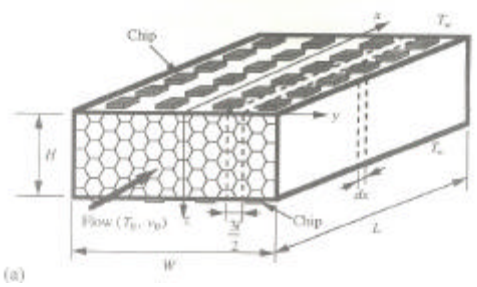
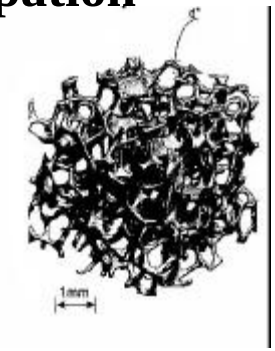
Heat Transfer Capabilities for Open Cell Metal Foams & Micro-Honeycombs Comparable, Offer Orders of Magnitude Improvement in Heat Dissipation



VS

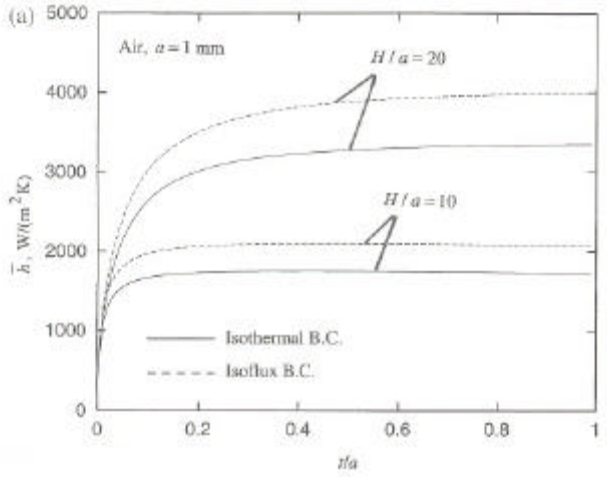


$$\frac{\bar{h}}{\lambda_s/a} = \left(\frac{6c\lambda_f}{\lambda_s}\frac{t}{a}\right)^{1/2} \tanh\left[\frac{H}{a}\left(\frac{3\lambda_s}{2c\lambda_f}\frac{t}{a}\right)^{-1/2}\right]$$

- Laminar flow
- High surface area/ volume
- h comparable to foams

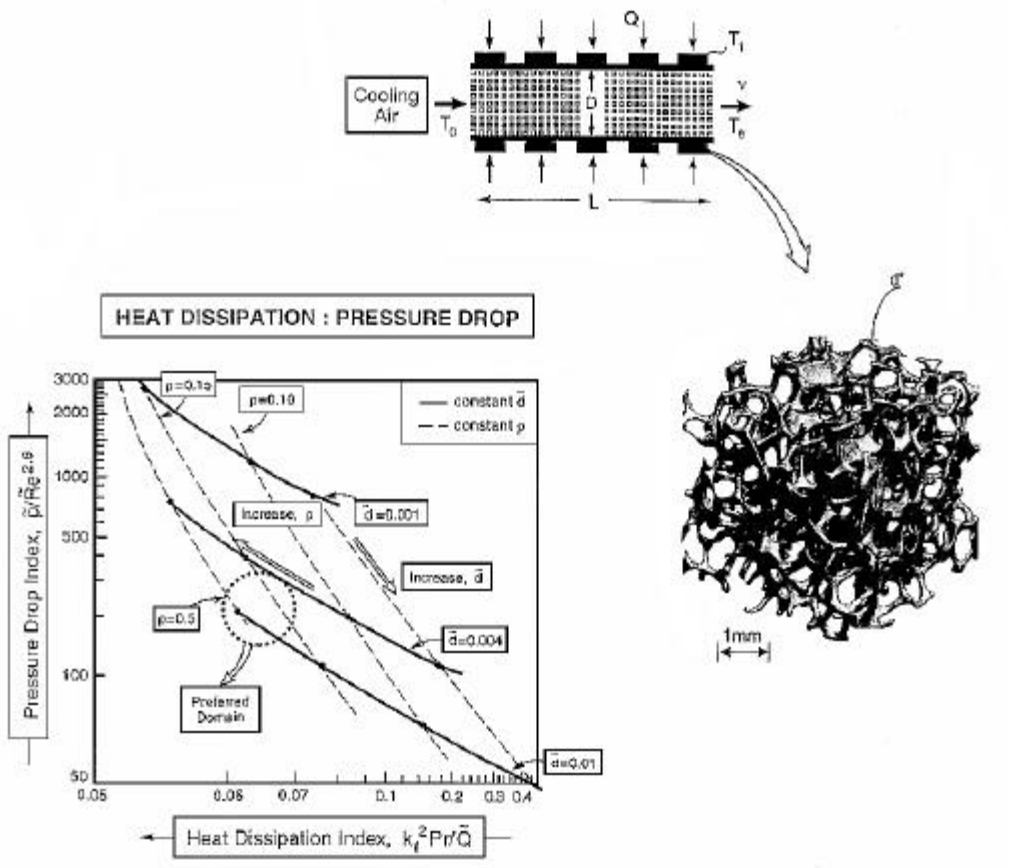
$$\frac{\bar{h}_{foam}}{\lambda_s/a} = 1.682\left(Pr^{1/3}\frac{\lambda_f}{\lambda_s}\right)^{1/2}\left(\frac{v_0 a}{\nu_f}\right)^{0.3}\frac{\rho^{1/2}}{(1.535\rho^{-1/2}-1)^{0.3}}$$

