

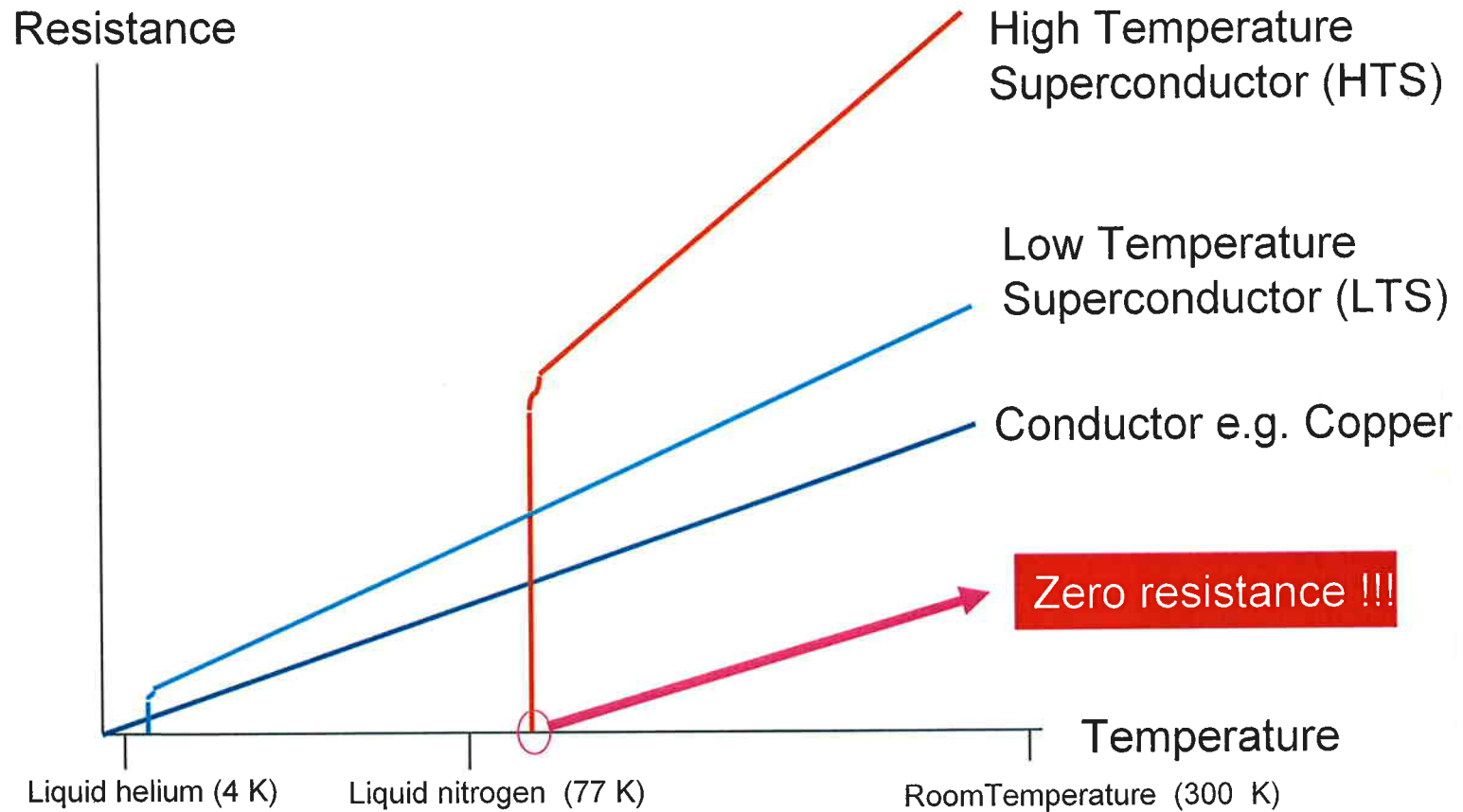


## **Fabrication of Long Lengths of Flexible High-temperature Superconductor Thin Film Tapes for Electric Power Applications**

