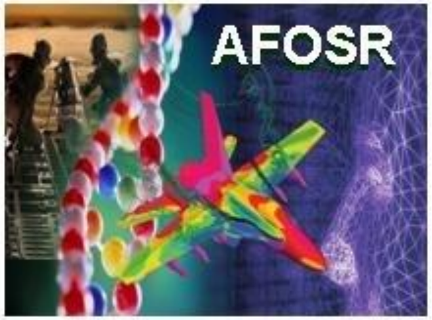
THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

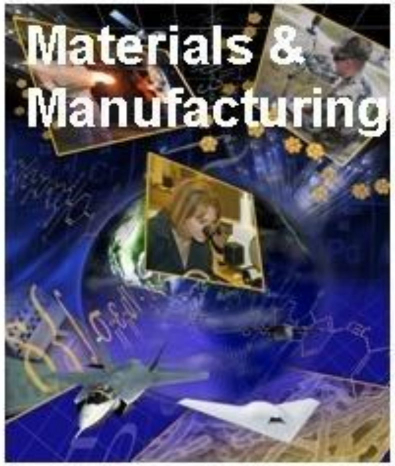
Air Force Office of Scientific Research Overview

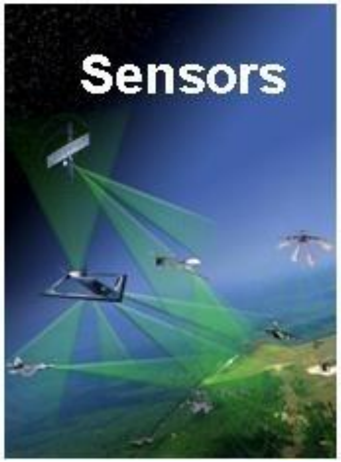
Dr. Joan Fuller
Director, Aerospace and Material Sciences
Air Force Office of Scientific Research

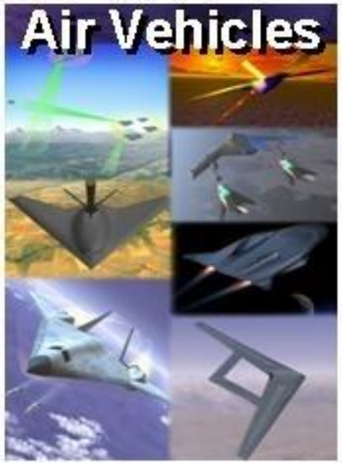
Approved for public release.

Air Force Research Laboratory









The Air Force's Corporate Research and Development Laboratory

AFOSR Mission

Discover, shape, and champion basic science that profoundly impacts the future Air Force

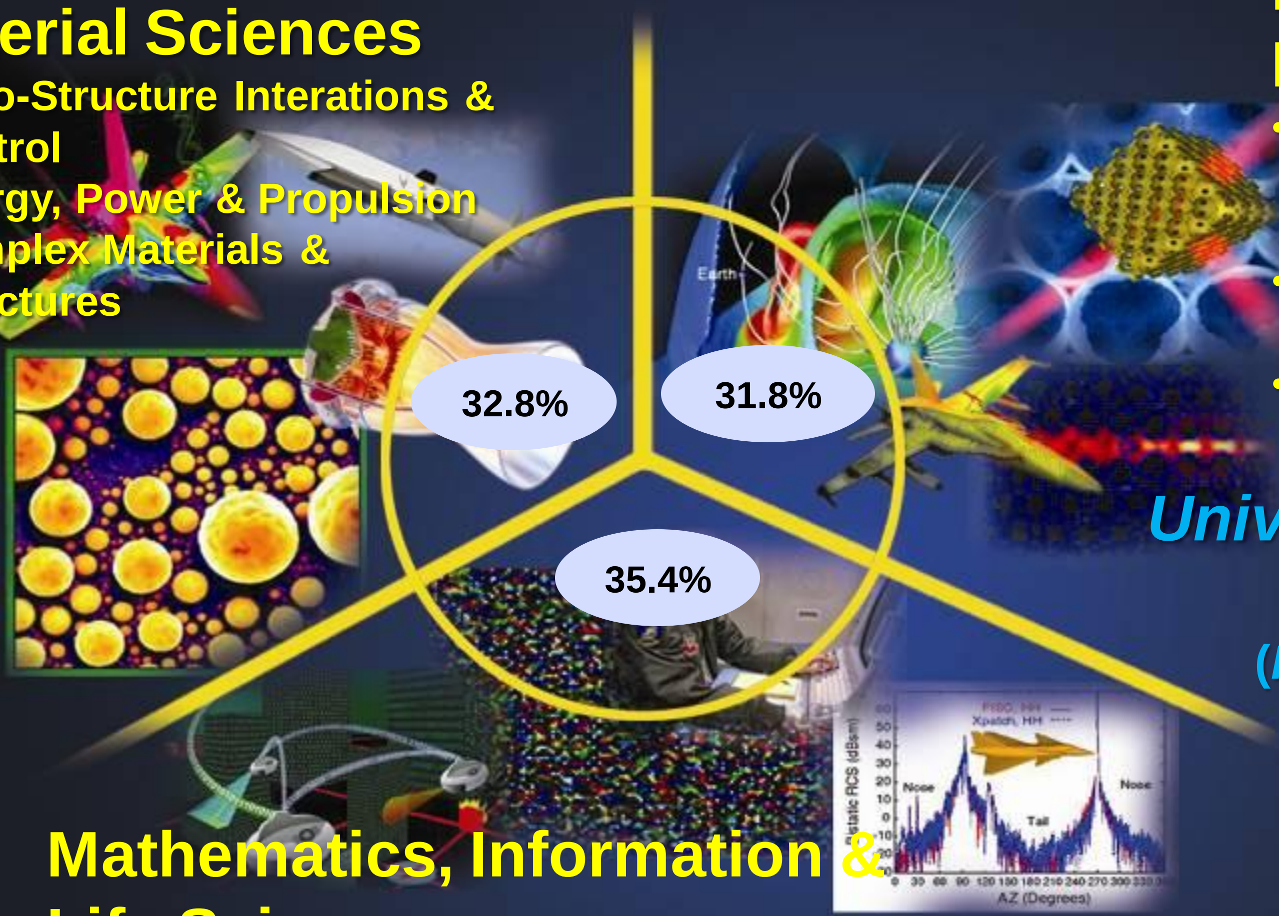
- ID Breakthrough Research Opportunities – Here & Abroad
- Foster Revolutionary Basic Research for Air Force Needs
- Transition Technologies to DoD and Industry

Basic Research (Focus Areas)

(*FY11PB* - $351M)

Aerospace, Chemical & Material Sciences

- Aero-Structure Interations & Control
- Energy, Power & Propulsion
- Complex Materials & Structures



Physics & Electronics

- Complex Electronics & Fundamental Quantum Processes
- Plasma Physics & High Energy Density
- Optics, EM, Comm, Signals Processing

