PowerFibers - Thin-Film Batteries on Fiber Substrate

Science And Technology For A Better World

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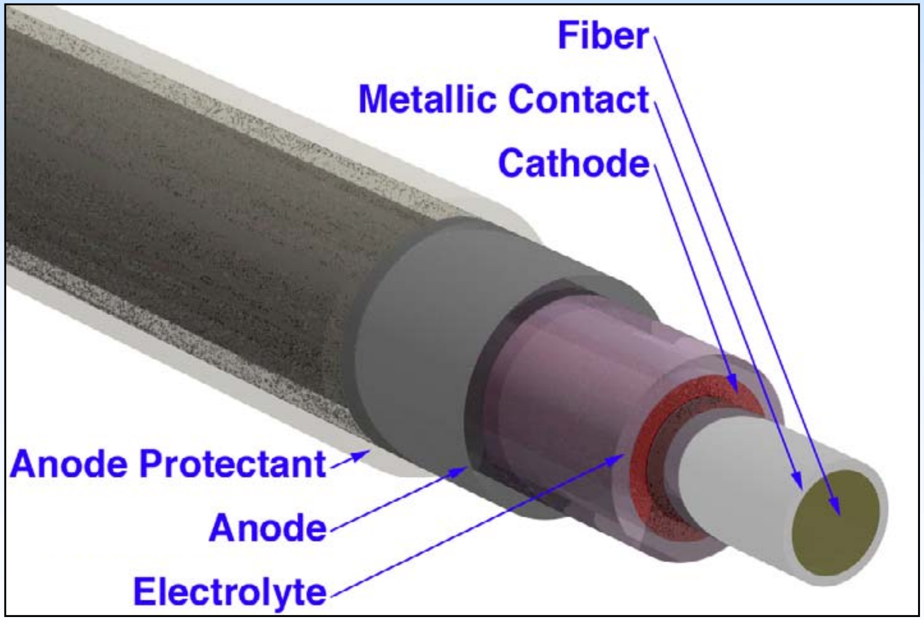
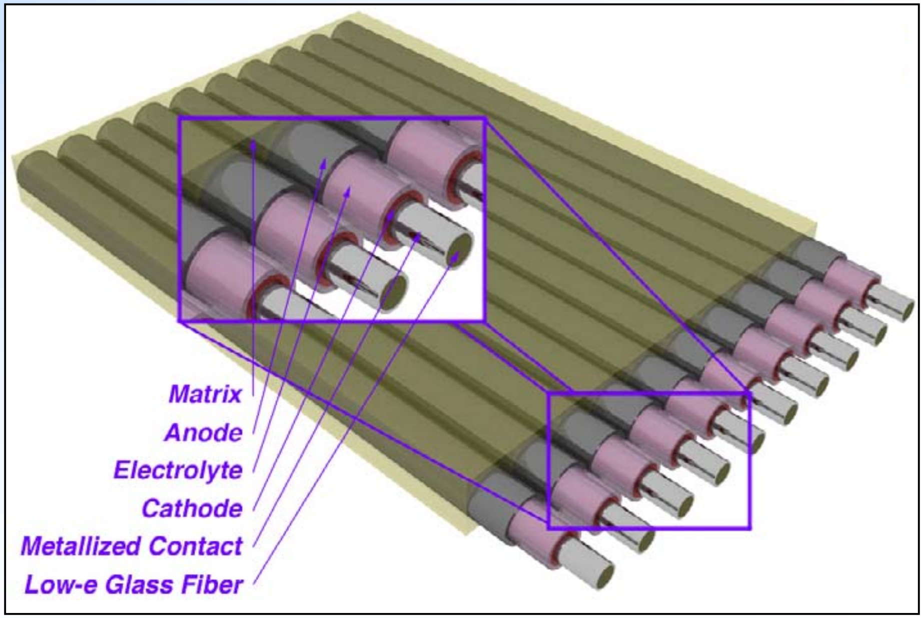
The Concept: PowerFiber ⇨ PowerComposite

- *Objectives:*
  1) Fabricate solid-state thin-film batteries directly onto structural fibers
  2) Incorporate these "PowerFibers" into structural composites and fabrics

"PowerFiber"



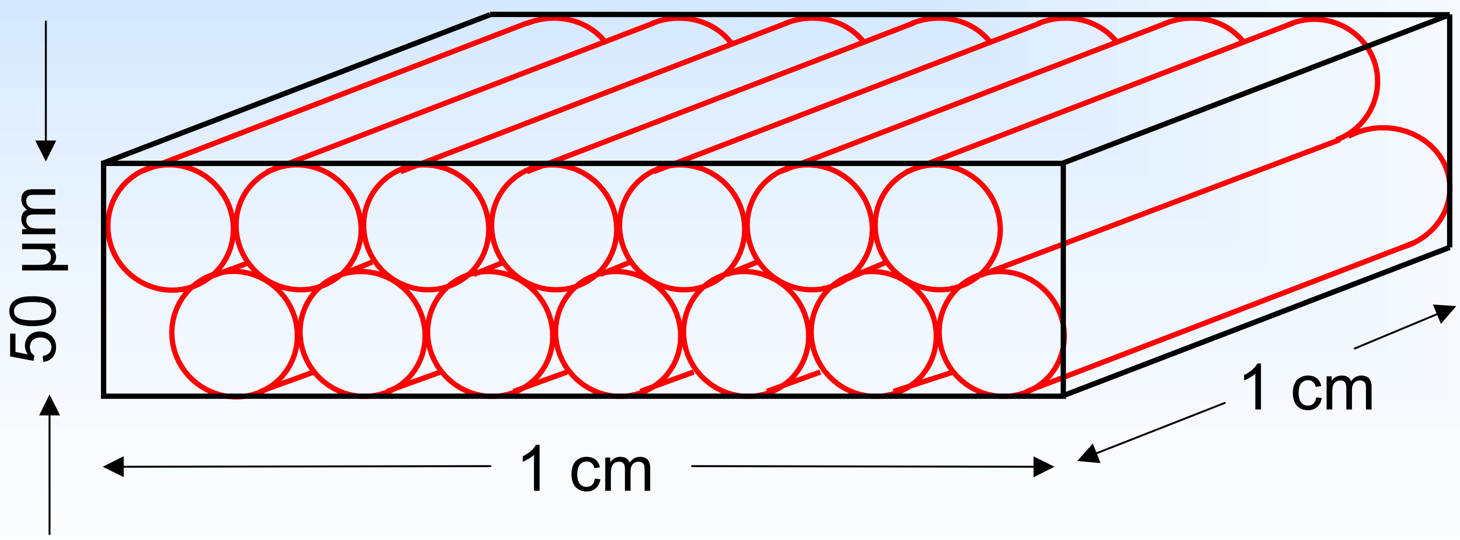
"PowerComposite"



