Nanomaterials for Advanced Life Support in Space systems

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Topic Outline

- Introduction
  - Nanomaterials research at NASA JSC
  - Focus on carbon nanotubes
- Research and accomplishments in CO_2 removal
  - Current Technology
  - Goals
  - Results
- Research and accomplishments in water purification
  - Current Technology
  - Goals
  - Results
- Next Steps

Nanomaterials: Fundamentals to Applications

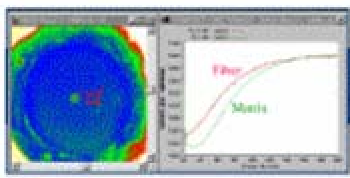
Growth/Production
Laser and HiPco
Production and
Diagnostics

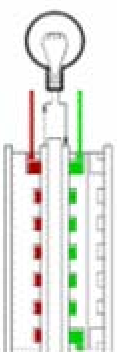
Characterization
Purity, Dispersion, Consistency, Type
SWCNT Load Transfer
Single Fiber Diffusivity

Collaboration
Academia, Industry, Government

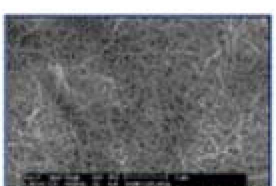
Processing
Purification
Functionalization
Dispersion
Alignment

Applications For Human Spaceflight

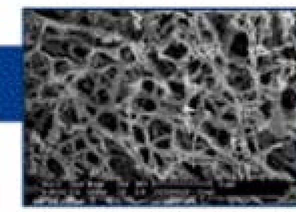

Single Fiber Thermal Diffusivity


Fuel Cells

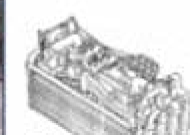

Ultracapacitors (SAFER)


Nanofiltration

APPLICATION	PARTNERS	TRL 1	2	3	4	5
Ultracapacitors	EP, Glenn, Industry	X	X	X	X	
Proton Exchange Membrane – PEM - Fuel Cells	EP, Glenn, Industry	X	X			
RCRS - Regenerable CO_2 Removal System	EC, Ames, Industry	X	X			
Active / Passive Thermal Management Materials	EC, Rice, ORNL, Industry	X	X			
Nanofiltration for Water Recovery	EC, Industry	X	X			
Electromagnetic Shielding Materials (ESD/EMI)	EV, Rice, LaRC, Industry	X	X	X		
Advanced Nanostructured Materials for Thermal Protection and Control	ES3, Ames, Goddard, Industry	X	X			
Radiation Dosimeter	NX, Rice, PV, LaRC, Ames	X				
Nanotube-Based Structural Composites	ES, Rice, UH, LaRC	X	X			


Ceramic Nanofibers (TPS)


High Thermal Conductivity Fabrics

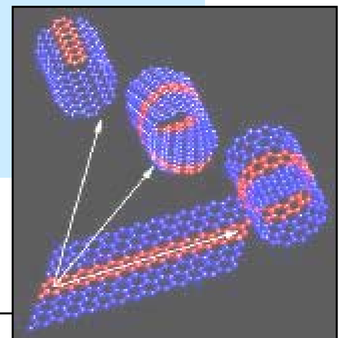

CO_2 Removal

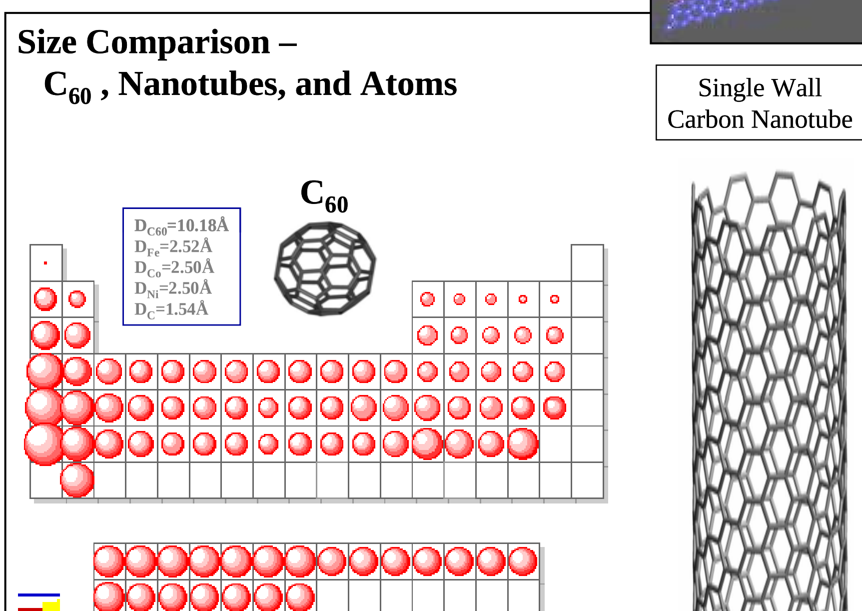
Electromagnetic Shielding

Nanomaterials: Single Wall Carbon Nanotubes

Unique Properties

- Exceptional strength
- Interesting electrical properties (metallic, semi-conducting, semi-metal)
- High thermal conductivity
- Large aspect ratios
- Large surface areas