- Turbulent flow
- Smaller surface area/ volume
- h comparable to micro-honeycomb



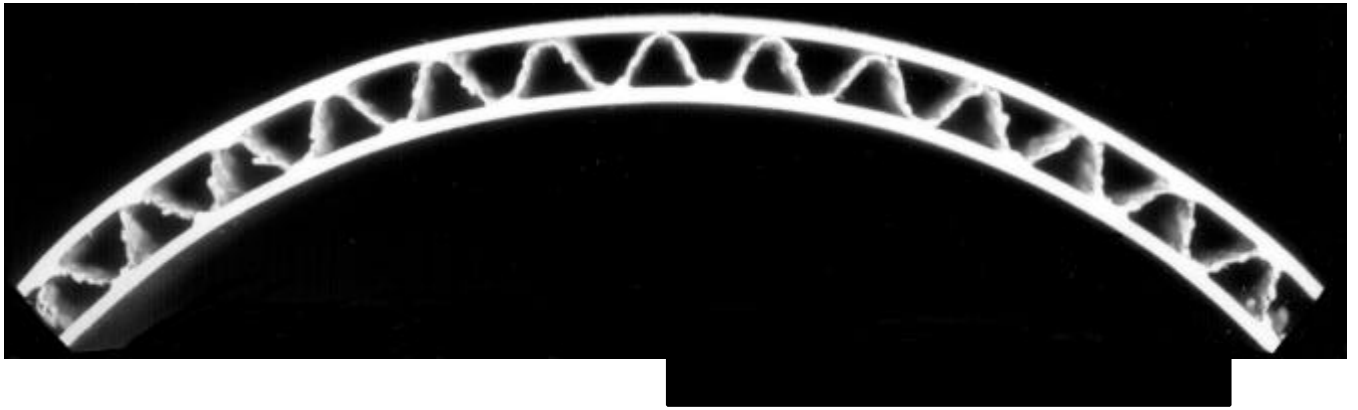
$\bar{h}$ typically ~10 W/m K
for air cooling and ~10^2 W/m K
for water cooling in duct
consisting of parallel plates!