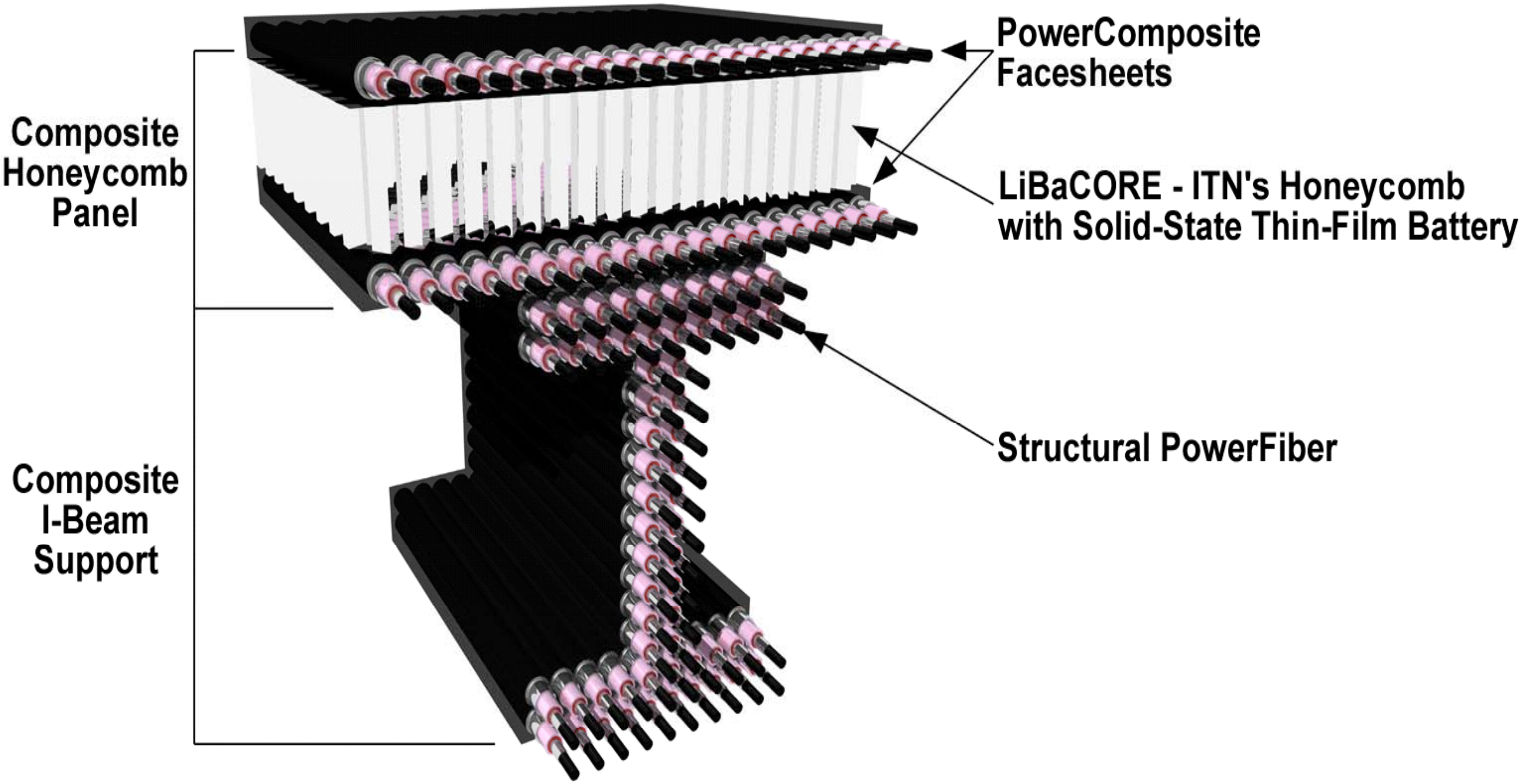
Energy, Power (Thin-Film Batteries) = Proportional to Battery Area !

- ***Substrate Area: Foil vs. Fiber Stack***

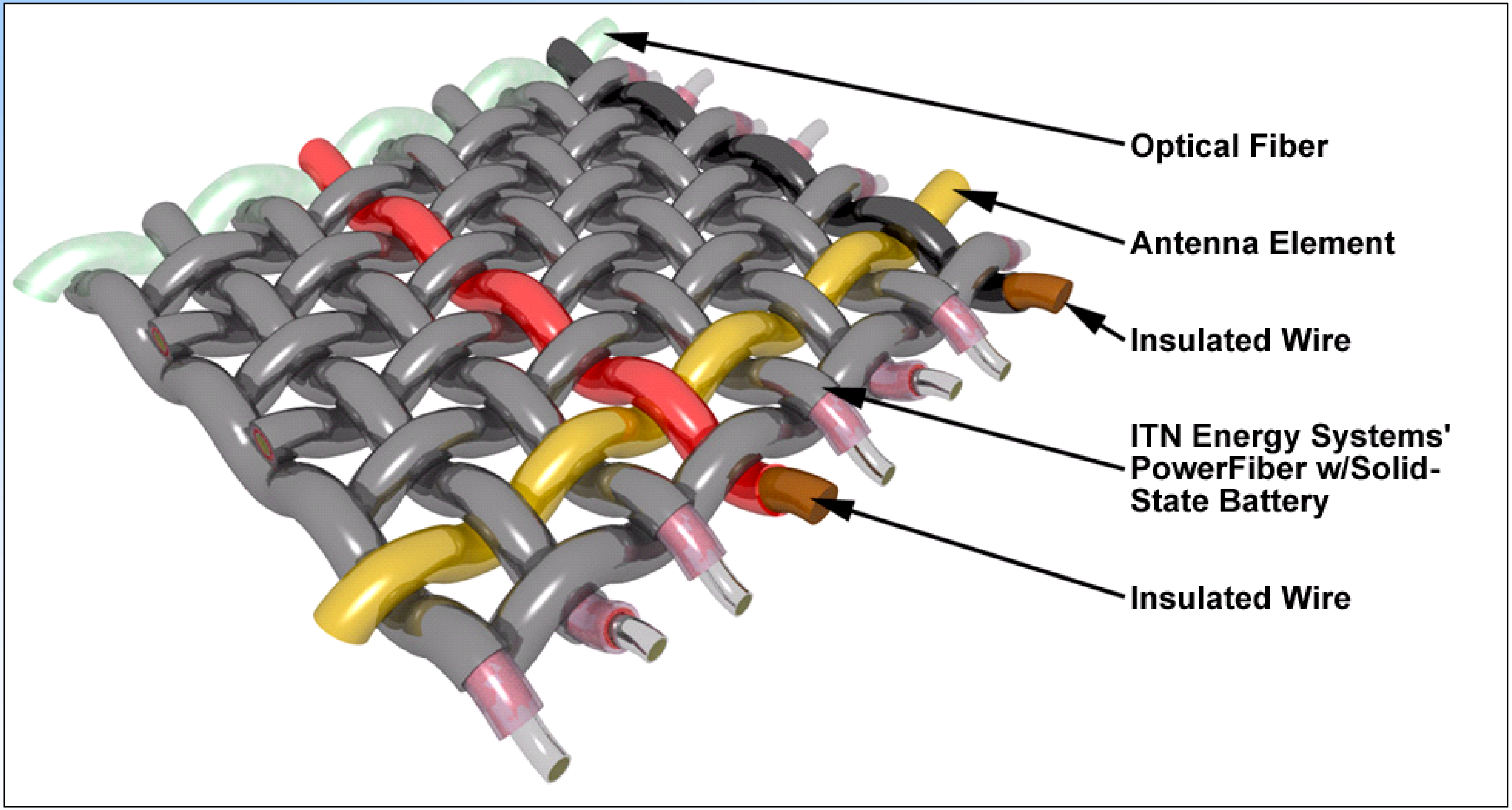
Double-sided foil substrate (50 μm thick)	=	2 cm^2
1 Layer of fibers (50 μm in dia.)	=	3.14 cm^2 (57% more area)
2 Layers of fibers (25 μm in dia.)	=	6.28 cm^2 (214% more area)
3 Layers of fibers (17 μm in dia.)	=	9.42 cm^2 (371% more area)