Possible Applications

- High-strength, light-weight fibers and composites
- Nano-electronics, sensors, and field emission displays
- Radiation shielding and monitoring
- Fuel cells, energy storage, capacitors
- Biotechnology
- Advanced life support materials
- Electromagnetic shielding and electrostatic discharge materials
- Multifunctional materials
- Thermal management materials

Current Limitations

- High cost for bulk production
- Inability to produce high quality, pure, type specific SWCNTs
- Variations in material from batch to batch
- Growth mechanisms not thoroughly understood
- Characterization tools, techniques and protocols not well developed

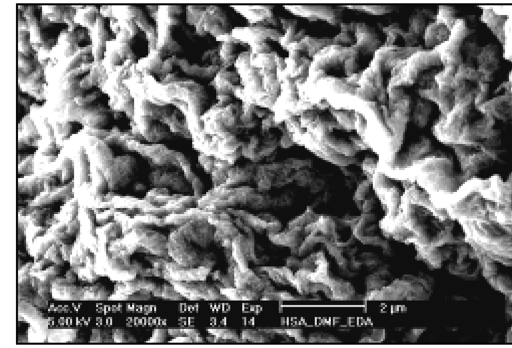
Air Revitalization using Carbon Nanotubes

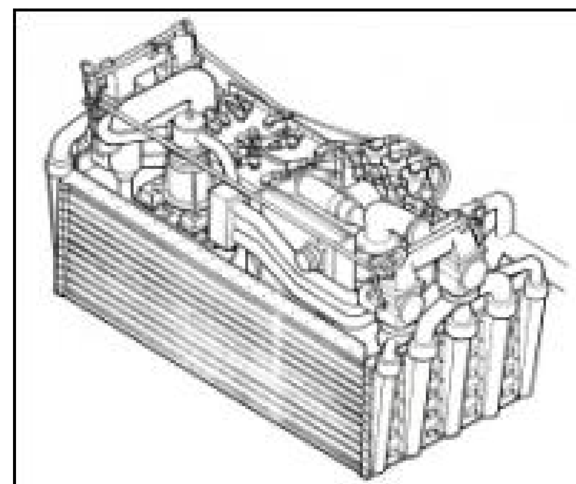
- CNTs have useful properties that make them suitable for use in regenerable adsorbent technologies
  - High surface area and porosity – more adsorbent in less volume
  - Thermal conductivity – useful for thermal regeneration of packed beds
  - Chemical inertness along with potential functionality – the support phase can be bonded to scrubbing polymers such as amines

Initial Results and Technology Assessment

2004 Results

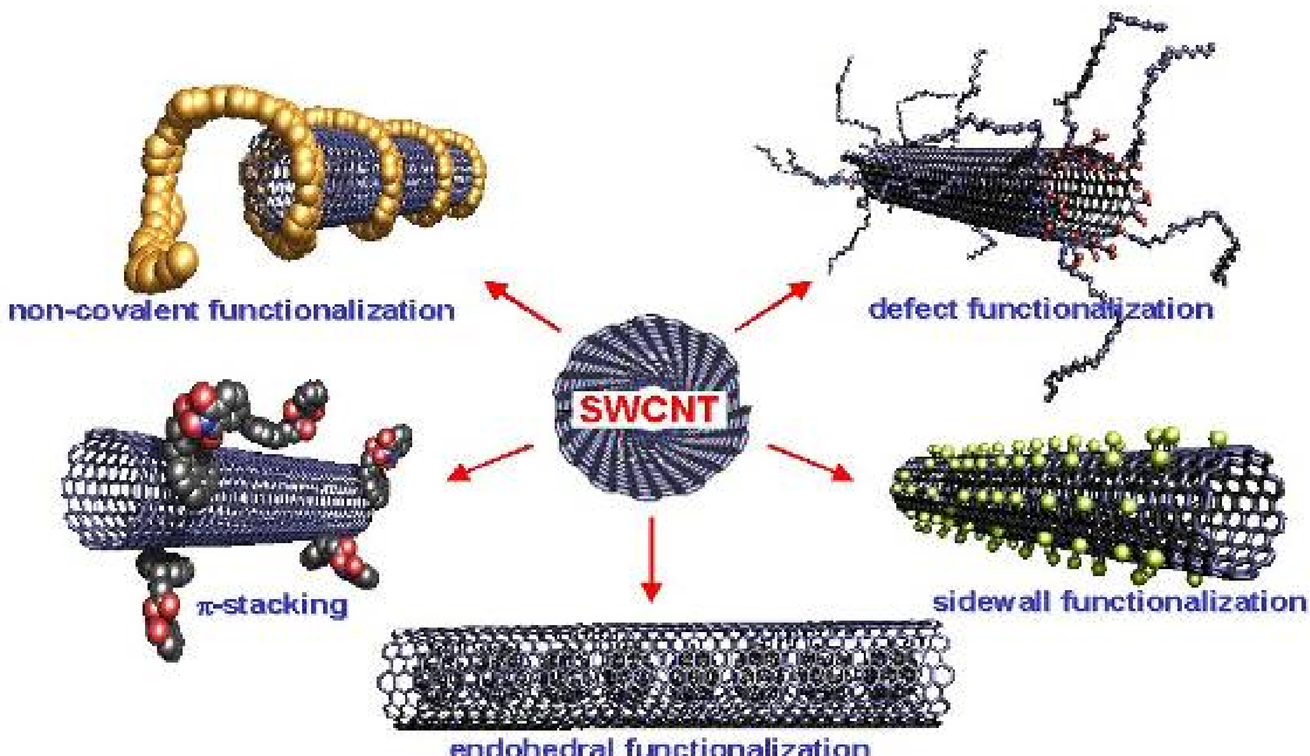
- Carbon Nanotubes have high surface area: bucky pearls, fibers, bucky paper
- TGA experiment: the amine is reactive with the CO_2 gas stream
- Poor adherence to nanotube surface - requires a specific pore size and shape
- We need a better way to integrate the support phase with the amine





