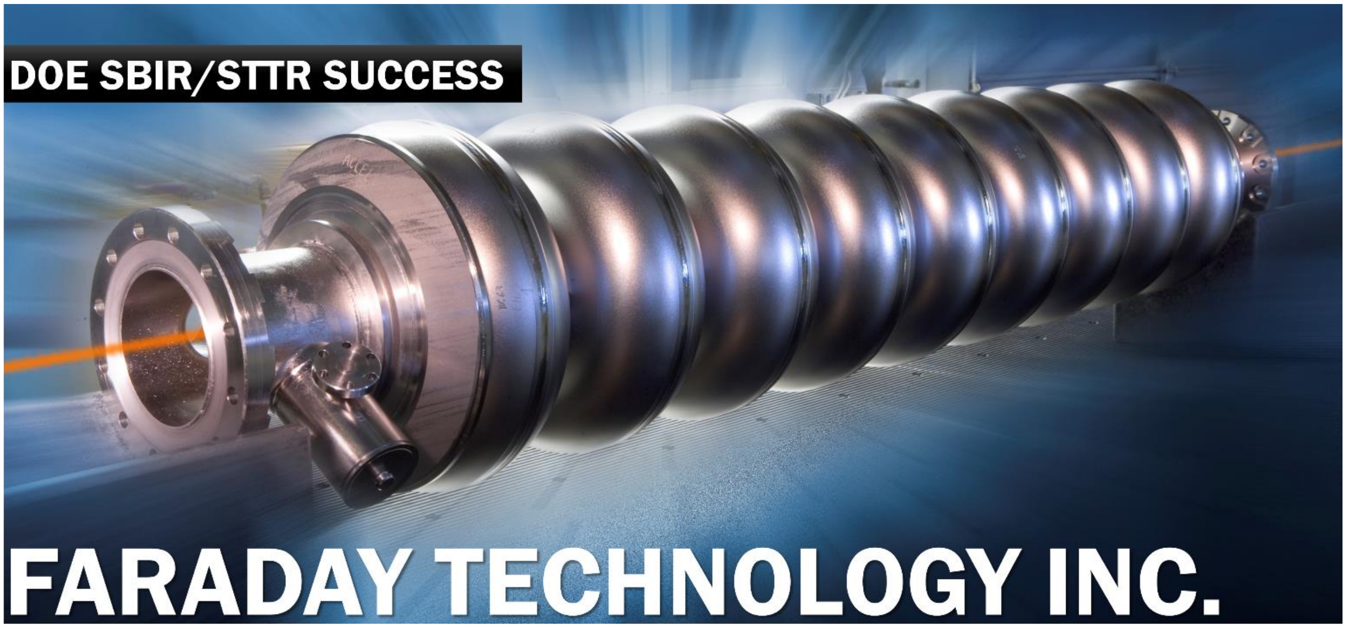
SBIR·STTR America's Seed Fund

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



FARADAY TECHNOLOGY INC.

Faraday Technology, Inc., or Faraday for brevity, is a great example of a small business that, although not fitting the definition of a startup, has nonetheless successfully leveraged the SBIR/STTR programs to increase National economic growth while at the same time advancing the frontiers of the physical sciences in line with the goals of the Department of Energy (DOE). With support from DOE SBIR, Faraday has developed and commercialized a novel electrodeposition/plating technology, which represents a paradigm shift from widely established past models. Faraday's discoveries have dramatic implications for the Nation's world-class particle accelerator facilities supported by DOE, which aim at understanding the building blocks of matter and how the universe has evolved instants away from the Big Bang.

FACTS

PHASE III SUCCESS
Faraday Technology collected a total of $1.5M in purchase orders from DOE National labs, and contracts and licensing fees from a private company.

IMPACT
The FARADAYIC® pulse reverse electrochemical process has transformed surface polishing of Nb SRF cavities by eliminating hazardous concentrated acids and lowering equipment and labor costs.

DOE PROGRAM/OFFICE
Nuclear Physics (NP); High Energy Physics (HEP).

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Superconducting Radio-Frequency (SRF) cavities made with niobium (Nb) are a key developing technology for high-performance particle accelerators. Further development of SRFs is also critical for future industrial and medical uses of particle accelerators. RF cavities accelerate the charged particle beams and collimate them to maximize the number of collisions. In the superconducting state, the surface resistance, which is a key parameter for the cavity's performance is five to six order of magnitude smaller than for a normal metal, drastically reducing energy losses in the accelerating electromagnetic field. However, operating in the superconducting state requires high-purity Nb, free of native oxides and with a surface roughness in the sub-nanometer range. The conventional process to obtain the required surface finishing has proven too hard and expensive to be optimized on an industrial scale, due to the cavities' large area, peculiar shape, and handling of extremely hazardous solutions.