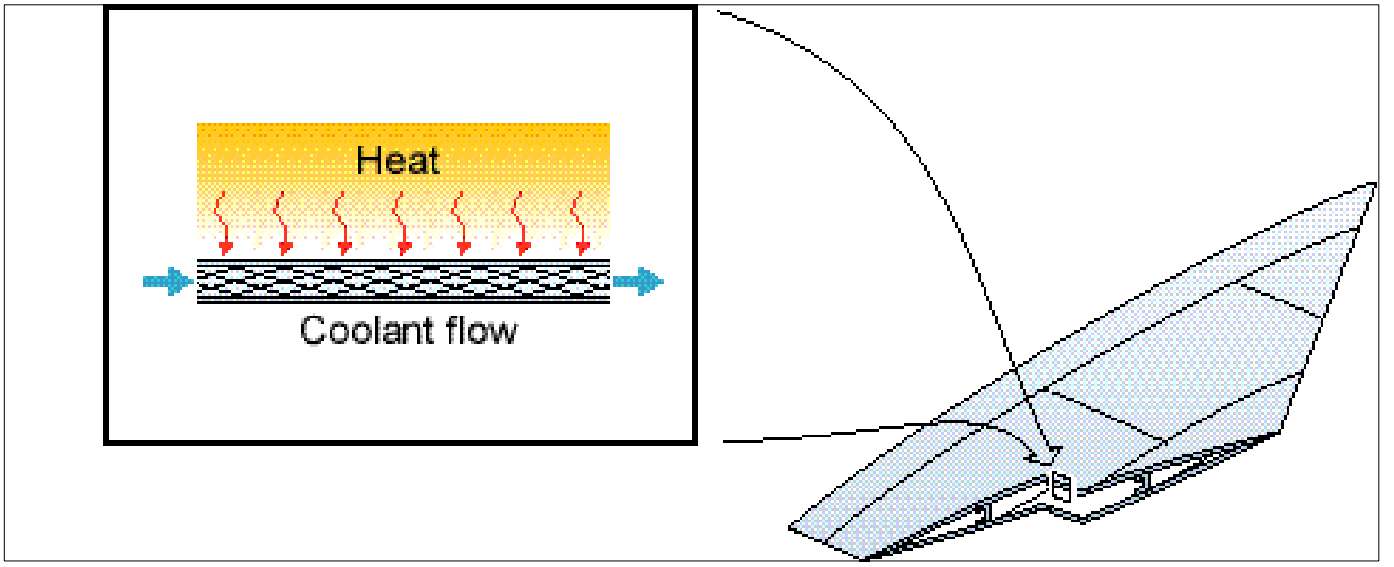
Ultralight Porous Metals
10X Reduction in Heat Sink Size
High Power Electronic Cooling



- **Basic Trends Between Cell Morphology and Heat Dissipation Established**
- **High K, Large Surface Area, Turbulence => Larger H**
- **High Thermal Mass Fluid, Designed Foams => Larger Q**
- **Compact High Flux Cooling:**
  - **Motor Drives**
  - **PEBB**
  - **TPS**
  - **Heat Exchangers**

Flexible, Low Cost Fabrication Method Suitable for Open-Celled Structures Based Upon Textile Technology, Transient Liquid Phase Sintering





Future Opportunities for High Efficiency Porous Metal Heat Exchangers

EA-6B
ICAPIII Avionics Upgrade
Jamming Pod Cooling

F-18

JSF

Commercial

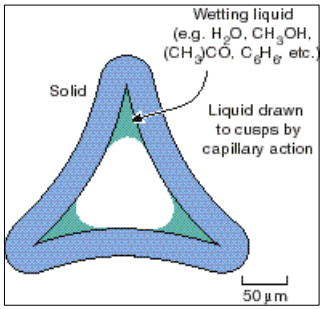
F-18/JSF/Commercial AC
Improved Cooling Systems
Greater Capacity/Lower Weight and Size

- **30% Lighter**
- **40% Smaller**
- **10% Less expensive**
- **Integrated Design**

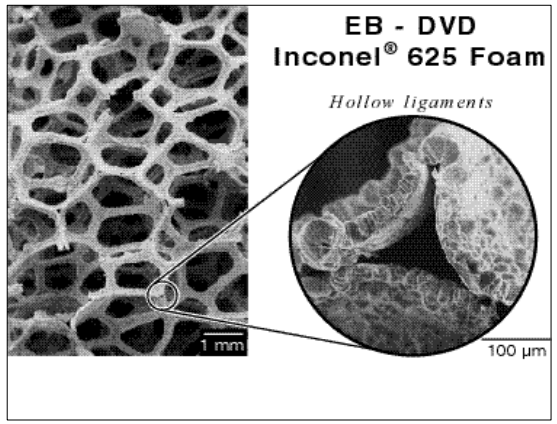
Global Hawk
High Altitude Cruise
Avonics Heating