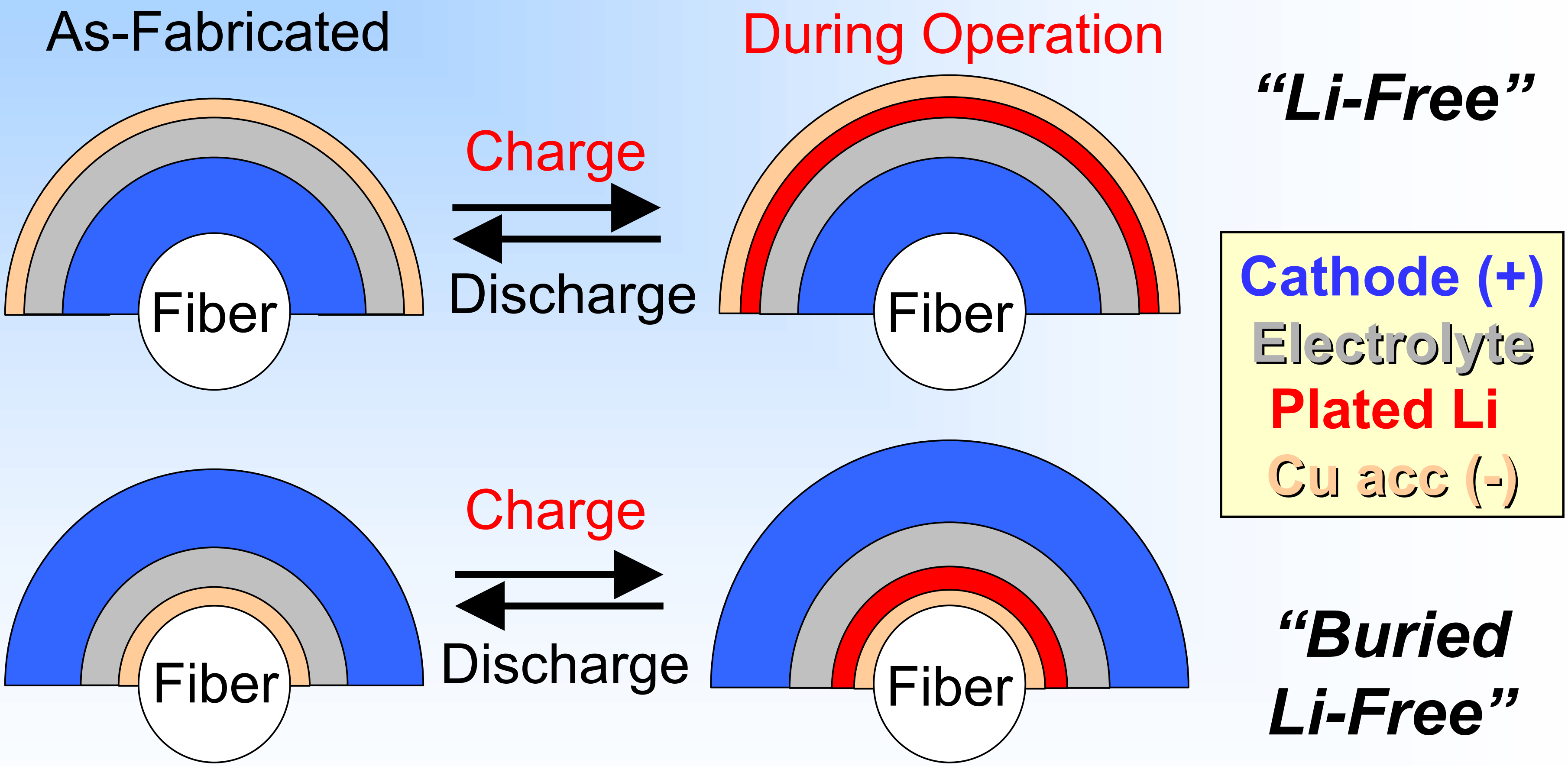
PowerComposite Applications



ITN's ElectroTextiles Concept: PowerFiber ⇨ PowerWeave

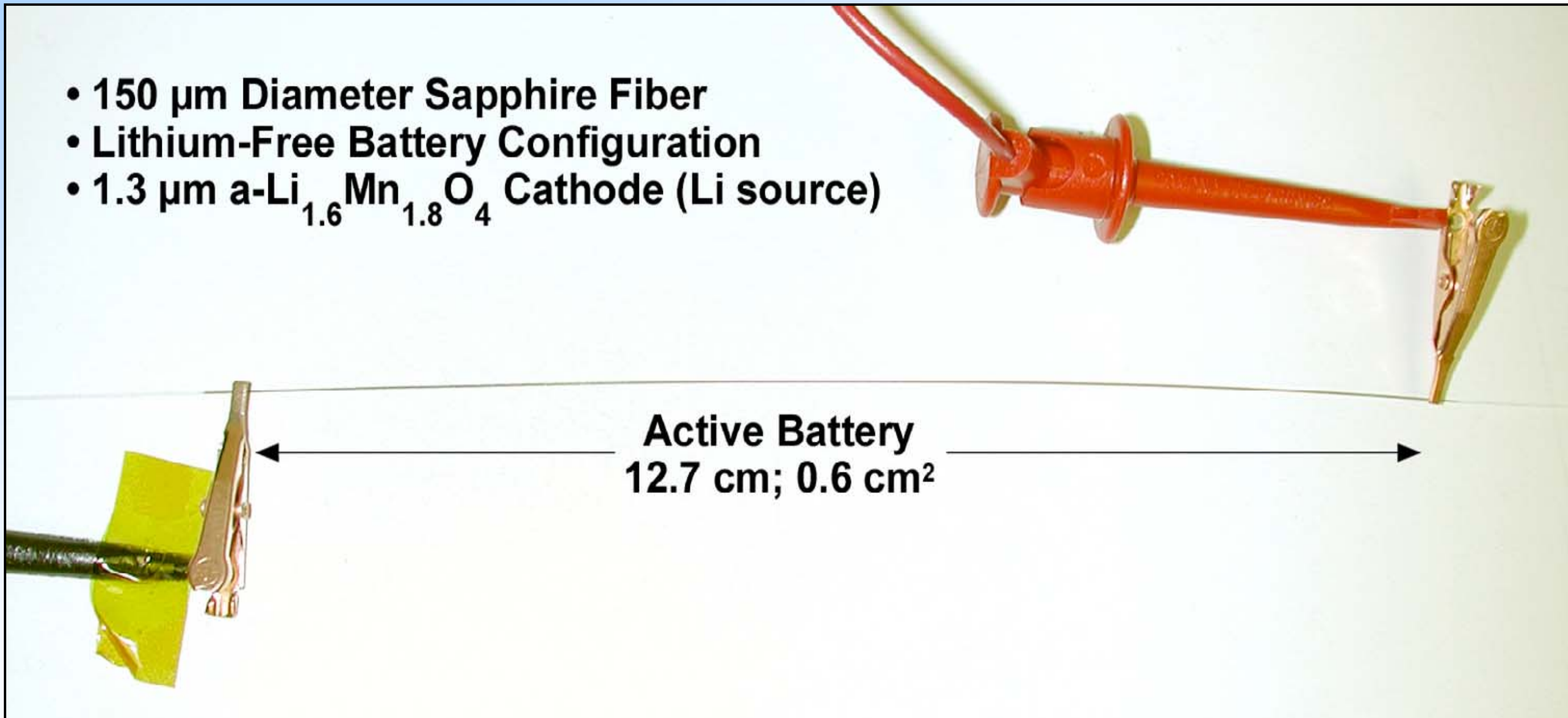


"Li-Free" Battery Configurations