University Research Initiatives

(*FY11PB* - $136M)

Mathematics, Information & Life Sciences

- Info & Complex Networks
- Decision Making
- Dynamical Sys, Optimization & Control
- Natural Materials & Systems

AFOSR Roles
AF Basic Research Manager

- **Identify Breakthrough Research Opportunities – Here & Abroad**
  - Regular interactions with leading scientists and engineers
  - Int'l liaison offices in Europe, Asia, Latin America
  - 227 short-term foreign visitors; 22 personnel exchanges
  - 96 summer faculty; 50 postdocs/senior scientists at AFRL

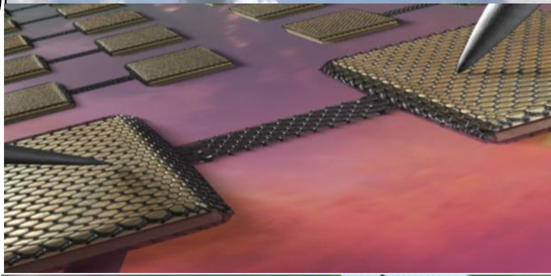
- **Foster Revolutionary Basic Research for Air Force Needs**
  - 1327 extramural research grants at 228 U.S. universities
  - 268 intramural research projects at AFRL, USAFA, AFIT
  - 153 STTR small business - university contracts
  - 590 fellowships; 2224 grad students, 344 post-docs on grants

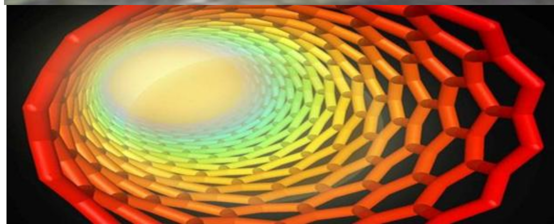
- **Transition Technologies to DOD and Industry**
  - 64 workshops conducted; 195 conferences co-sponsored
  - 700 funded transitions (follow-on-uses) from FY10 PI data call

Trends in AFOSR Emphasis

RED = PBD709 Topics
BLUE = Tech Horizons Grand Challenges
GREEN = Both

- Advanced Mathematics
- Hypersonics (Turbulence Control)
- Complex, Multi-Functional Materials
- High-Temperature Superconductivity
- Info Assurance and Network Sciences
- Micro Air Vehicles (Autonomy, Adaptive Aero)
- Interfacial Sciences (Thermal, Tribology)
- Counter-Directed Energy Weapons
- Robust Decision-Making, Info Fusion
- Socio-Cultural Modeling, Minerva
- Quantum Information Sciences
- Space Situational Awareness
- *fs*-Laser Material Interactions
- Artificial Intelligence





Basic Research Focus Areas

Aerospace, Chemical & Materials Sciences (RSA)

- Aero-Structure Interactions and Control
- Energy, Power, and Propulsion
- Complex Materials and Structures

Physics & Electronics (RSE)

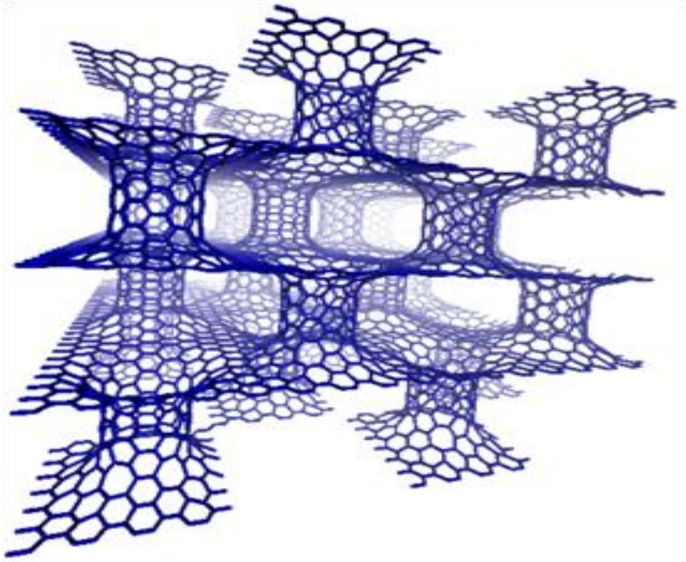
- Complex Electronics and Fundamental Quantum Processes
- Plasma Physics and High Energy Density Nonequilibrium Processes
- Optics, Electro-magnetics, Communication, and Signal Processing

Math, Information & Life Sciences (RSL)

- Information and Complex Networks
- Decision Making
- Dynamical Systems, Optimization, and Control
- Natural Materials and Systems

Complex Materials and Structures

- Objective: Future materials and structures that incorporate hierarchical design and functionality from the nanoscale through the mesoscale to effect functionality and/or performance characteristics to enhance the mission versatility of future air and space systems.
- Critical Subjects Include:
  - Materials with tunable properties
  - Adaptive morphing structures
  - Active materials with on-demand shape and phase change
  - Reconfigurable structures



3D Pillared CNT/Graphene Nano Structure

Ductile, Fracture Resistant Bulk Metallic Glass – Crystalline Composites

K. Flores / Ohio State University & W. L. Johnson / CALTECH

[New Glass Stronger and Tougher Than Steel](#) (Jan. 11, 2011) —

[Metallic Glass Yields Secrets Under Pressure](#) (Mar. 17, 2010) —

[Metallic Glass For Bone Surgery](#) (Sep. 29, 2009) —

[Nanoscale Structures With Superior Mechanical PropertiesDeveloped](#) (Feb. 13, 2010) —

[A Plane With Wings Of Glass?](#) (June 24, 2008) —

[Fast-Tracking the Manufacture of Glasses](#) (June 29, 2010) —

[Nanostructured Material Offers Environmentally Safe Armor-Piercing Capability, May Replace Depleted Uranium](#) (Feb. 1, 2007) —

[Chemists Look Through Glass To Find Secrets That Are Less Clear](#) (June 6, 2006) —