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- ▶ **X. Xiong, Y. Chen, P. Hou, T. Salagaj, Y. Xie, M. Gardner, J. Reeves, Y. Qiao, Y. Li, K. Lenseth, and V. Selvamanickam**

# High Temperature Superconductors (HTS) can carry much higher current than copper

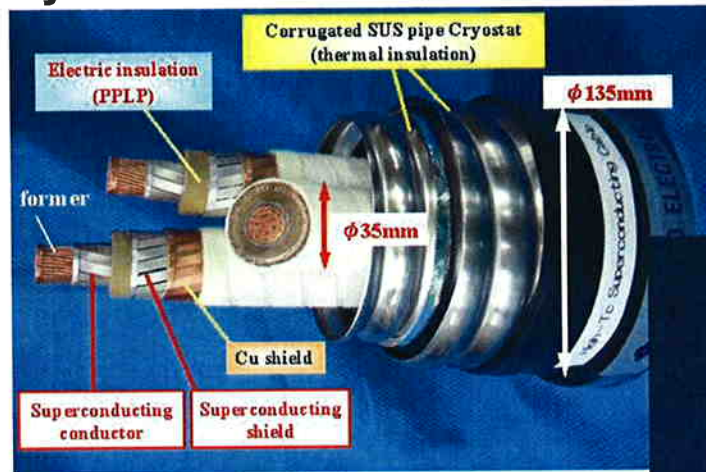


**Current carrying capability of copper ~ 100 A/cm<sup>2</sup>**

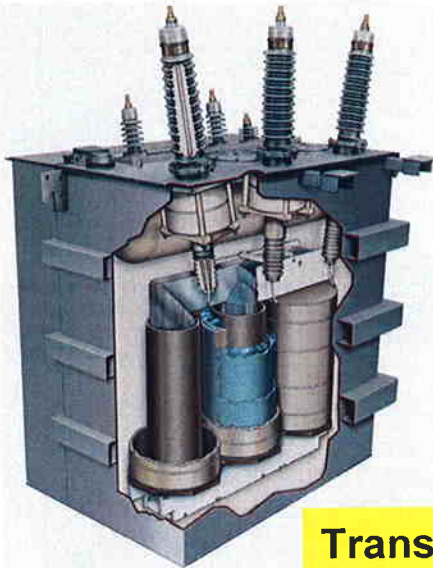
**Current carrying capability of superconductor ~ 1,000,000 A/cm<sup>2</sup>**

# Significant benefits of HTS for electric power industry

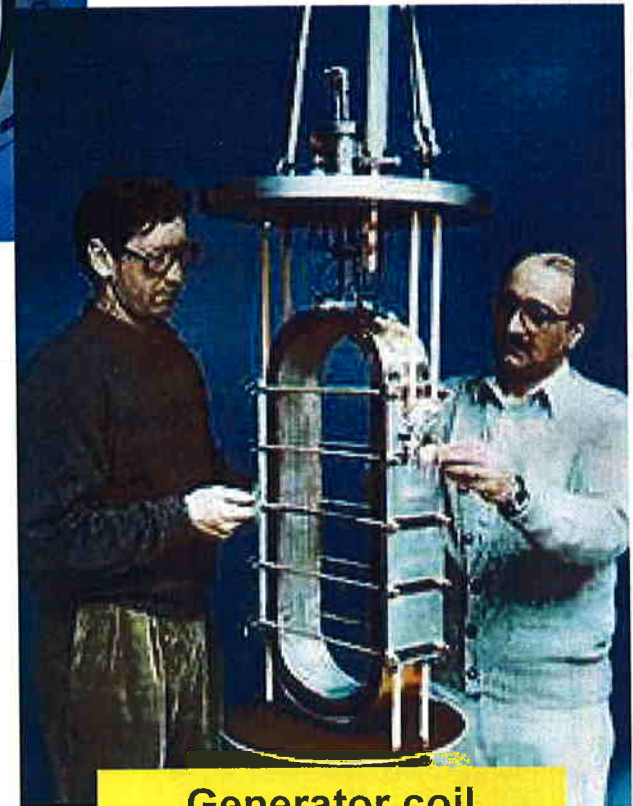
- Environmentally friendly
- More efficient
- Safer
- Smaller footprint
- Lighter
- Security benefits