AN EMERGING MATERIALS BREAKTHROUGH: SUPERTHERMAL CONDUCTORS AND HEAT EXCHANGERS

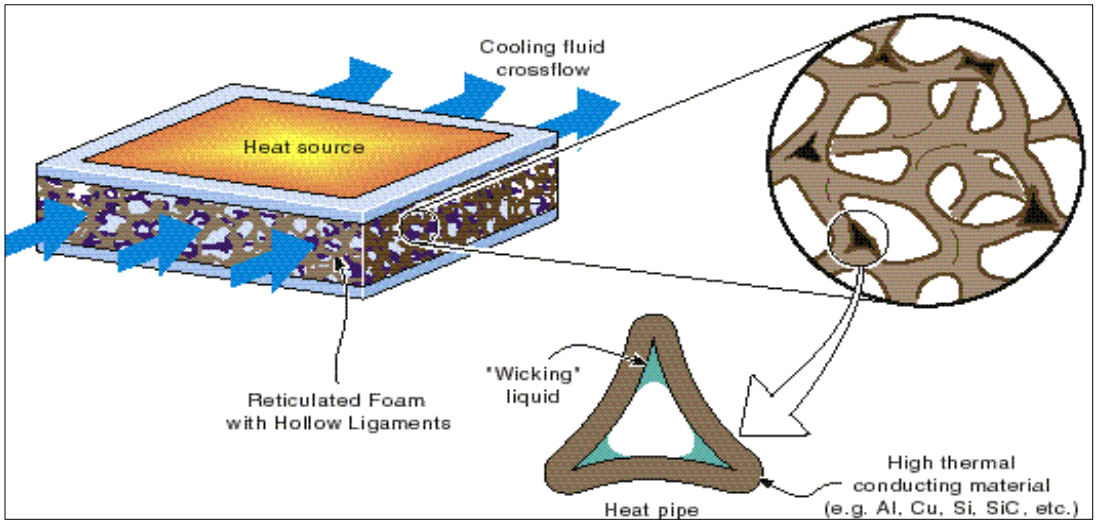
A Microheat Pipe



Heat transported by Evaporated &Conducted Heat Flux (out of plane). 10x improvement.