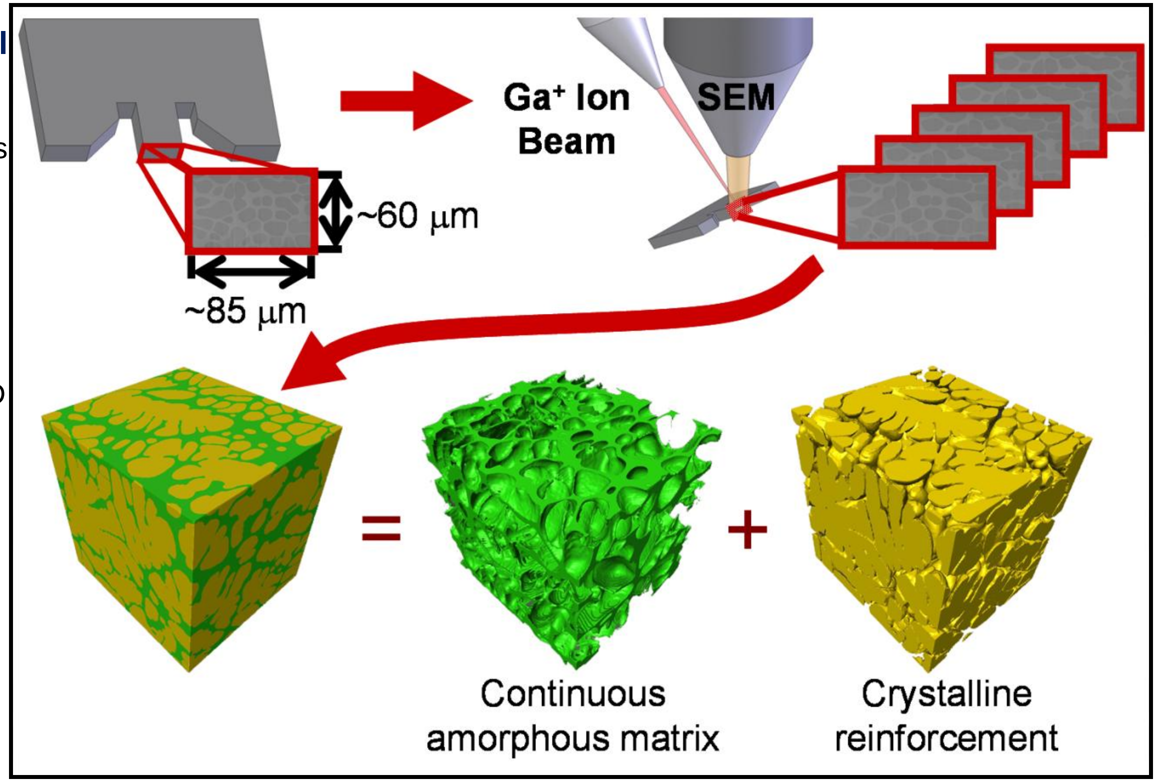
Status Quo: Metallic glasses exhibit negligible tensile ductility due to highly localized deformation in shear bands.

New Insight: Ductile crystalline dendrites formed in situ via thermal treatments can increase ductility to > 10%.

Project Goal: * Understand structure and resulting properties through combination of experiment and modeling
* Optimize performance of glass/crystalline composites

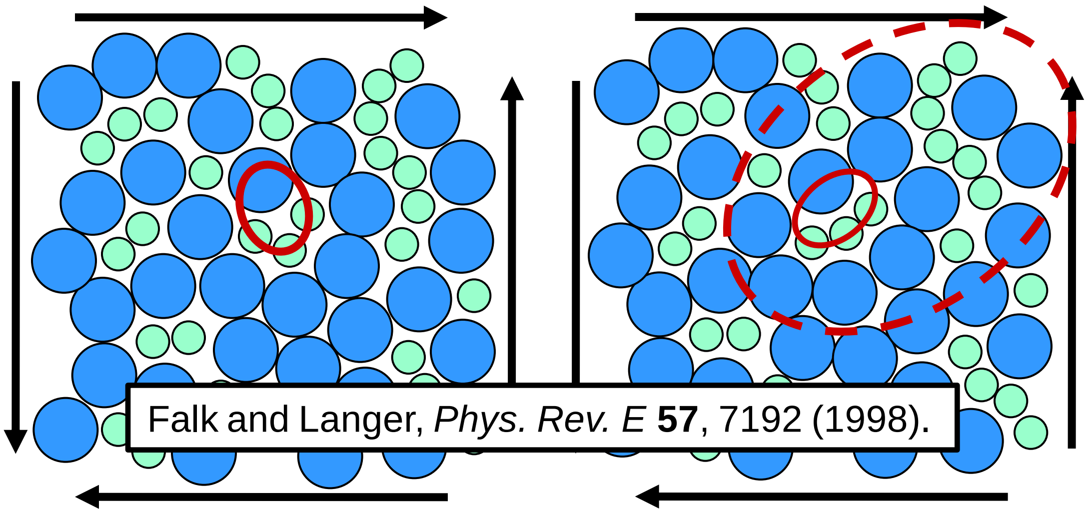
Highlight:
3D Microstructural Characterization

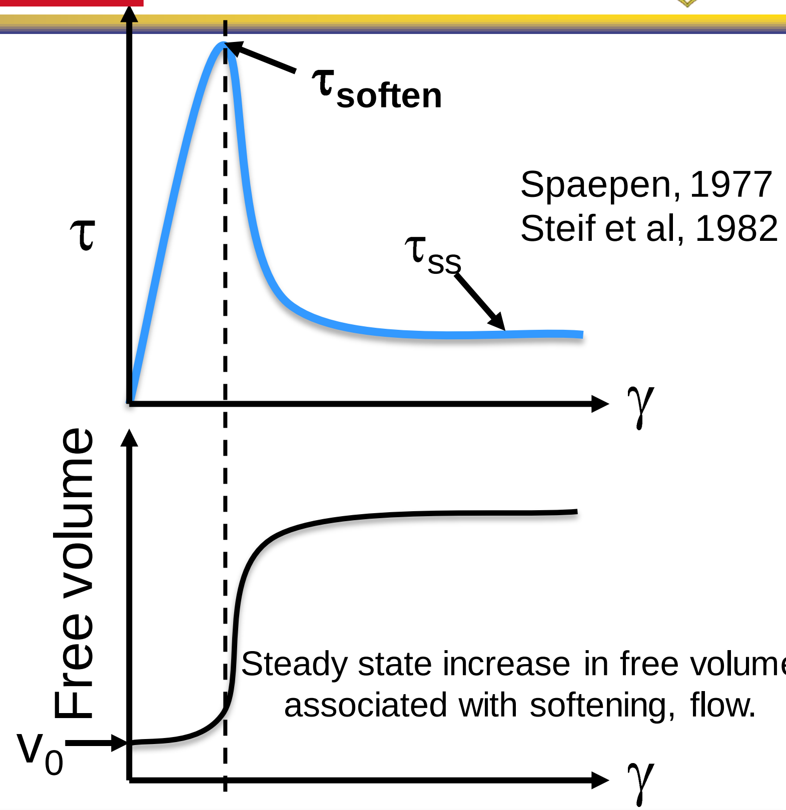
- A cantilever beam is FIB milled and serial sectioned.
- SEM images of each slice face are stacked and post-processed to produce detailed 3D reconstructions.
- Results show, for the first time, that the glassy phase is completely continuous, even at crystalline dendrite volume fractions exceeding 70%!



Deformation and free volume: What is the flow defect?