HTS Cable



Transformer coil set



Generator coil



# HTS can provide premium power for military applications

**SuperPower** Inc.

High current density of HTS can enable devices that are

- High power
- Lightweight
- Compact

Suitable for military applications that require premium power without interference in battlefield mobility

## Long Duration High Power Microwave (HPM)



- Airborne Active Denial
- Large Aircraft Self-Protect

## High Peak Power Pulsed HPM

- Small Aircraft Self-Protect
- UCAV DEW Applications



## Solid State Laser



- Diode Pumped Solid State High Energy Laser (HEL)

All are electrically driven systems!



## Challenge is to produce HTS in form of a flexible wire

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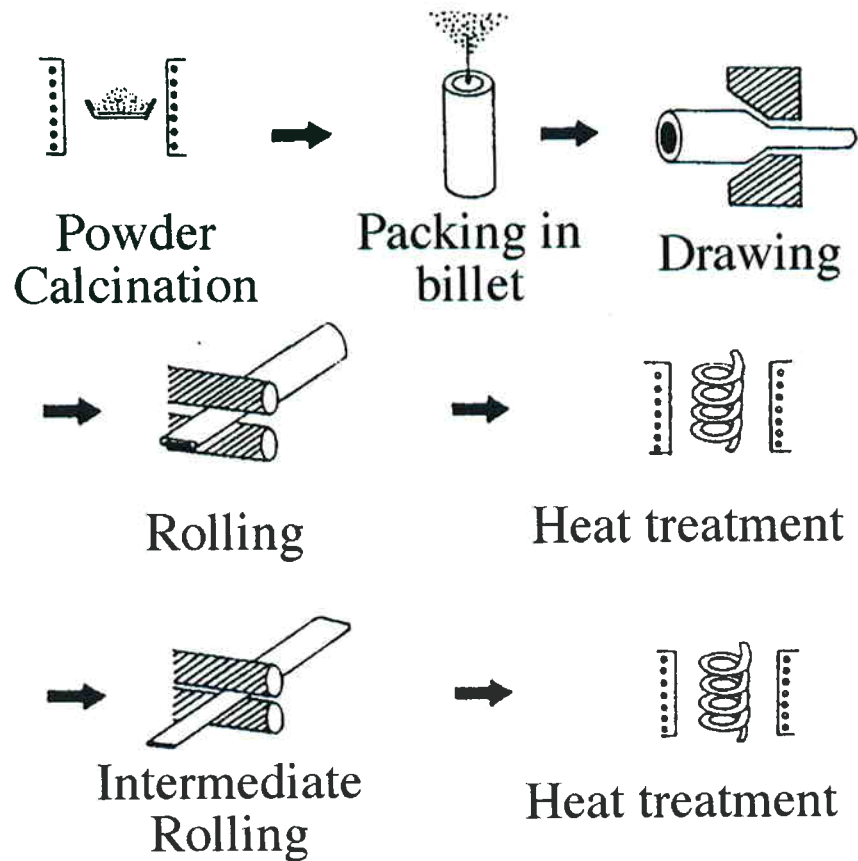
High-temperature superconductors are ceramic materials and are inherently brittle. Challenge is to produce them in a flexible wire form in lengths of kilometers

Two approaches to produce HTS in flexible wire form:

- First-generation (1G) HTS - HTS is encapsulated as filaments in a silver sheath
- Second-generation (2G) HTS- HTS is deposited as a thin film by semiconductor-type coating processes on a flexible nickel alloy substrate