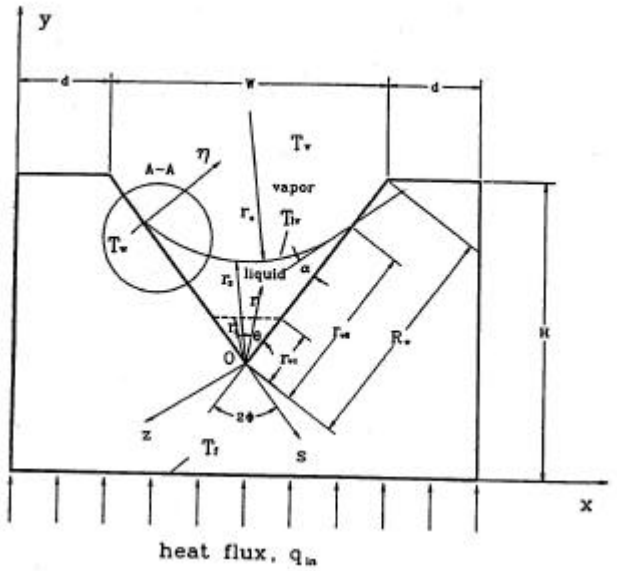


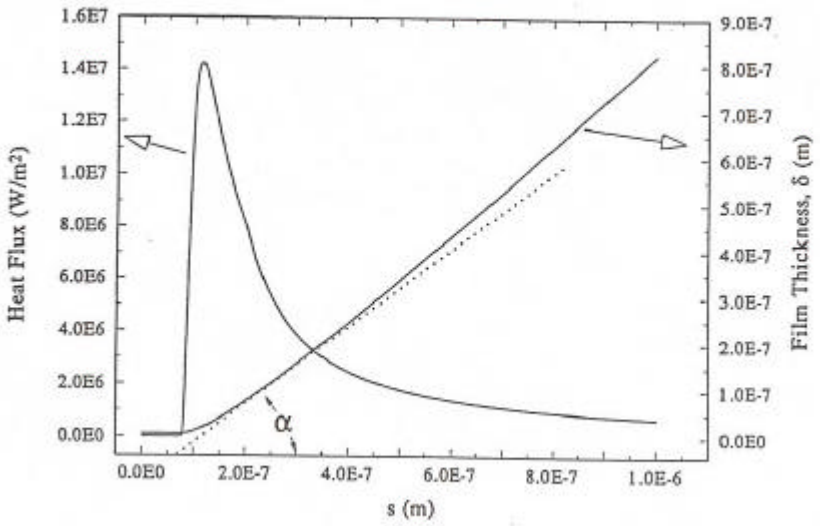
Three - dimensional “SUPER” Thermal Heat Exchanger



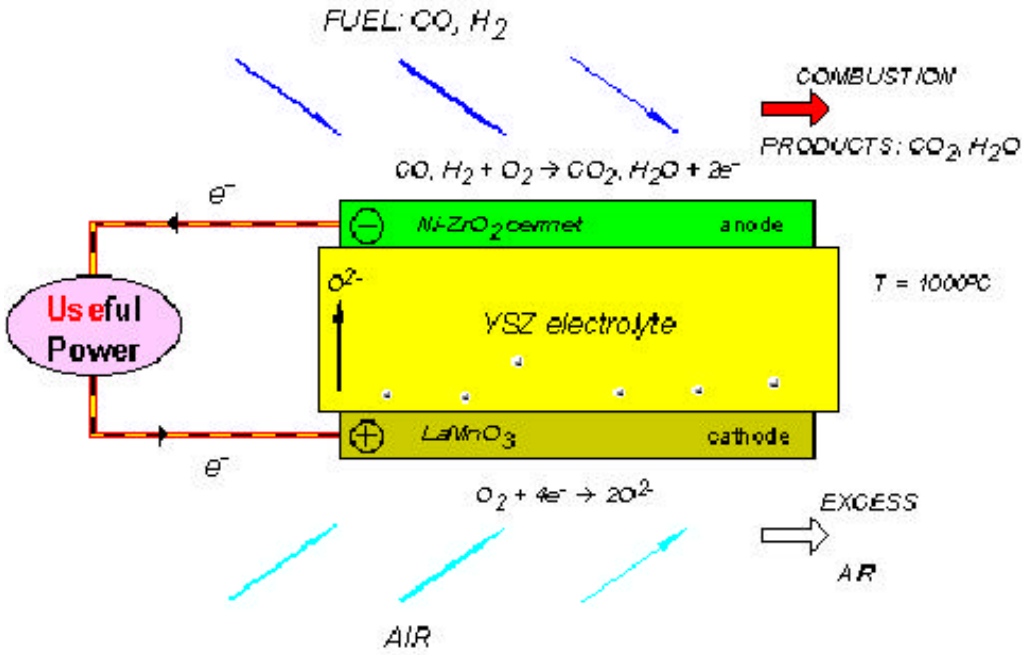
UVA, H.N.G. Wadley

Transport Properties in Nanothick Films Enabling Technology for Next Generation Electronics, Power Devices, Microvehicles