Cathode (+) = Only Initial Li Source

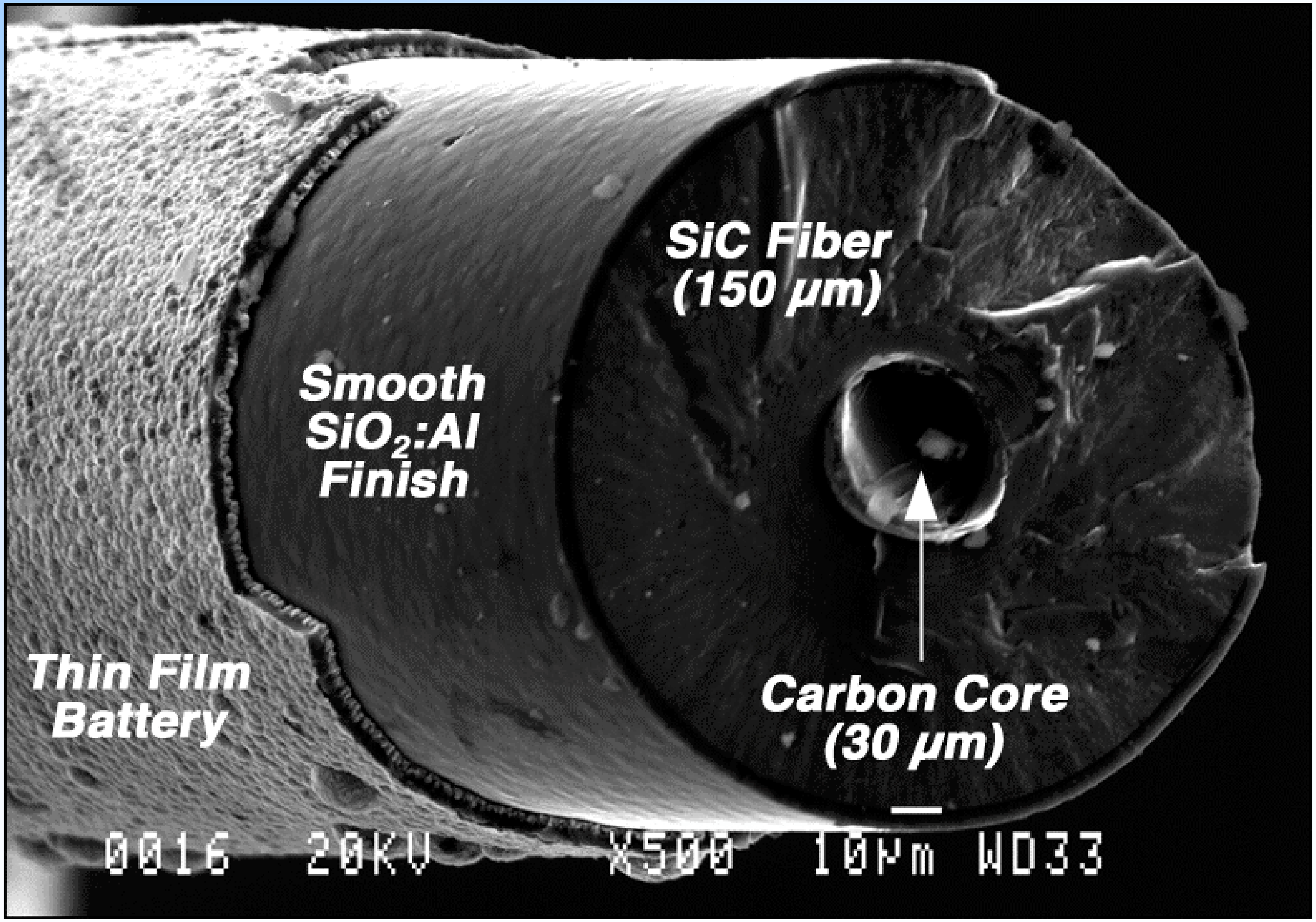


"Li-Free" PowerFiber on Sapphire - Electrochemical Testing -

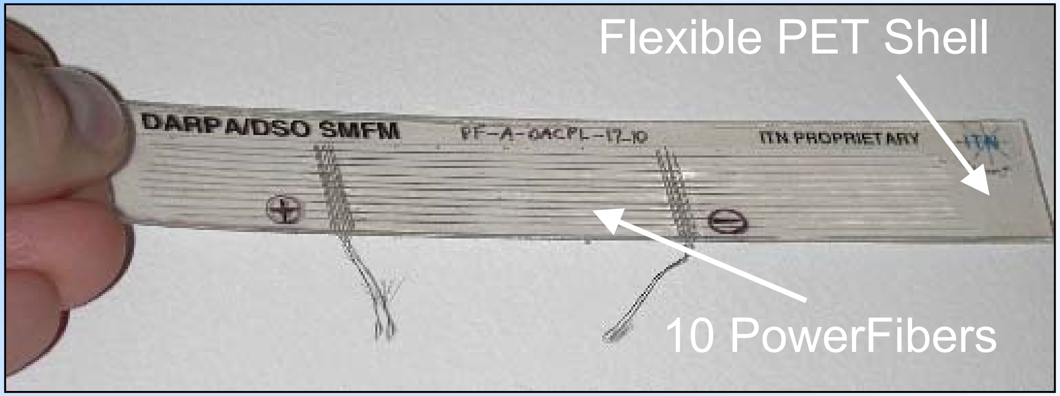