# 1G HTS Technology - ready today, but expensive!

## 1G HTS Process Scheme



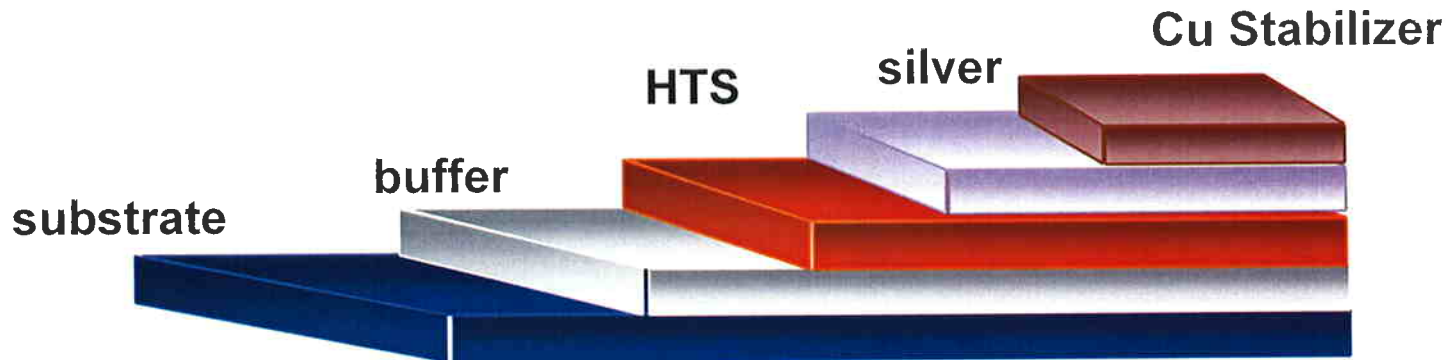
Monofilament



Multifilament

- ▶ Labor Intensive
- ▶ Long Processing cycle (6 to 8 weeks)
- ▶ Need 60 to 70% silver
- ▶ Difficult Process Control
- ▶ Best approach to make 100 m HTS

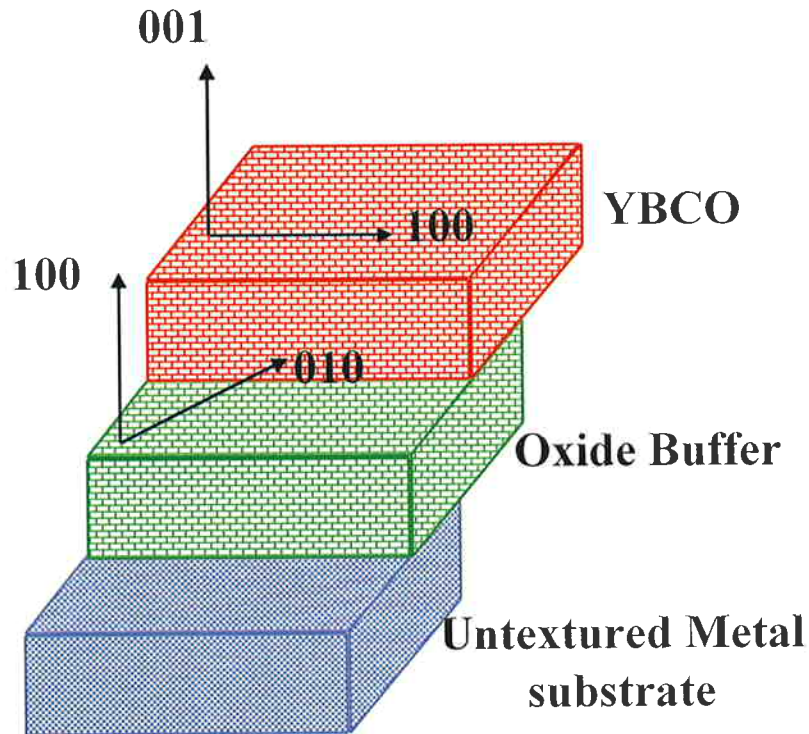
# 2G HTS is inherently a low-cost HTS conductor manufacturing approach