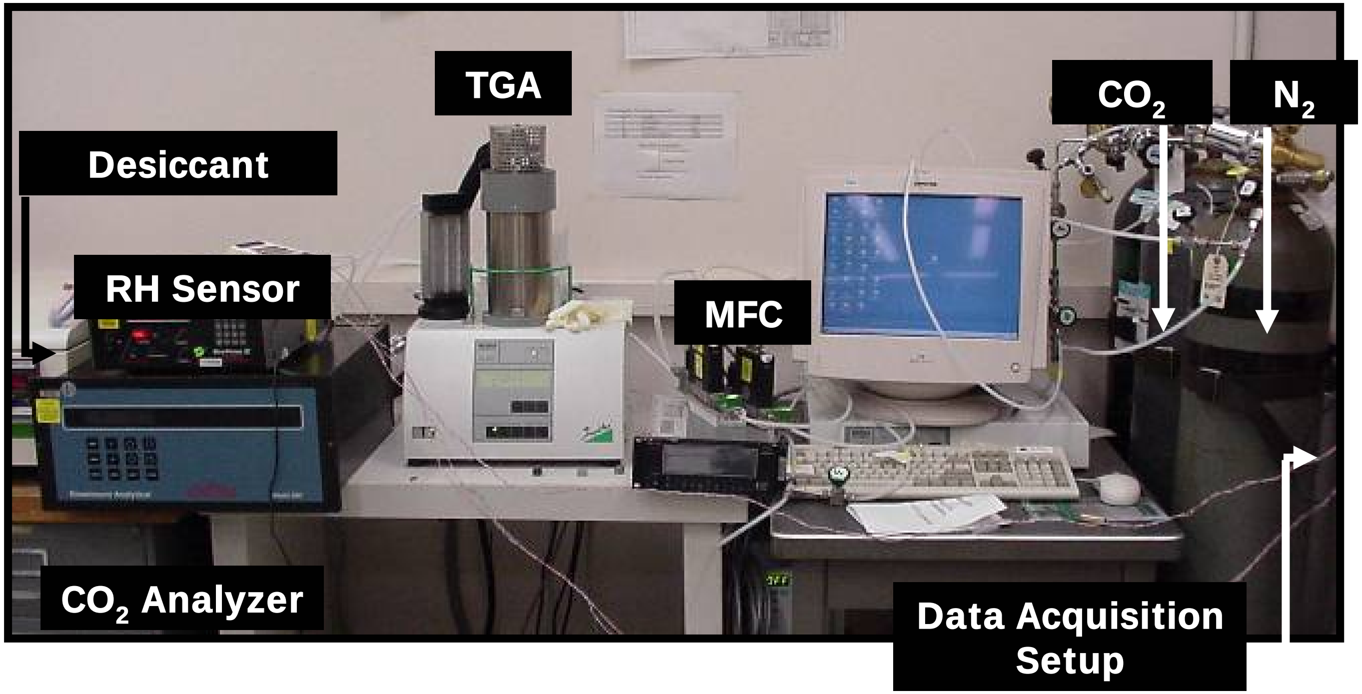
Functionalization of SWCNTs with Amines

- Since amines are volatile the coating would be prone to degradation during repeated thermal or vacuum driven renewal of the adsorbent.
- Chemically bonding of the amine to the support phase was a solution to this problem



Hirsch et al.