- *First PowerFiber (February 2001)*

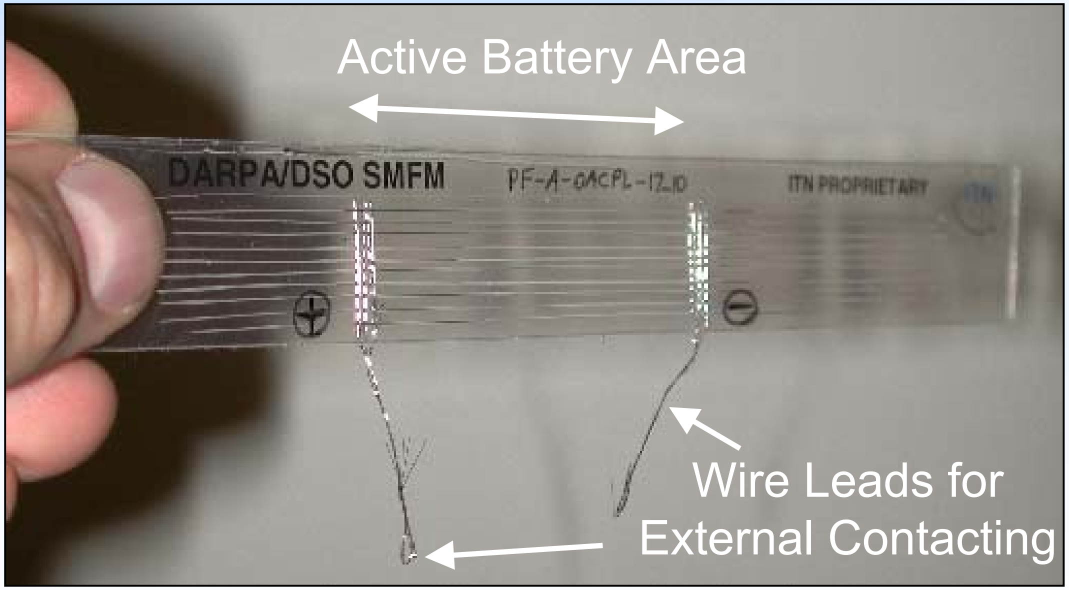


SEM Micrograph of "Buried Li-Free" PowerFiber on SiC Fiber

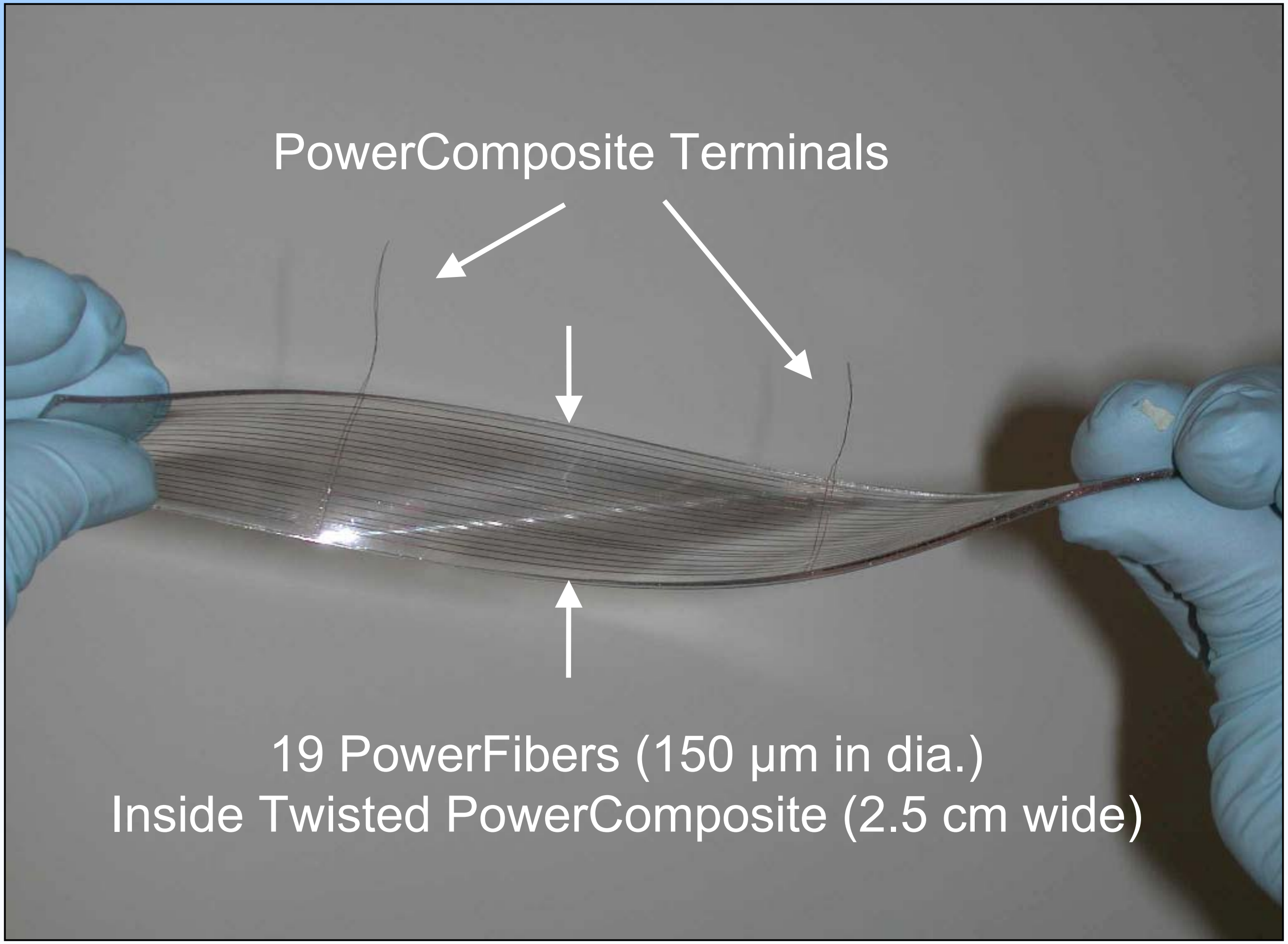


