CAM

CENTER for ADVANCED MATERIALS

University of Houston

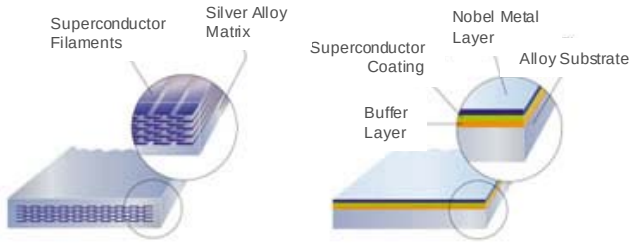
High Temperature Superconducting Wire

(2nd Generation HTS Wire)

Technology

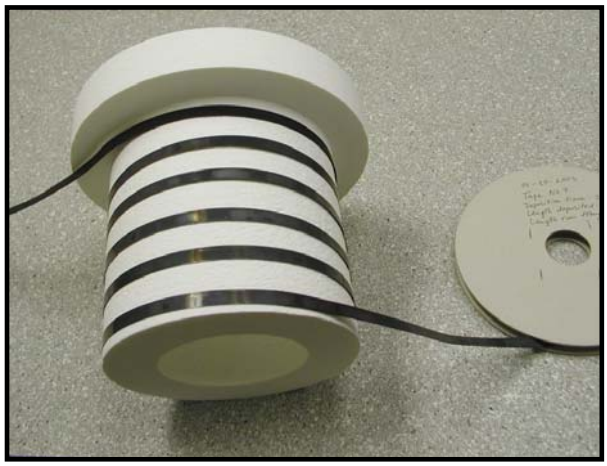
The last 20 years have witnessed a revolution in superconductor science. As the critical temperature (T_c) of superconducting materials rises, so does the promise of the practical application of loss-free transmission of electric power. However, high temperature superconductors (HTS) are ceramics and present a fundamental problem for wire fabrication: *they are brittle*.

"First Generation" powder-in-tube HTS wire has relied on traditional wire drawing technology and variations on the compound $Bi_2Si_2Ca_2O_7$ (T_c = 112°K). Powder-filled silver tubing is pulled through a form and rolled to create sheathed superconductor filaments made up of microscopic HTS crystal grains in a ductile silver alloy matrix. In large part, wire performance becomes a function of the efficiency of grain-to-grain conductivity. Such wire has shown reduced performance in magnetic fields and operates well only at temperatures well lower than those achieved in the laboratory. Since operation costs are driven by cooling costs, the temperature of ubiquitous and inexpensive liquid nitrogen (77°K) is the threshold for potential wide scale commercial feasibility of HTS wire products.



HTS Wire cross-sections: 1st generation (left); 2nd generation coated conductor wire (right).

The Center for Advanced Materials (CAM) and Metal Oxide Technologies, Inc. (MetOx, Houston, TX) are collaborating on the development of "Second Generation" HTS wire based on a propriety process relying on thin film technology to deposit flexible layers of $YBa_2Cu_3O_{7-X}$ (T_c = 93°K) on a rugged metallic foil. Critical to the performance of 2nd generation wire is the buffer layer between the foil substrate and the HTS coating which limits material inter-diffusion and preserves its superconducting behavior. The resulting



wire has very high current carrying capacity at LN_2 temperatures and excellent ductility. The process calls for a single continuous manufacturing pass with a simple material layer architecture. Thicker superconducting layers result in wire more current capacity and is easier to join and repair. And the CAM/MetOx process accommodates different wire shapes, providing application design flexibility.

Market

While superconductor technology will eventually transform most aspects of society, many high impact applications are still decades away. However, HTS has already entered the marketplace where it can begin to address immediate and critical needs.

The US power transmission system is increasingly congested and inefficient. It is estimated to represent a $1-trillion infrastructure, and an annual product market of $250-billion. New technologies are crucial to relieving a dangerous and growing problem. New grid technologies involving conductors and cables, modular equipment (generators, transformers, etc.), energy storage and transmission, will ALL be directly impacted by HTS development in the near term.

CAM/MetOx 2nd Generation HTS wire is being developed to address both technical needs and current market realities, with a focus on lowering the capital and production costs that can make superconductivity economically feasible on a large scale.