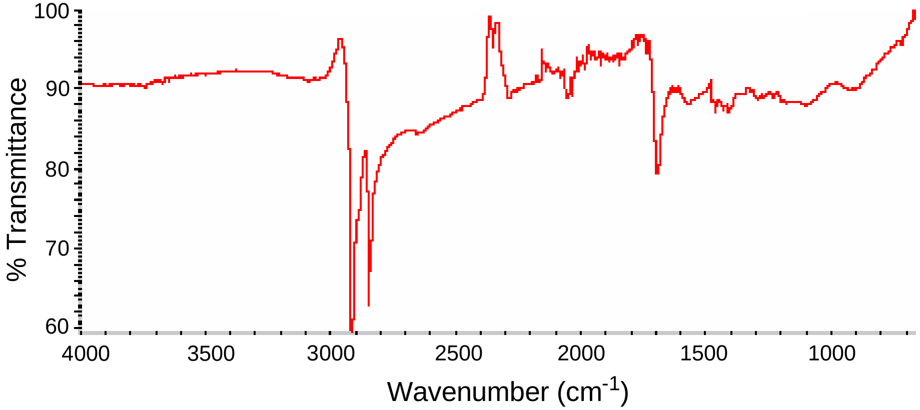
CO_2 Uptake Measurements

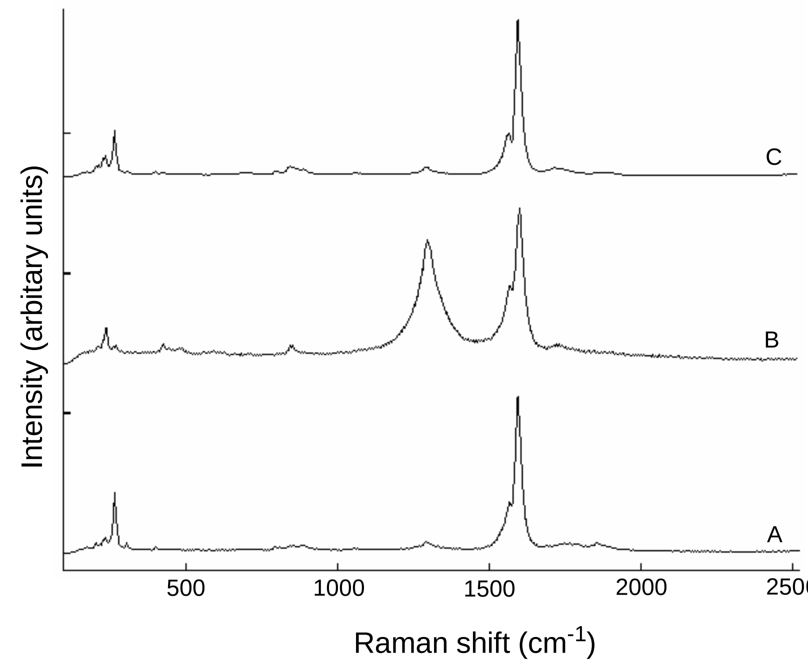


Experimental conditions

- Flow rate 500 cc/min – 1% CO_2 (balance N_2)
- Regeneration: Low vacuum (off-line) for 1 hour