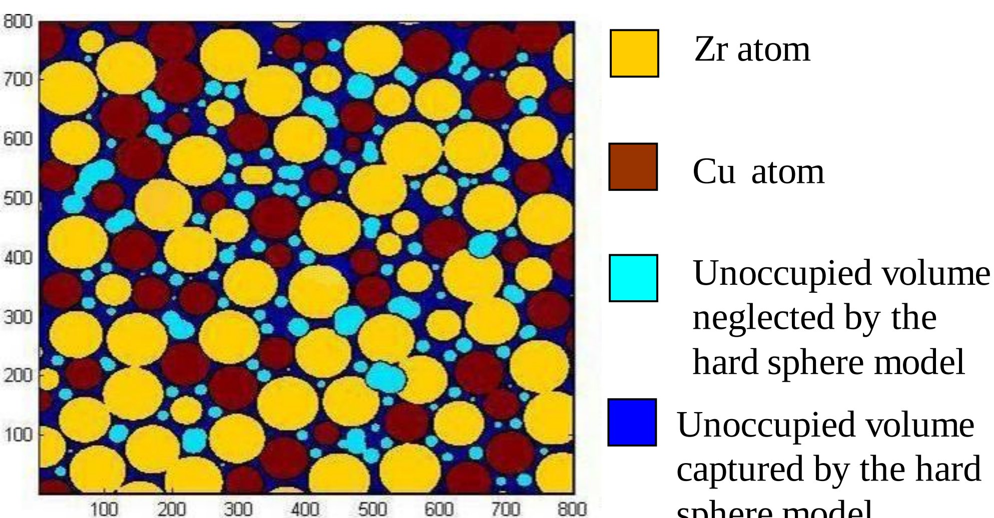
K. Flores / Ohio State University





"Free volume" is defined as the volume in excess of the ideal glass structure.

- Defined over the <u>entire structure</u>, not locally.



- Definition of "free volume" is volume in excess of the ***ideal glass structure***.
- How is the ideal defined?
- Typically perform voronoi tesselation, define "free" volume as voronoi cell less volume of hard sphere atom core.
- What is atomic radius?
- Neither of these approaches address ***connectivity*** of "free volume"

Overview of AOARD Laser Program

Ceramics for high-power lasers
(Final report submitted Feb 2011, PI: Ikesue)

Average power and brightness scaling of diamond Raman lasers (Macquarie University, PI: Mildren)

Silica and germanate glass high-power fiber laser sources
(University of Adelaide, PI: Monro)

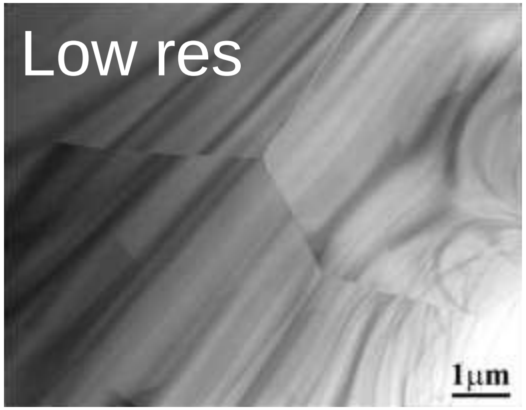
Exploration of advanced ceramic gain media with broadband: sesquioxides and garnates
(Osaka Institute of Technology, PI: Kamimura & World Lab Inc, PI: Ikesue)

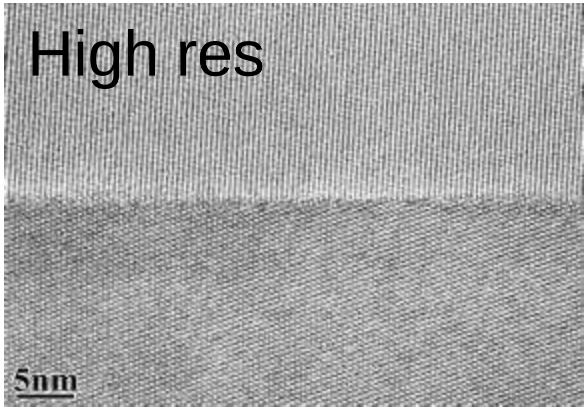
Mode locking of lasers using atomic layer graphene as absorber material (Nanyang Technology University, PI: Tang)

Transition
Solid-State Ceramic Laser Research

Processing science is actively transitioning to RX and Navy

Key: Uniform doping, clean boundaries and diffusion bonding



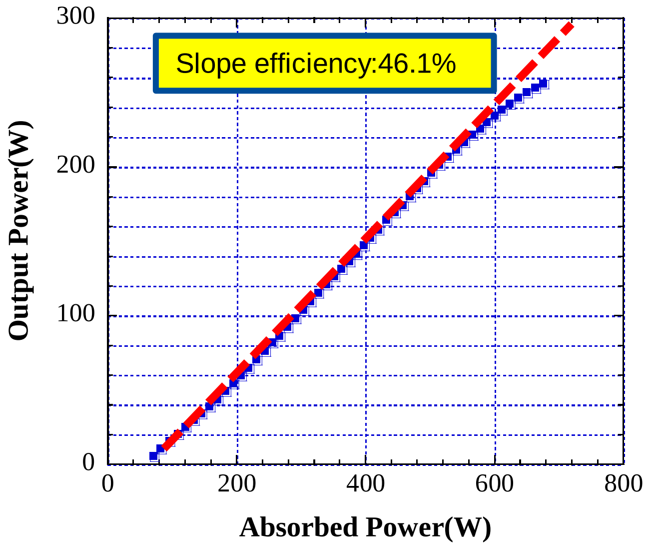


Clean boundaries is a challenge

2010 Breakthrough!

Waveguide fabrication

270 watt @1064 nm



Nd^{3+}:0.6 at% (with 400 µm core)

Pushing the limit to >500W in FY 11

Diamond Raman Lasers
Power and Brightness Scaling

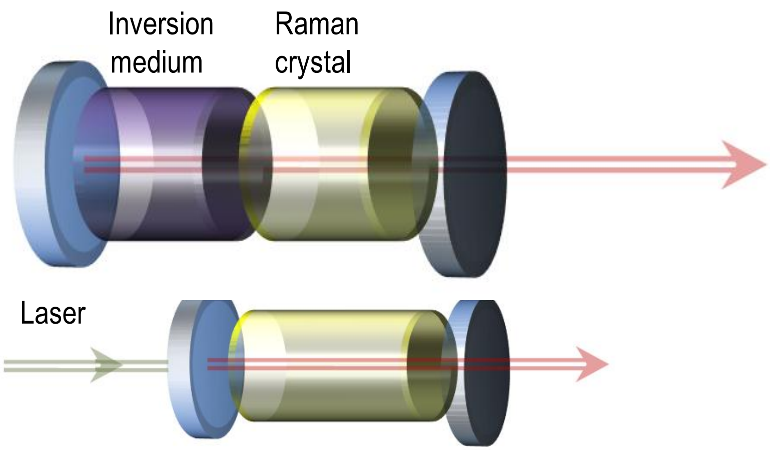
PI: Richard Mildren, Macquarie University

Raman scattering generate Stokes waves that have:

Stoke waves: $\omega_{-n}=\omega_0-n\,\omega_{p}$.