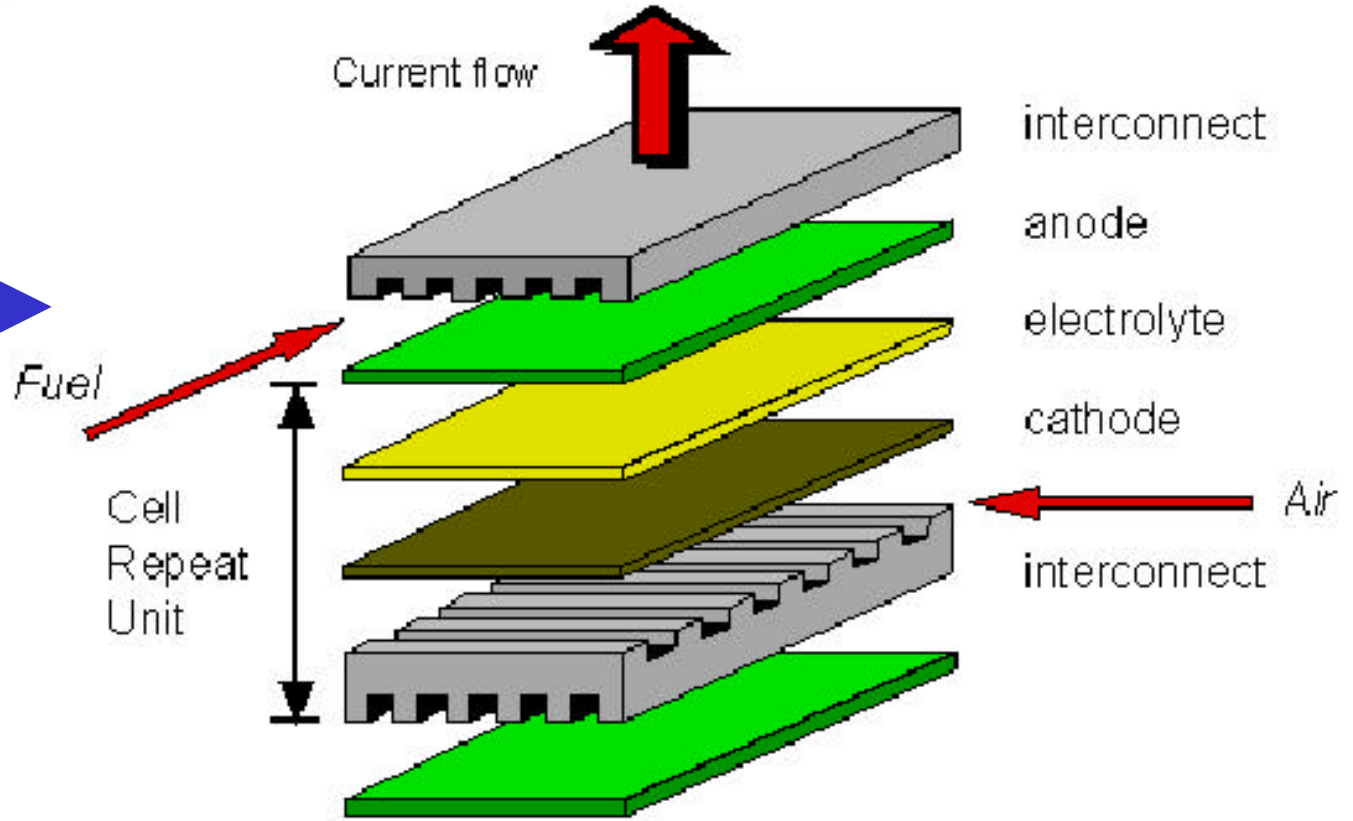


- Capillary flow/ effective K_T / permeability relations
- Fluid flow/ evaporation mechanisms in nanothickness liquid film regions
- Optimization of size, shape and number of “interline” regions for significantly enhanced heat transfer
- Cost-effective fabrication technology