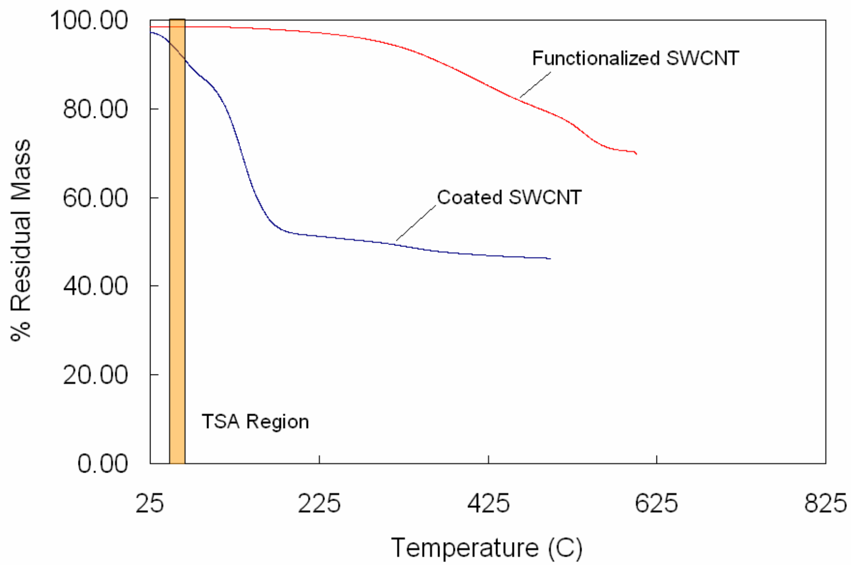
Results: Functionalization

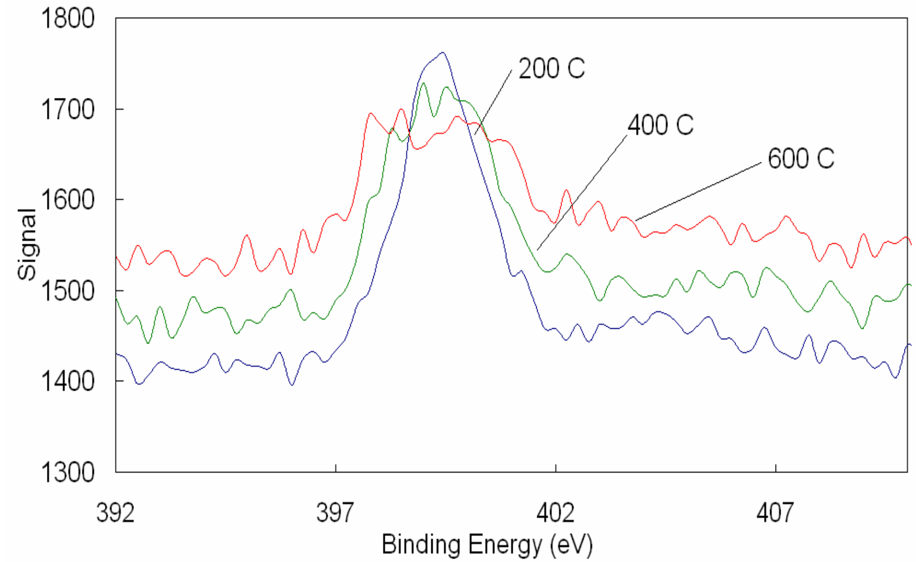




FTIR and Raman spectroscopy data provide evidence of surface modification of the SWCNT, which indicates that carboxylic acid groups are bonded to the carbon nanotubes.

Results: Thermal Decomposition and XPS

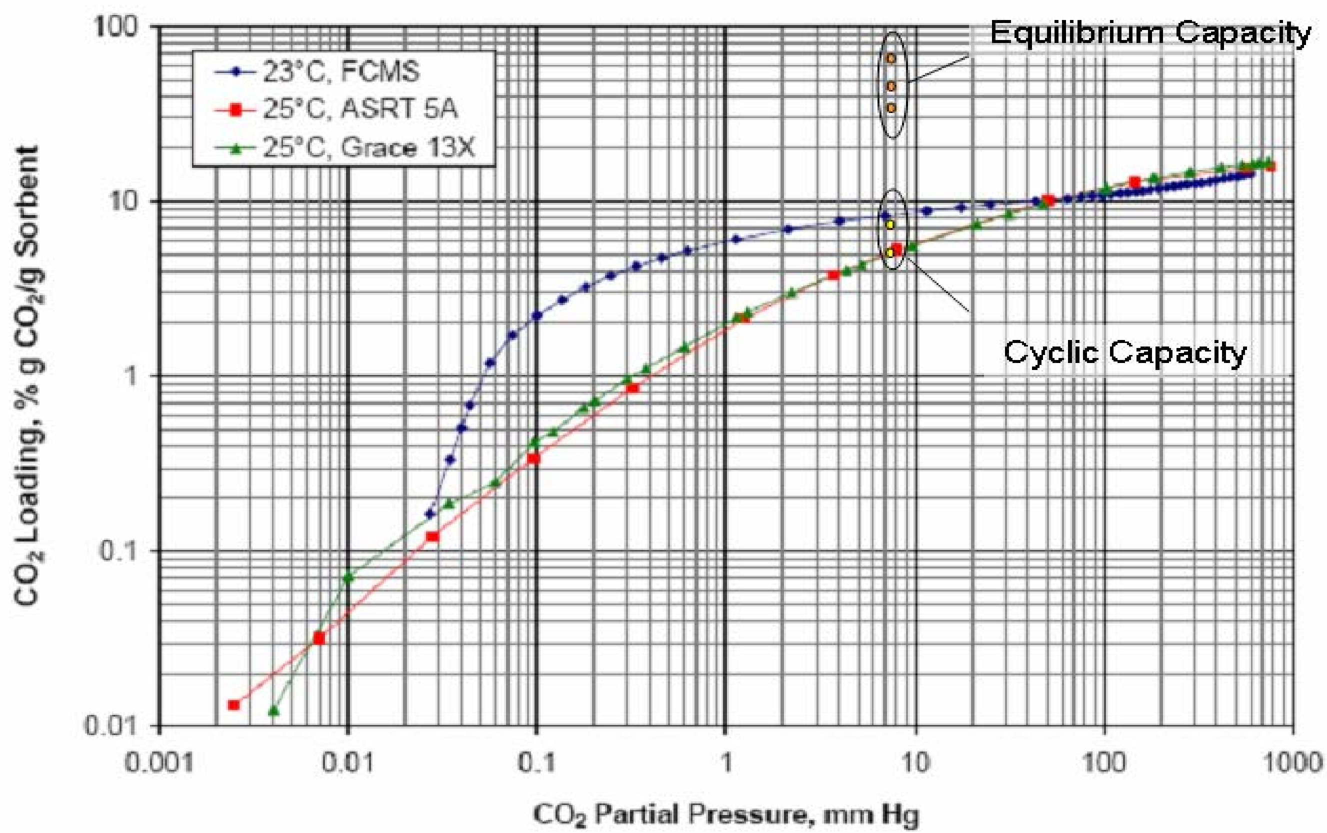




XPS analysis of the nitrogen peak serves to monitor removal of amines (nitrogen) as a function of temperature via changes in peak height

Comparison of TGA curves for functionalized and coated SWCNT indicates that the amine remains attached to SWCNT well above the TSA temperature range