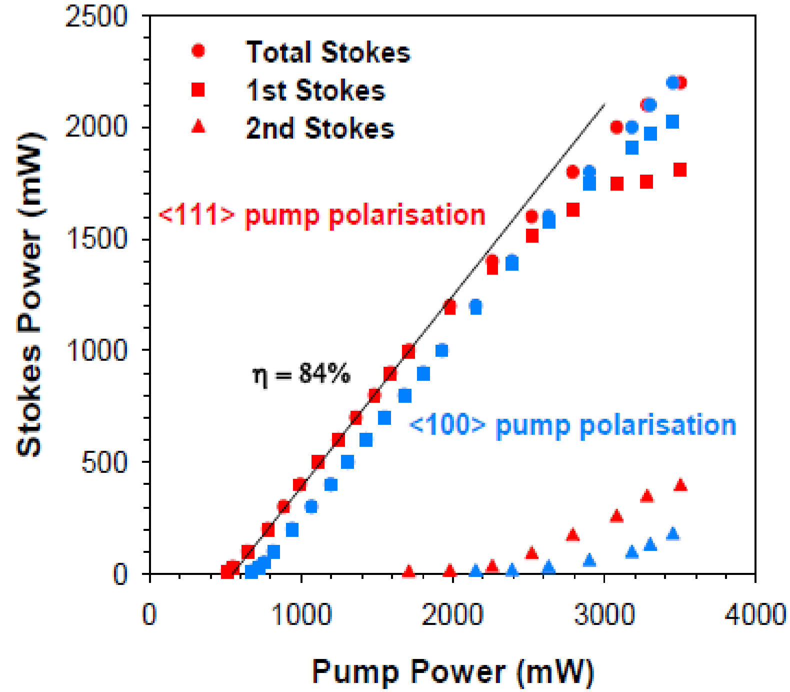
Anti-stokes waves $\omega_{-n}=\omega_0+n\,\omega_{p}$.

ω_{p}. **is the Raman vibration frequency**



Why Diamond ?

– High Raman gain, outstanding thermal properties and damage threshold, and good transmission range



- Mildren first to demonstrate CW Raman operation in solid state system in 2008
- Current limitations 5 W
- DSTO is engaged

Explore power scaling rules and limitations through experiment and theory

Output performance for 1064-nm pumped external cavity laser (1st & 2nd Stokes (1240nm and 1480 nm)

High-Power Fiber Laser
Silica and Germanate Glasses

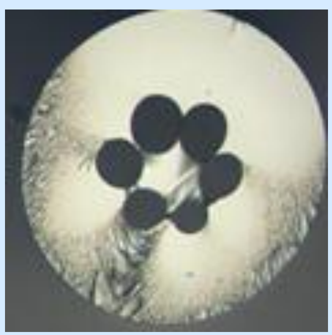
PI: Tanya Monro, University of Adelaide

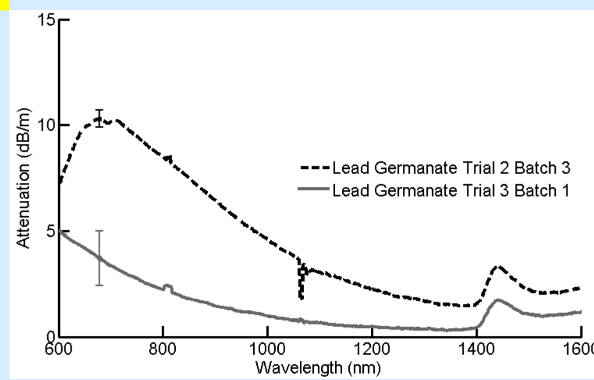
How do you overcome the challenges of the design and thermal limitations of silica- and germanate-based glasses

Can you design for high-power and high-beam-quality laser output in the 2–2.1 μm wavelength range?

World-class processing facility has been established at the University of Adelaide for fiber lasers; DSTO is engaged

60 GeO_2 – 30 PbO – 5 La_2O_3 – 5 Na_2O



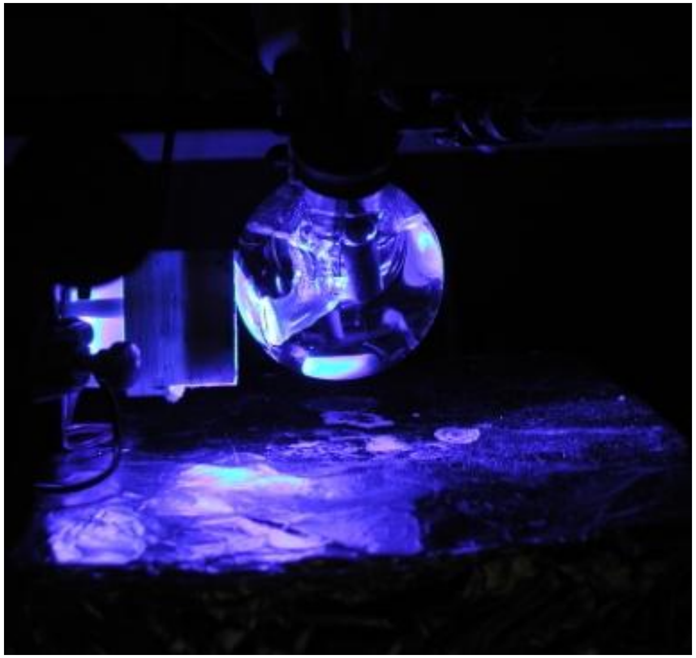


First demonstration of a microstructural germanate fiber drawn from an extruded preform