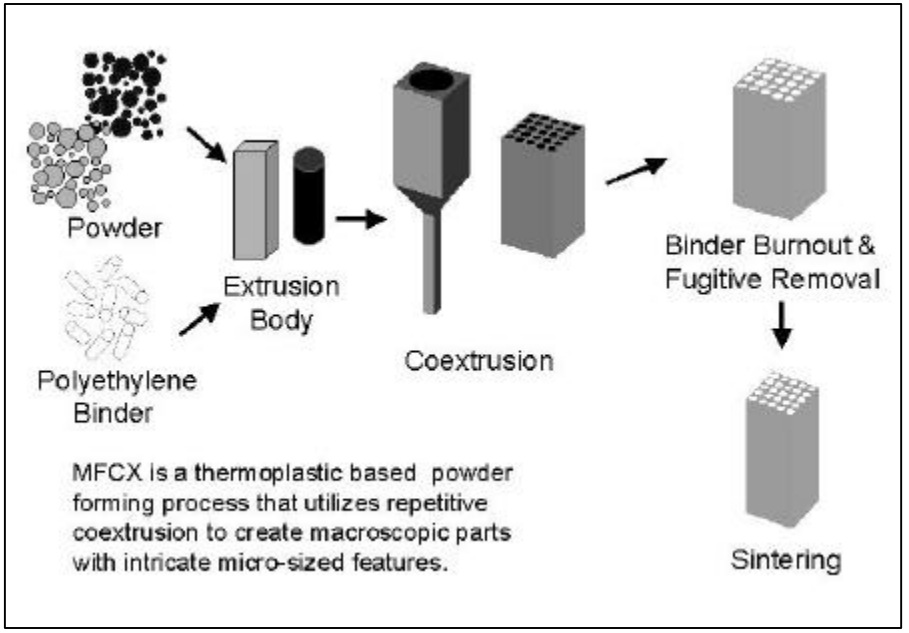
YSZ Electrolyte SOFC

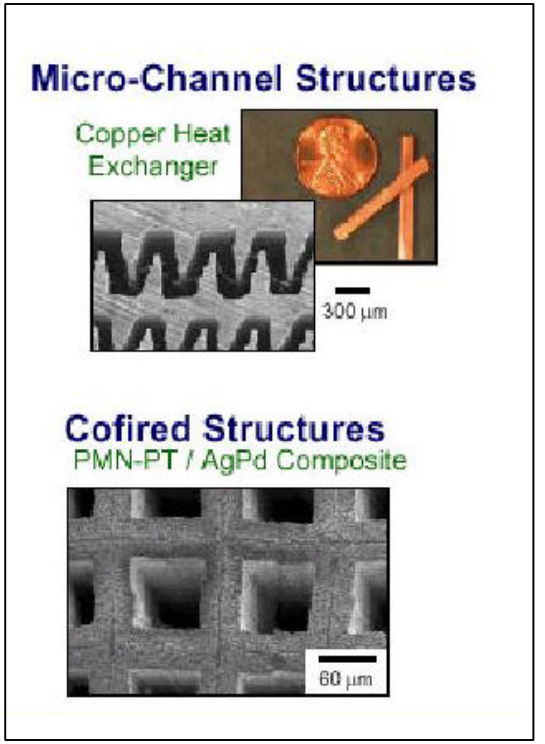
Conventional Planar Operation SOFC



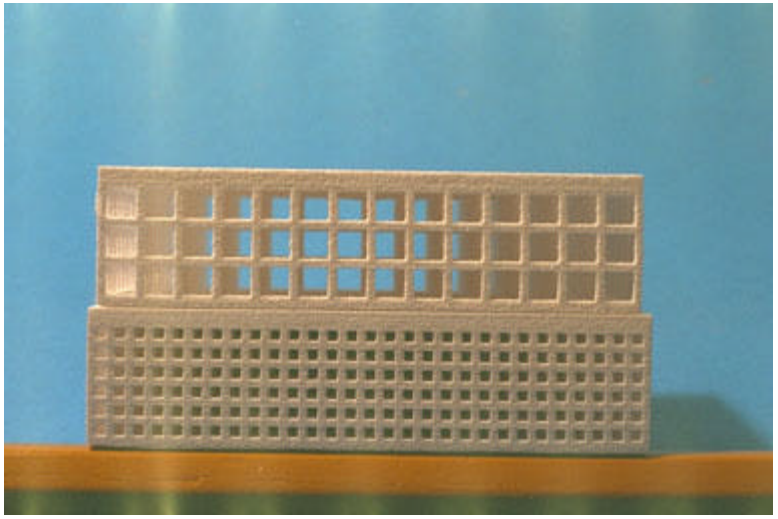
Coextrusion Technique for Fabrication of Microsized Multifunctional Devices