Results: Comparison with current technologies

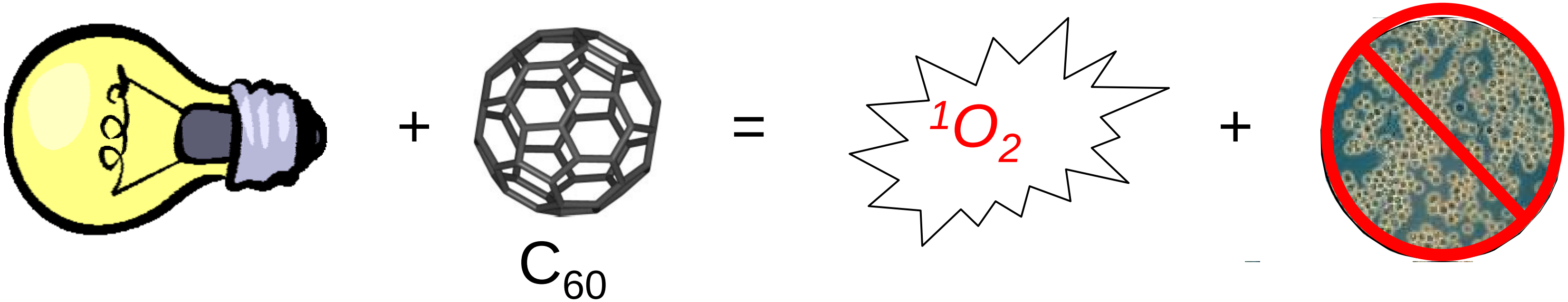


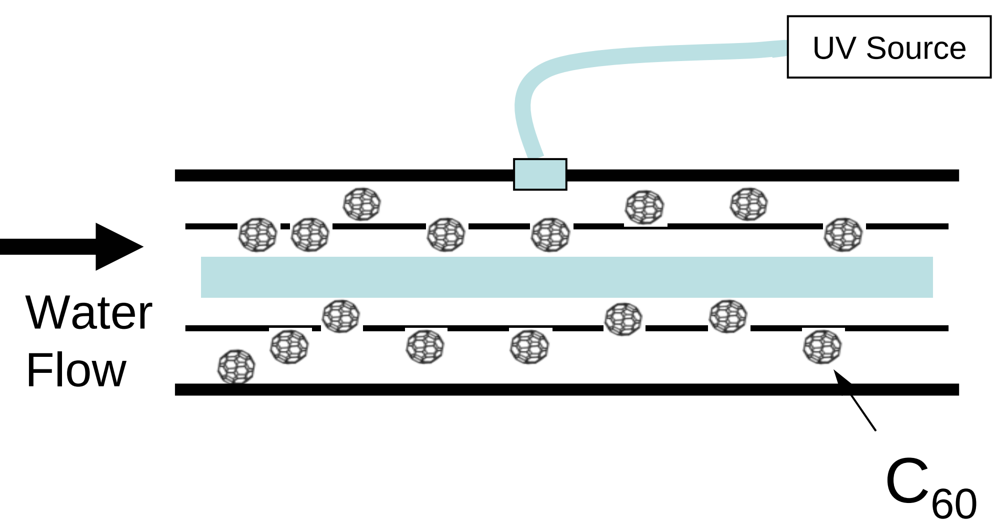
High equilibrium capacity
Lower regeneration capacity – poor vacuum results in incomplete desorption

Next Steps

- Investigate derivatizing SWCNTs with NASA approved amine formulation
- Testing and determining CO2 uptake capacity; both maximum and cyclic
  - Thermal swing
  - Vacuum swing
- Plans for scale-up
- Integration into flight hardware