JTO Interest and co-funding

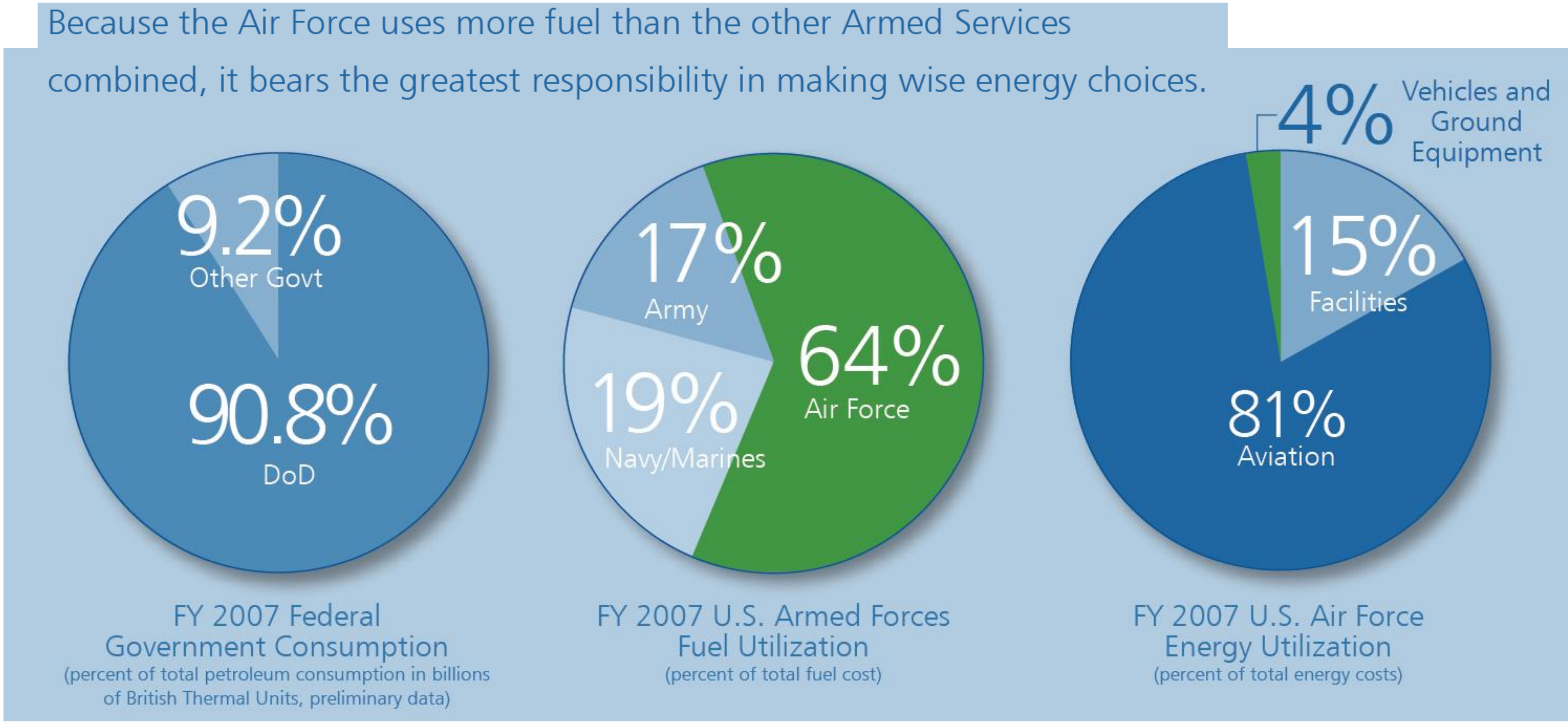
Energy, Power, and Propulsion

- Objective: Focus on the production, storage, and efficient utilization of energy.
- Critical Subjects Include:
  - Novel energetic materials
  - Combustion research
  - Thermal science
  - Novel propulsion methods
  - Catalysis chemistry
  - New ways in which energy can be produced/collected/stored/utilized



Blue light (465 nm) is used to convert CO_2 to alcohols with a substituted pyradine catalyst and a p-GaP electrode.

Air Force Energy Usage



Annual AF Fuel Usage: 2.6 billion gallons per year

Air Force Energy Initiatives are Many and Varied

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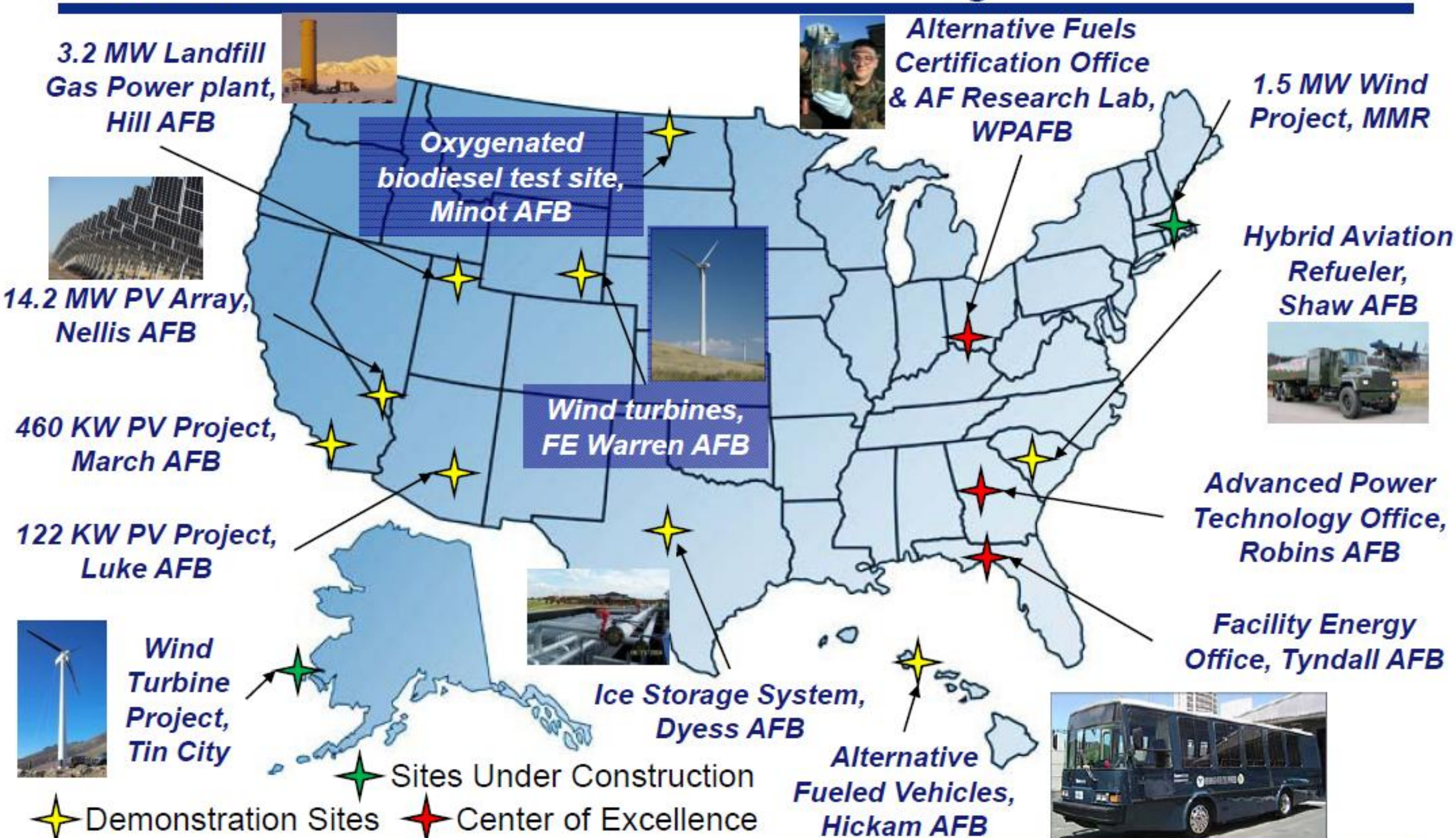