J. Halloran, U Mich

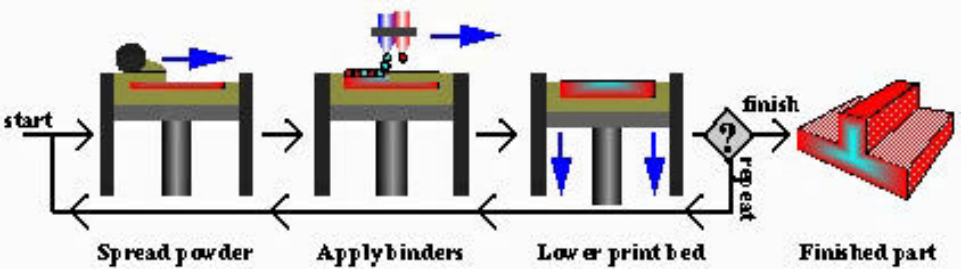


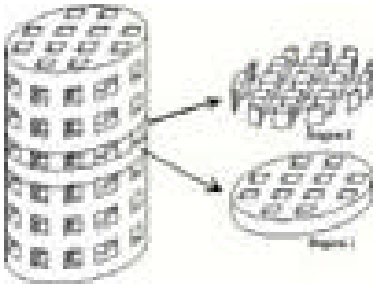


3-D Printing, (MIT)
(tool for building with complexity)

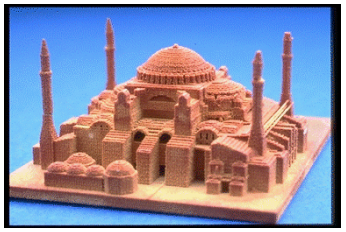


3-D Printed lattice structure

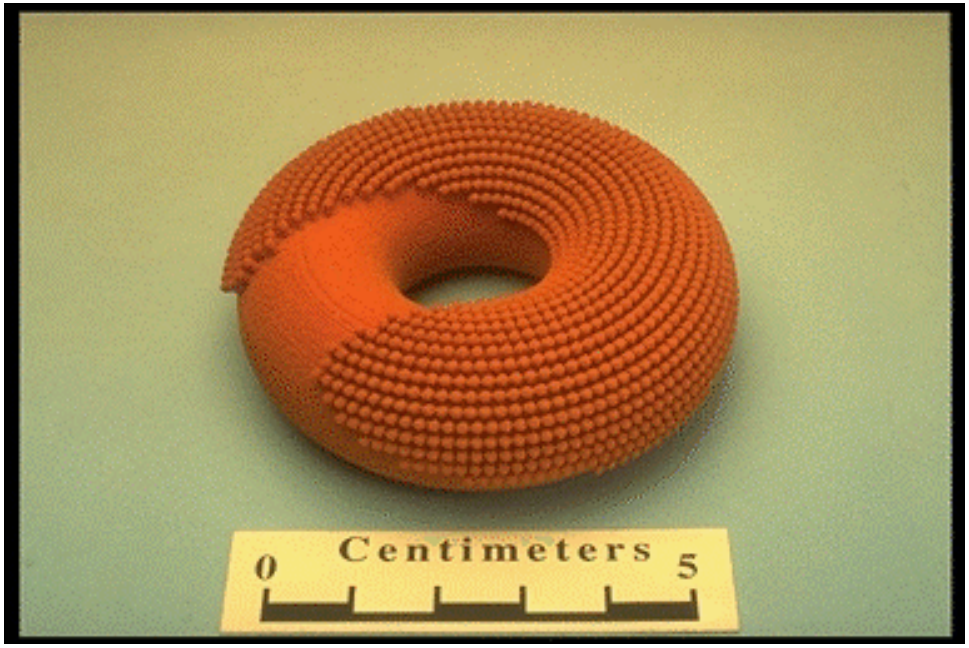




Rat femur bone



Haj Sophia



Donut printed with surface texture

The Father of SFF