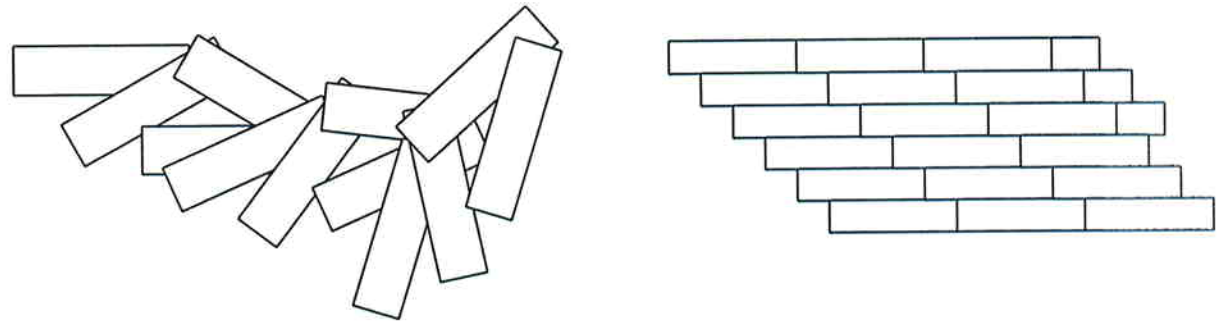
- ✓ **Much lower labor costs:** 2G can be produced in an automated continuous process compared to elaborated drawing and rolling procedures in 1G
- ✓ **Much lower materials costs:**
  - 95% of the structure of 2G is comprised of inexpensive nickel alloy substrate and copper
  - Only 3% of 2G is made of silver compared to 70% in 1G
  - About 40 times less HTS in 2G than in 1G.
- ✓ **Much less operational costs:**  
Hours to produce kilometer lengths of 2G instead of weeks for 1G
- ✓ **Much lower capital costs:** \$ 15 to \$ 20 M compared to \$ 100 M for 1G



# Challenges in scaling up 2G HTS conductor

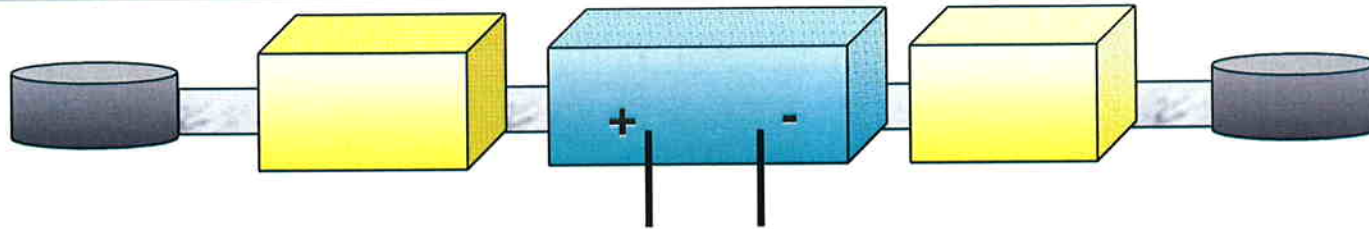
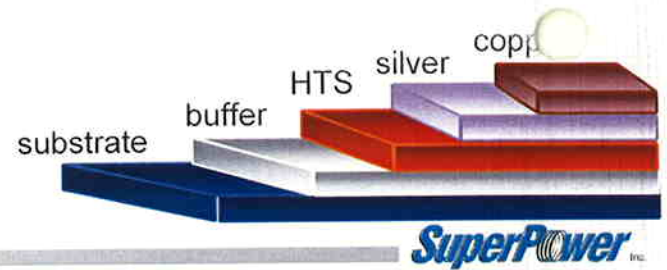


- Highly polished metal substrates
- Robust buffer layer(s) that is biaxially-textured
- High current carrying superconductor layer
- All of the above with very uniform quality in kilometer lengths
- and more....