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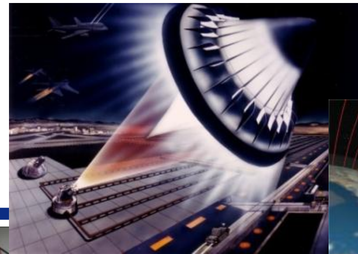
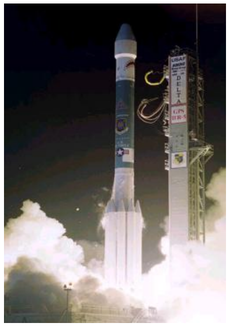
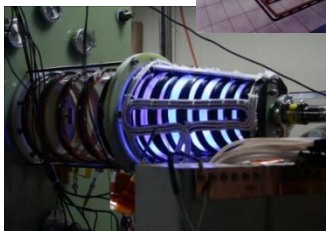
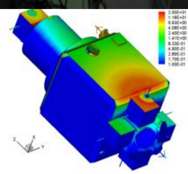
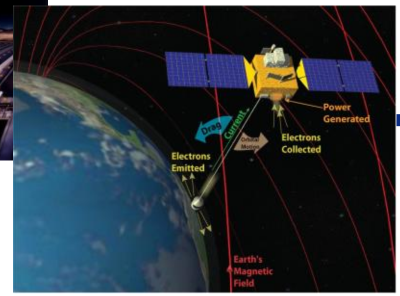
Novel Power Generation in Space

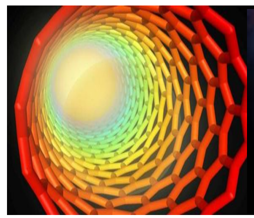


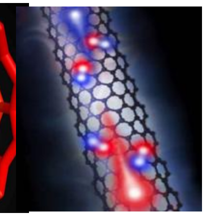












TRL Level 1
(***PM's***: *RSA- Mitat Birkan, B.“Les” Lee; RSE- Kitt Reinhardt)*

Program Description/Objective

(a) To increase specific power of space systems through novel concepts of hybrid fuel cell/propulsion and next generation of solar cells, (b) to reduce satellite bus mass requirements via more efficient power management/storage, and (c) to enhance solar cell lifetime through new understanding of radiation/particle degradation and surface physics.

Operational Energy Benefits

(i) Increase satellite payload mass and power budgets; (ii) Extend satellite operational lifetime; (iii) Reduce satellite mission lifecycle costs

AF Energy Alignment

REDUCE DEMAND

INCREASE SUPPLY

Technologies/Approaches

(1) new fuel cells for extreme temperature and auxiliary power generation, (2) 50%+ efficient compact solar cells, (3) breakthrough approach of solar cells based on multi-hetero-interface, (4) surface physics at the material-plasma interface, (5) pulsed and steady-state electric propulsion systems, (6) thermo-power waves, (7) space tethers to harvest energy from the planetary magnetic field

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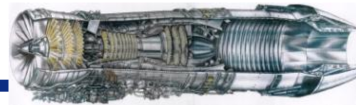
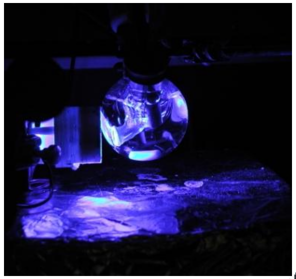
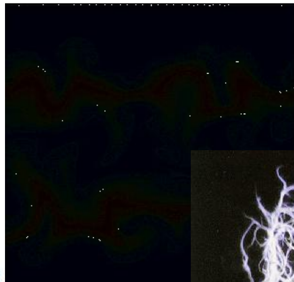
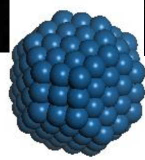
Novel Propellants









TRL Level 1
(***PM's***: *RSA- Michael Berman, Julian Tishkoff)*

Program Description/Objective

(a) To create the methods and processes to enable sustainable, stable and scalable sources of novel fuels for aircraft propulsion applications, and (b) to develop optimum means of utilizing conventional and novel fuels most efficiently.

Operational Energy Benefits

- Secure supply of propellants with low to near-zero net greenhouse gas emissions
- Endothermic fuels for cooling of air vehicles
- Combustion processes allowing improved system efficiency and low pollutant emission

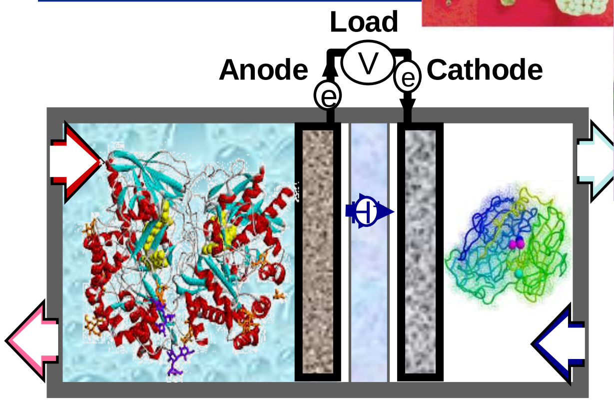
AF Energy Alignment

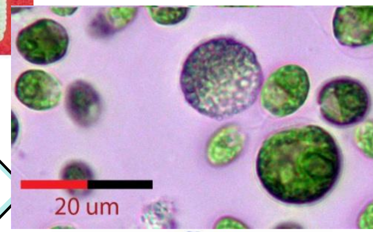
INCREASE SUPPLY

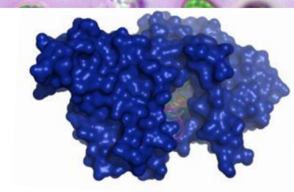
REDUCE DEMAND

Technologies/Approaches

(1) Develop catalysts able to utilize CO_2 and sunlight as feedstocks for making fuels; (2) Utilize molecular clusters and nanostructures to improve catalysis specificity and efficiency; (3) Develop surrogate fuels to better model combustion systems; (4) Develop diagnostic tools for prediction and control of multi-phase turbulent reacting flow of propulsion systems.







Bioenergy & Biofuels

TRL Level 1
(***PM's****: RSL- Walter Kozumbo, Hugh DeLong; RSA- Michael Berman)*

Program Description/Objective

To acquire a fundamental understanding of the relevant photosynthetic, microbiological and algal processes that would allow (i) genetic engineering of natural systems or (ii) bio-inspired fabrication of bionic and synthetic systems for the purpose of enabling renewable biofuels and improving the power output of biofuel cells.