PowerComposite with 10 PowerFibers inside PET Matrix

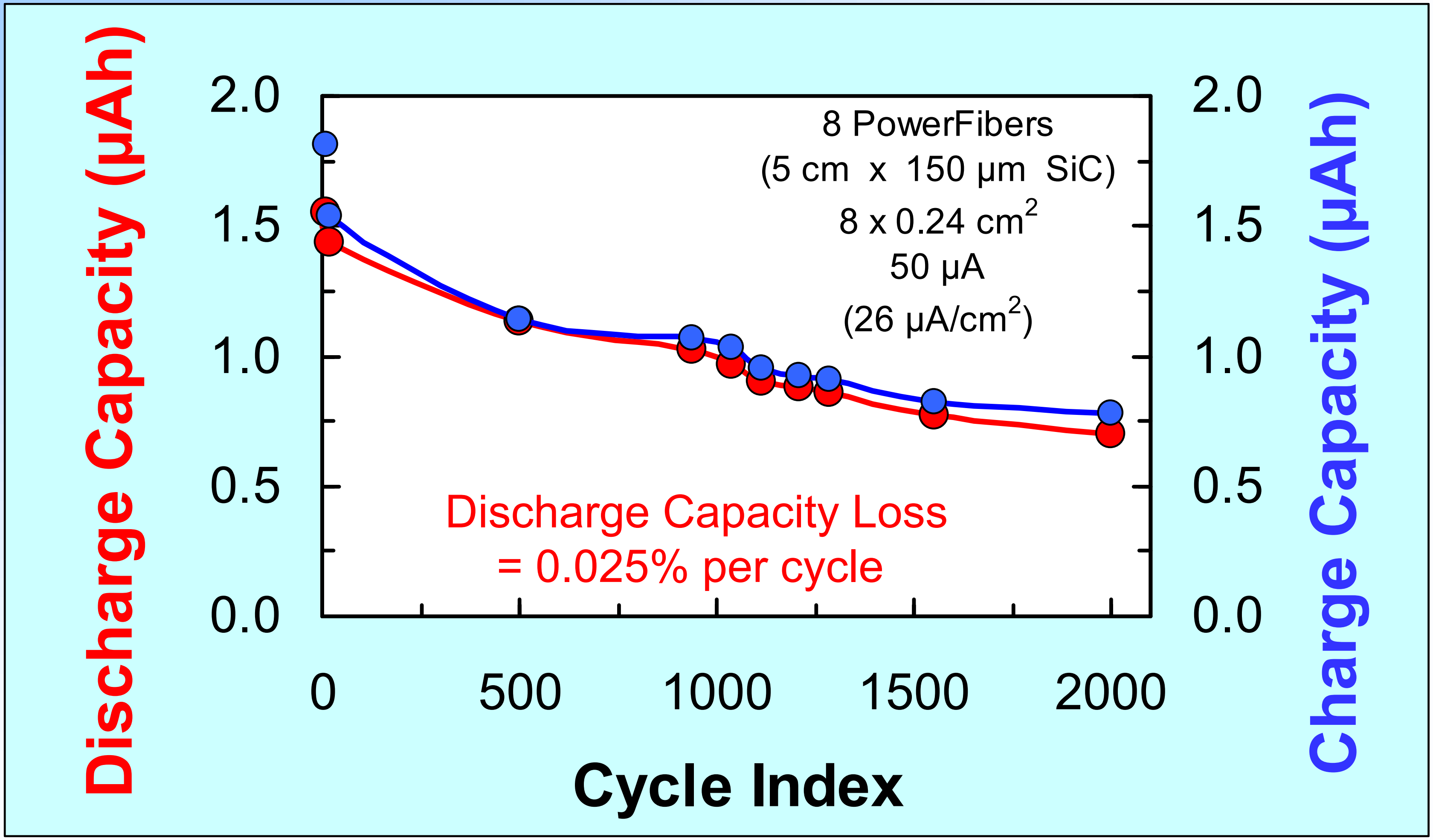




PowerComposite: Electrochemical Testing under Deformation



PowerComposite ("Buried Li-Free" with $Li_2V_2O_5$ Cathodes)