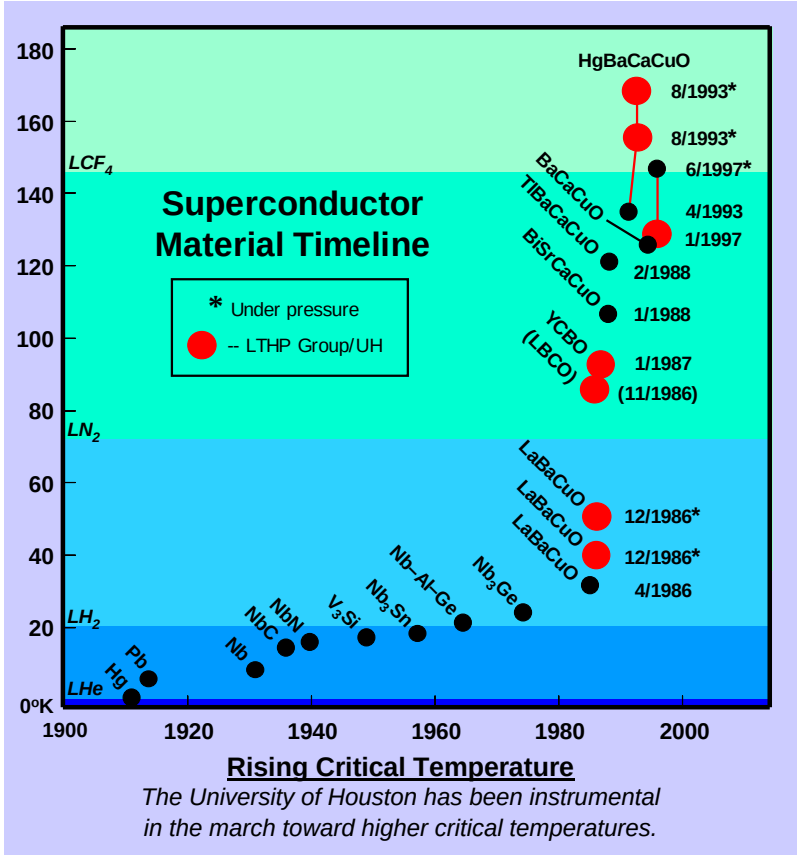
Applications

Transformers – With HTS technology, transformer efficiency with approach 100%. Reduced size and weight will result in power densities 30 times greater that current components. Without cooling oils and the danger of explosion, siting in urban areas will be easier. Projections show a reduction in the cost of ownership greater than 20%

Generators – Initially, existing cold rotor design generators can be upgraded/retrofitted yielding a 20% increase in power output. Future HTS generators will be 1/5 the size and ¼ the mass.

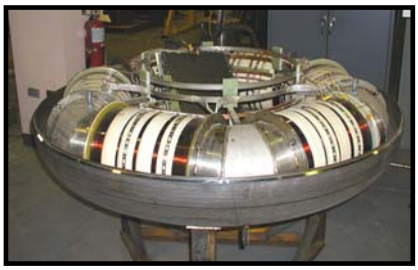
Conductors and Cables – HTS provides for high voltage DC/DC transmission (greater than 345 kV) with underground, liquid nitrogen cooled cables. Fewer above-ground logistical problems (weather, vehicular, siting, etc.) will result in fewer outages and other indirect economic impacts.

Fault Current Limiters – HTS FCL eliminate expensive circuit breakers for generator, transformer, and line protection, and can provide rapid ½-cycle recovery after fault clear (8 *msec*).



Rising Critical Temperature

The University of Houston has been instrumental in the march toward higher critical temperatures.



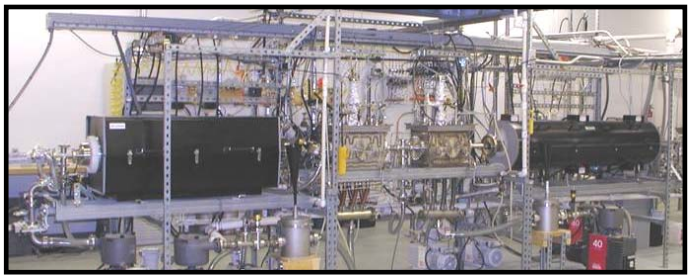
Superconducting Magnetic Energy Storage – SMES technology (left) allows storage of energy in the magnetic field generated by circulating current with ~98% efficiency; capable of nearly instantaneous discharge. In grid infrastructure, SMES applications include load leveling and reactive power quality control.

HTS Wire Market Outlook HTS technology could offer energy/dollar savings of $80-billion annually while enhancing grid stability and increasing grid capacity 50-fold. Both an aggressive business approach and cost-effective HTS wire are necessary to overcome the natural inertia of long asset lifetime and energy sector conservatism.

metox

Metal Oxide Technologies, Inc. *MetOx is a Houston-based Center for Advanced Materials spin-off company developing processes that will significantly reduce the cost of 2nd generation HTS wire.*

Wire Type	Performance amps/sq-cm	Price per 1000 A-m	Operations costs
MetOx 2nd Gen HTS	***1,000,000***	***$25***	***Moderate***
Other 2nd Gen HTS	1,000,000	$200	Moderate
Copper	1,000	$25	Low – High
1st Gen HTS	30,000	$250	Moderate
LTS (Tc < 40°K)	200,000	$25	Very High



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