Nanostructured Water Disinfection Device

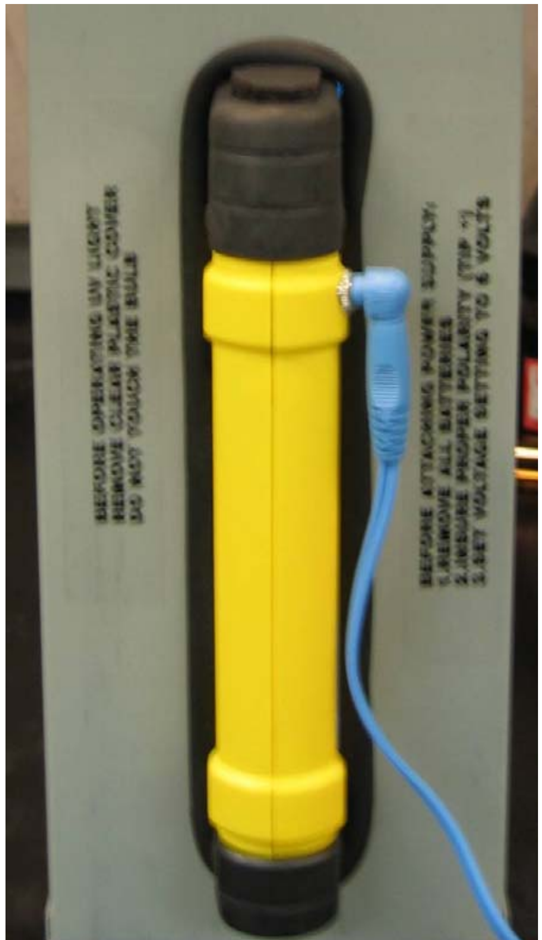


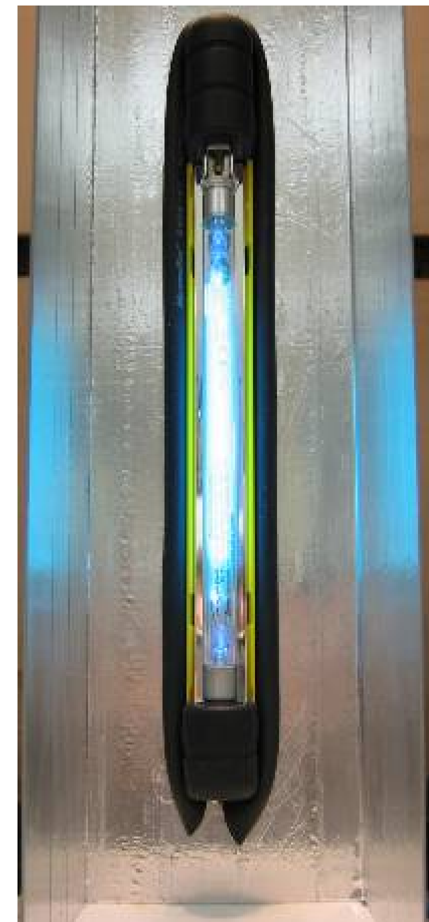


- Efficient disinfection
    - Low power
    - No consumables
- Collaboration between Crew&Thermal Systems and Structural Engineering Divisions of NASA JSC

Ultra Violet Test Stand

Bring all those pieces together and .....