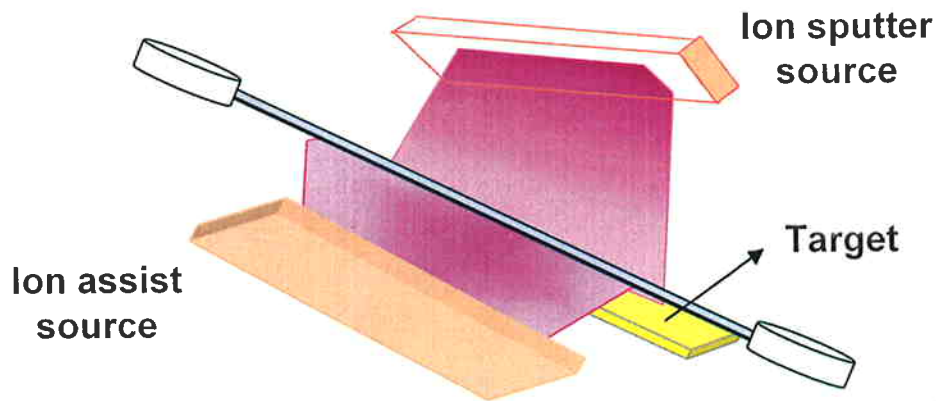




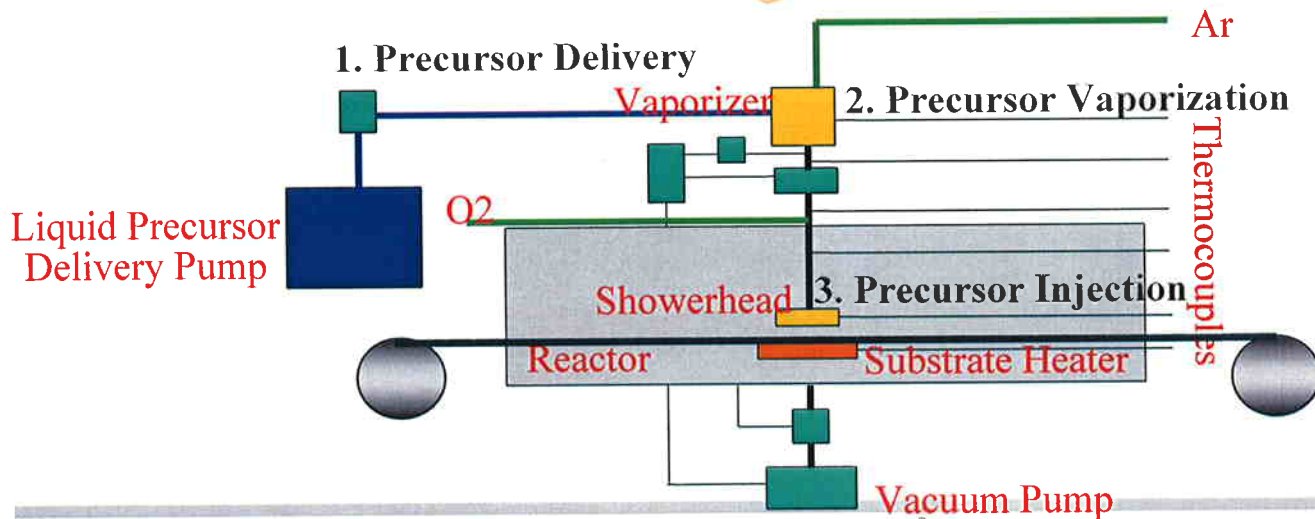
# 2G HTS Conductor Manufacturing at SuperPower: Steps 1 - 3



Metal Substrate  
Electropolishing



Buffer Layer by Ion  
Beam Assisted  
Deposition



HTS Layer by Metal  
Organic Chemical  
Vapor Deposition

# Superiority of IBAD technology



## Virtually any substrate could be used

- High-strength substrates
- Non magnetic substrates
- Low cost, off-the shelf substrates (Inconel, Hastelloy, Stainless Steel)
- Very thin substrates
- Resistive substrates – for low a.c. losses
- Easy to handle – less possibility of defects

## Small grain size – sub micron range

- No issues with percolation
- Can pattern conductor to very narrow filaments for low ac loss conductor



**Pilot IBAD**