The current state-of-the-art final surface preparation protocol uses electro-polishing (EP) with a solution of concentrated sulfuric acid (H_2SO_4), and hydrofluoric acid (HF), a particularly corrosive acid, in the ratio 9:1. The use of HF is problematic in terms of worker safety and waste control, and results in high capital and operating costs. In addition, the present EP method, which involves turning the long 9-cell cavity horizontally and spinning it, comes with a large cost in terms of capital equipment and labor burden. Although a static, vertical geometry is considerably less expensive, its implementation has not been possible so far due to bubbles that are formed by the evolution of gas in the EP cathodic reaction. The bubbles rise upward streaking the cavity and producing unwanted roughness. Streaking is currently avoided by turning the cavity horizontally and filling only 60% of the volume with the EP solution, which, in turn requires spinning.

As Dr. E. Jennings Taylor, Faraday's founder & chief technology officer explains, the use of a high-viscosity, concentrated acid solution, and in particular HF have been so far considered absolutely necessary to polish Nb with the required smoothness based on the currently understood physical/chemical paradigm. A viscous solution with concentrated H_2SO_4 is required to form a thick boundary layer to preferentially dissolve the peaks in the metal surface as opposed to the valleys, yielding a low surface roughness. At the same time, the presence of HF is necessary to remove the passive Nb oxide that forms as a parallel undesired consequence of the anodic reaction. These concepts were deeply ingrained in the knowledge framework for electrochemical polishing of cavities and other metal surfaces since the 1930s. This knowledge framework is referred to as the Jacquet viscous salt film paradigm. When Faraday announced the discovery of a valid alternative process based on bipolar current pulses vs. DC current, which made no use of HF or other concentrated acids, the company encountered significant skepticism from the scientific community for proposing concepts that did not conform to the universally accepted Jacquet paradigm.

Ultimately, by following systematic scientific observations and providing tangible results, Faraday was able to secure two DOE SBIR Phase II awards and additional SBIR funding from other Government agencies for applying the bipolar pulse concepts to electropolishing of materials for medical implants. The DOE SBIR grants were funded by two programs in the Office of Science: Nuclear Physics (NP) and High Energy Physics (HEP). Concurrent with the SBIR funds, Faraday received a $1M purchase order from Fermilab to scale the bipolar current pulse process from small Nb samples to real cavities.

Faraday's efforts have resulted in a polishing process that, while yielding optimal performance operates without moving parts using a solution no more harmful than a common household cleaning detergent. A more recent purchase order of $80,000 came from Oak Ridge National Laboratory to test Faraday's process on the Laboratory's Nb cavities. Faraday's breakthrough bipolar current pulse technology uses an anodic pulse which is timed to focus the anodic reaction at the metal surface's asperities, without need for a viscous solution. This is followed by an off time to dissipate heat, and a reversed (cathodic) pulse, which removes the passive metal oxide without the need for HF. Amplitude and frequency of the square waveform can be optimized for different materials and applications.

The applicability of Faraday's innovation is not limited to SRF cavities for upgraded and/or future scientific accelerator facilities. As plans for the construction of the International Linear Collider (ILC) are currently uncertain, Faraday is focusing on smaller cavities for portable accelerators with medical and industrial applications, for which significant market traction is expected in the near future. In addition, Faraday has applied the same core technology developed with SBIR support to remove oxides and polish medical devices such as implants and stents made of a NiTi alloy. As result of the latter development, Faraday has obtained private funds totaling over $400,000 from a manufacturer of NiTi wire for contracting R&D work and licensing fees. The latter is an example of synergistic applications resulting from the SBIR program.

Faraday's business model relies on strategic alliances with larger companies interested in acquiring Faraday's technology for their specific products, mainly through licensing. Because strategic partners are looking for a competitive advantage associated with the technology they acquire, Faraday is highly committed to generate intellectual property. The technology discussed in this article alone has produced eight patents, several of which are international patents.

Faraday's facilities were expanded in 2002 and feature an electrochemical engineering and corrosion engineering research laboratory. In addition, Faraday offers to its customers a large prototype manufacturing area for pilot-scale fabrication, and complete CAD design and controls engineering services.

Written by Claudia Cantoni, Commercialization Program Manager, DOE SBIR/STTR, September 2019.