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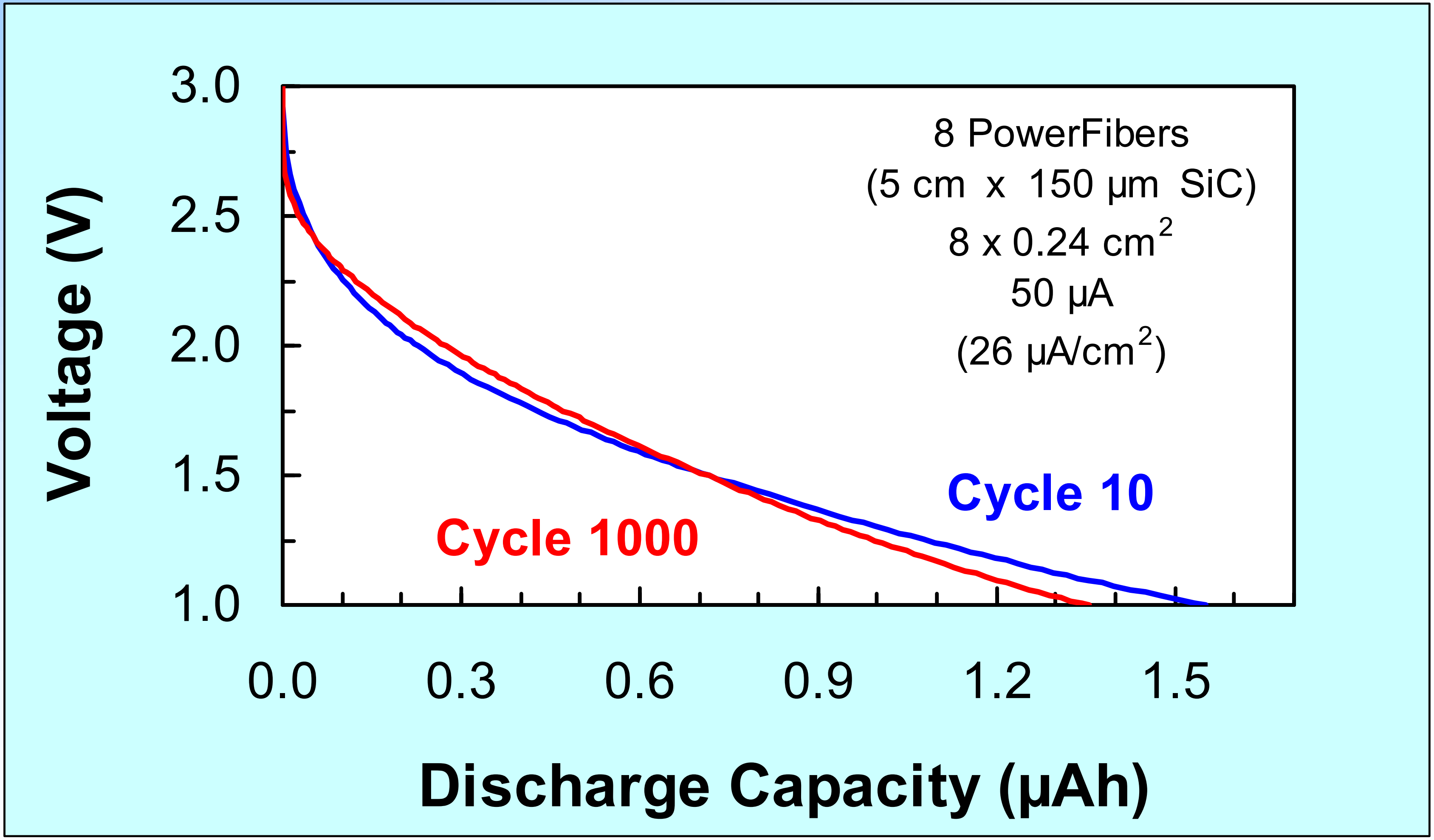


PowerFiber Cathodes

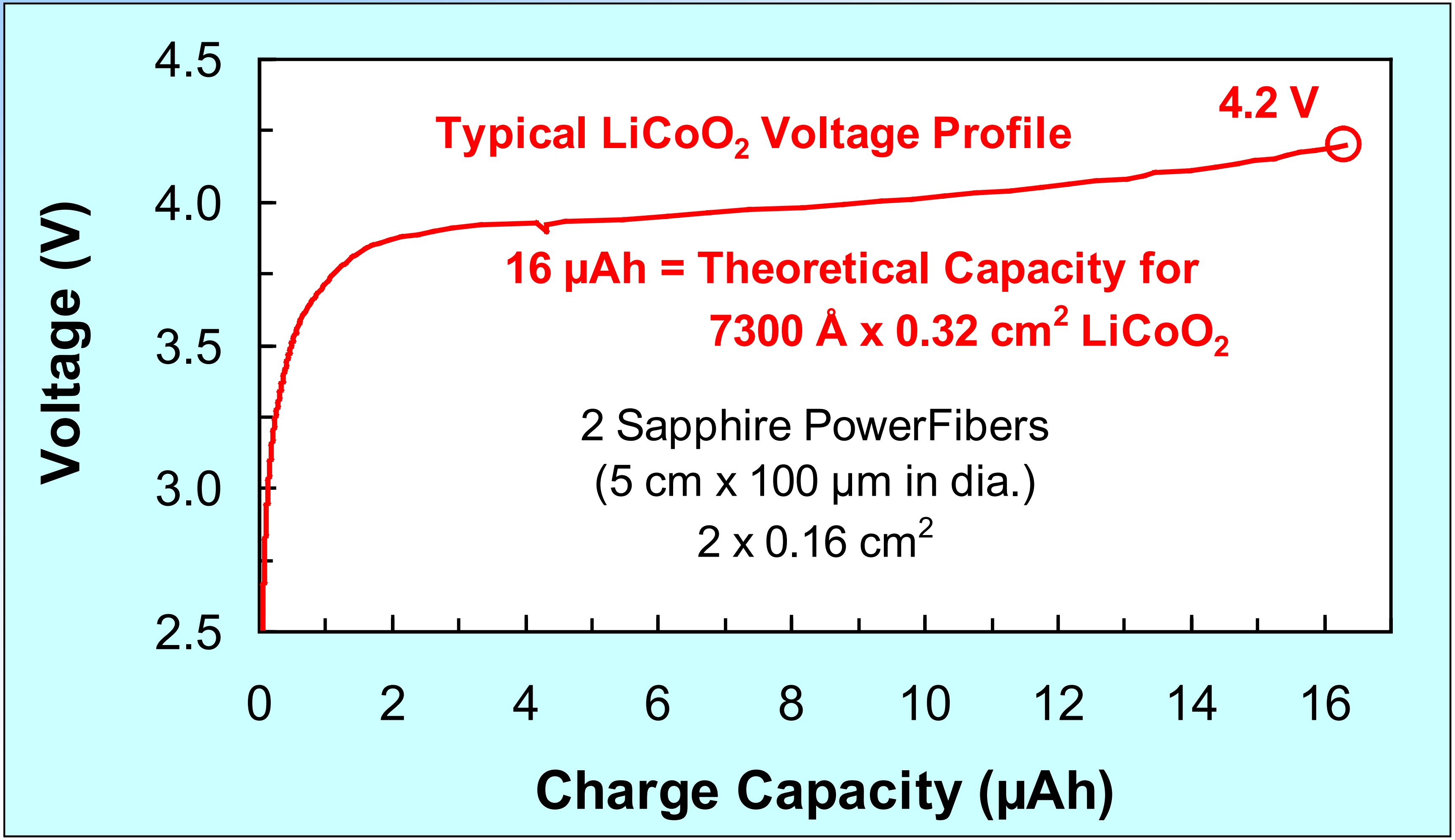
ITN ENERGY SYSTEMS INC.