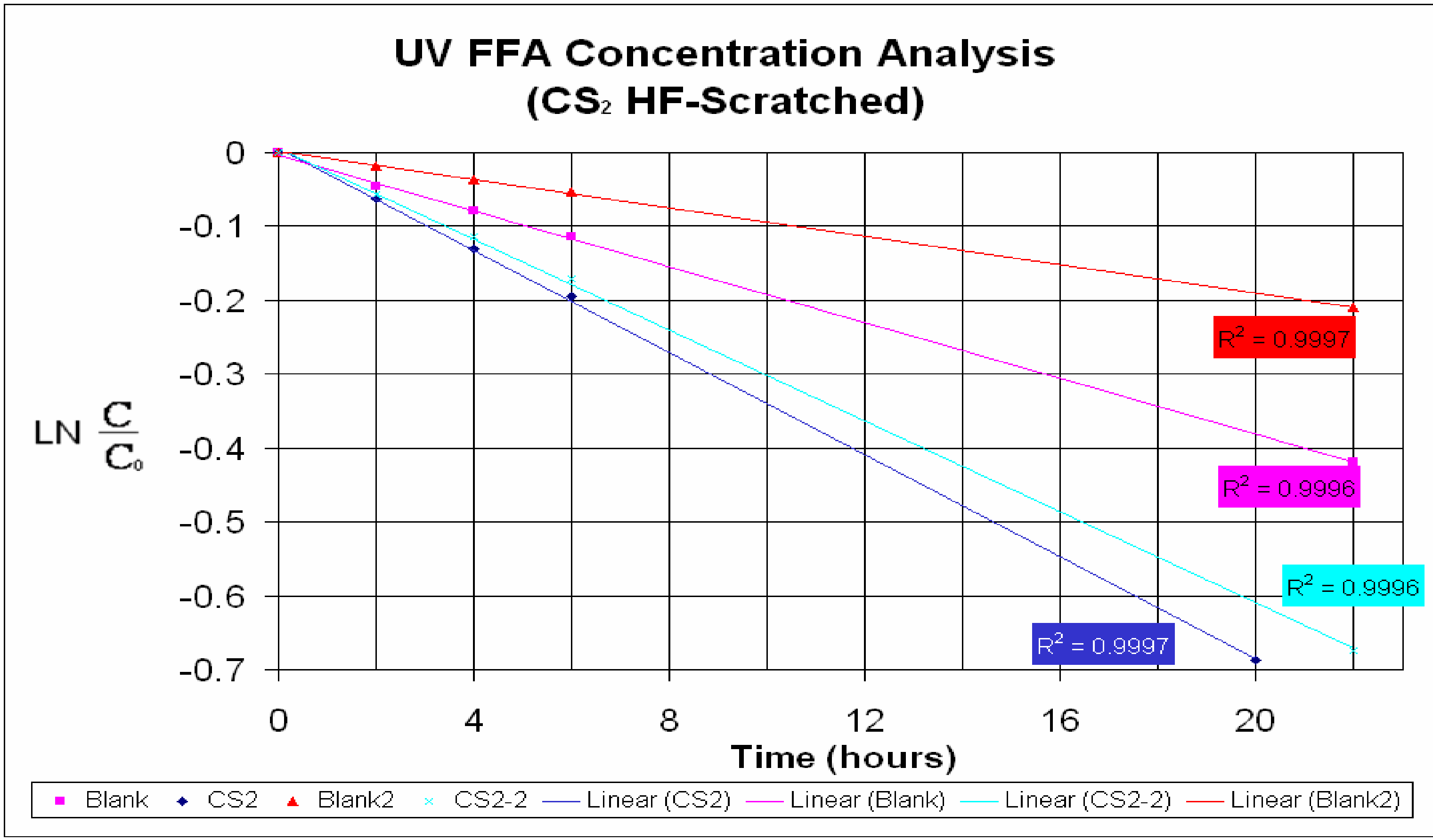




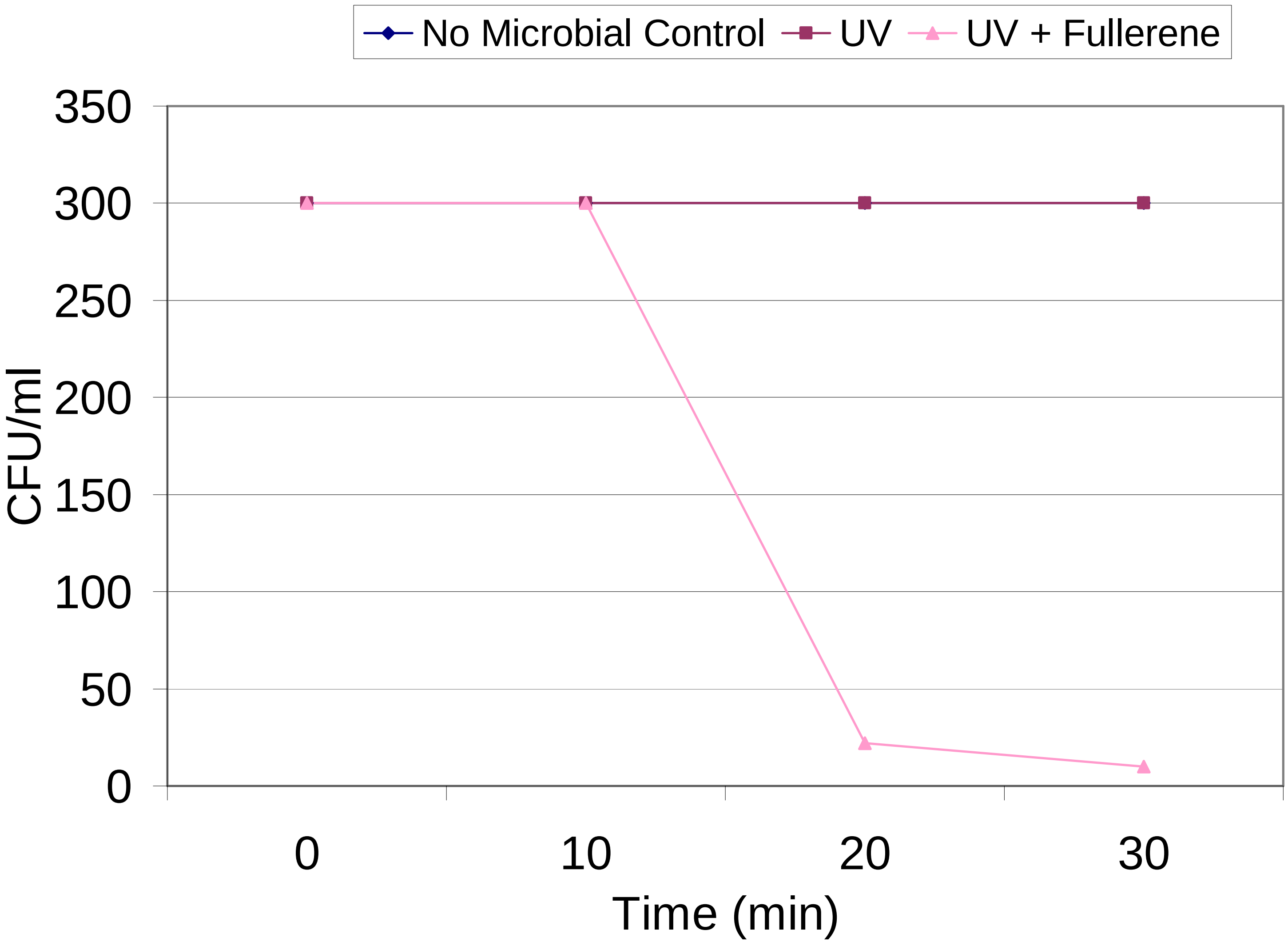
Fullerene Coated slides

- Fullerene can be dissolved from a bulk material (colloids) into single fullerene particles (Bucky balls) with certain solvents.
  - Toluene
  - Carbon Disulfide
  - Benzene
- Slide preparation
  - Etched
  - Hydrofluoric (HF) Acid
  - Etched and HF
  - Surface Application

Singlet oxygen generation



Year 1 results: Bacterial efficacy



Next Steps

- Investigating substrate preparation methods by vapor deposition
- Testing
  - bacterial degradation
  - coating longevity
- Scale-up to bench top device

Acknowledgements

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