- ***Cathodes (+) Determine Energy and Power !***

  Also: Voltage, Power, Weight, and Volume

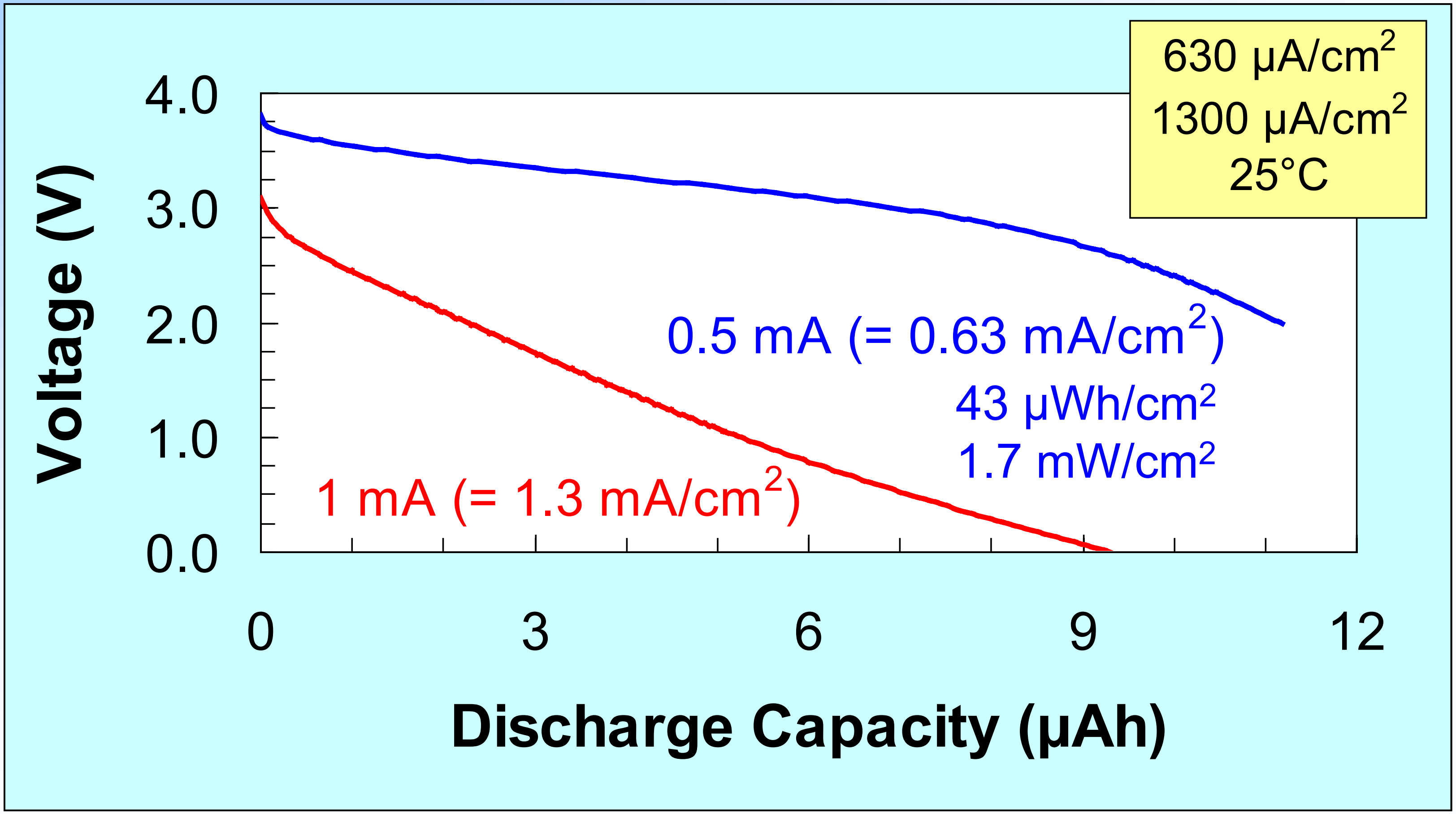
Year	**Cathode Material**	**Relative Discharge Energy @ > 1 mA/cm²**
2001	amorphous $Li_{1.6}Mn_{1.8}O_4$	1
2002	amorphous & crystalline $Li_xV_2O_5$	10
2002	**crystalline $LiCoO_2$**	**> 100**

PowerComposite: "Li-Free" and $LiCoO_2$ Cathodes



PowerFiber Rate Capability: "Li-Free" and $LiCoO_2$ Cathodes

- *1 mWh and 39 mW per 7m (23 feet) PowerFiber (Ø100 µm)*



PowerFiber Technology
Summary – Conclusions – Outlook

- ***ITN's Thin-Film Batteries @ 100% DOD***
  - >2,000 demonstrated for PowerFibers (with challenging "Li-free" !)
  - >90,000 demonstrated for flat configuration (38% overall capacity loss)
  - Battery operation demonstrated between – 45°C to +120°C
  - Battery life-time commensurate with device life-time
- ***Very Safe Inorganic Battery Technology***
  - No fuming, no outgassing, no burning, no explosion, no thermal runaway
  - Only limited local heat generation in case of accident
    - Small battery mass per unit length of fiber
  - Controlled heat dissipation in PowerFiber network
    - Vastly spread-out heat sink
- ***Payoffs for Space and Aviation Applications***
  - Spacecraft structure itself becomes a battery (increases payload)
  - Distributed power storage (power structure is "everywhere" in space bus)

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