Operational Energy Benefits

- Novel, efficient and sustainable sources of renewable energy for fuel cells and air breathing engines

AF Energy Alignment

INCREASE SUPPLY

Technologies/Approaches

(1) Understand and improve the capacity of photo-synthetic microbes to produce biofuels; (2) Enhance the power and energy densities of enzymatic and microbial biofuel cells as compact power sources; (3) Explore the processes that enable microalgae and cyanobacteria to produce molecular hydrogen and oil; (4) Characterize and model the structural, metabolic and regulatory mechanisms utilized by biological systems in producing or storing energy.

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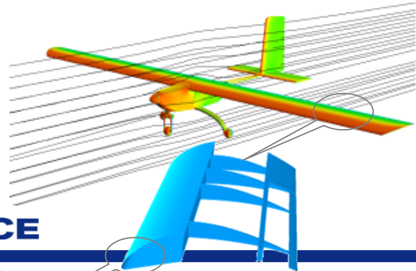
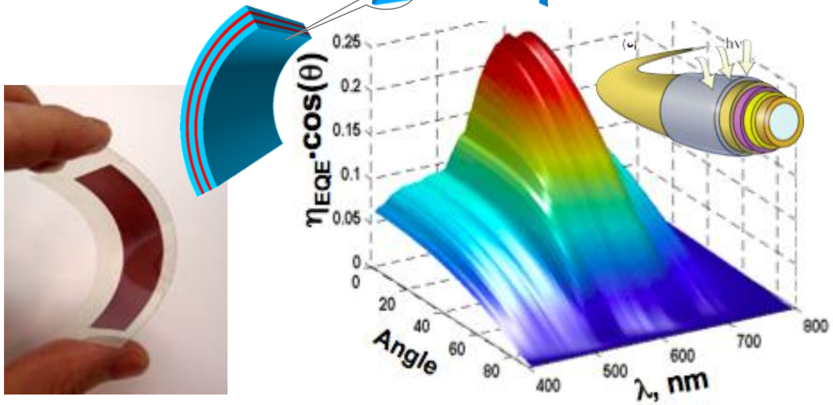
Energy Harvest/Storage from Non-Fuel Sources





TRL Level 1
(***PM's***: *RSA- B."Les" Lee, Charles Lee, Ali Sayir, Kumar Jata; RSE- Gernot Pomrenke)*

Program Description/Objective

(a) To develop novel materials, efficient devices and new methods for generating the energy from "non-fuel" sources and storing the energy generated in more readily available form, and (b) to establish multifunctional load-bearing structures with fully integrated energy harvest/storage capabilities allowing higher system efficiency, minimum parasitic mass and no need for heat exchanger.

Operational Energy Benefits

- Maximum operational endurance of space and airborne assets with minimum impact on surrounding environment

AF Energy Alignment

INCREASE SUPPLY

Technologies/Approaches

(1) solar cells of improved energy conversion efficiency with light weight and flexible substrate, (2) improved efficiency of thermoelectric modules to harvest energy from waste heat, (3) harnessing of new sources of energy harvesting, (4) improved efficiency of power storage, (5) multi-functional design for system integration of energy harvest/storage capabilities, (6) new energy devices based on nanotechnology and meta-material approaches.

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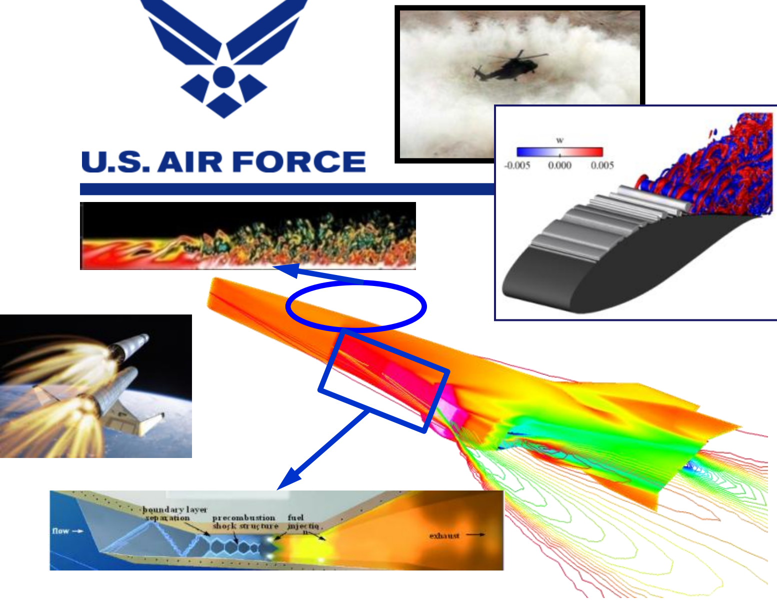
Energy Efficient Systems



TRL Level 1

*(**PM's**: RSA- John Schmisseur, Doug Smith, B."Les" Lee, Charles Lee, Joycelyn Harrison, Kumar Jata; RSE- Harold Weinstock)*

Program Description/Objective

To reduce the fuel demand for air platforms through (a) aerodynamic drag reduction, (b) reduction of structural weight through introduction of innovative materials, (c) improved propulsion efficiency and (d) reuse of harvested energy.

Operational Energy Benefits

- Significant reduction of operational costs stemming from the demand and required delivery infrastructure for fuel in theater
- 85% of AF fuel budget is spent to deliver 6% of the total fuel consumed via air-to-air refueling

AF Energy Alignment

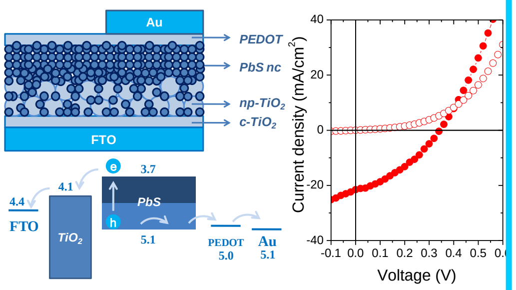
REDUCE DEMAND

Technologies/Approaches

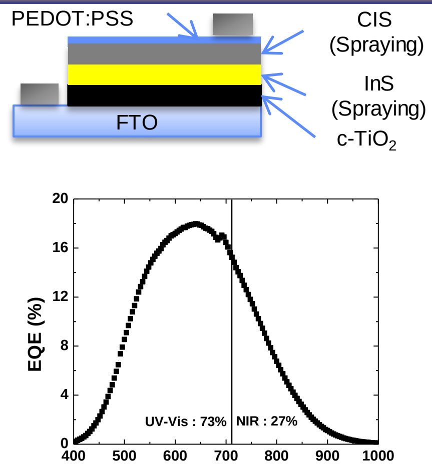
(1) Reduce aerodynamic drag through advances in control of turbulence transition, separated flows and surface roughness effects; (2) Reduce system weight through lightweight materials and novel structures; (3) Improve engine efficiency via internal flow path optimization; (4) Utilize new superconductors to lighten the load and enable magneto-hydrodynamic propulsion; (5) Harvest and redistribute lost energy in the flow field and structural vibrations

Novel Flexible Plastic-Based Solar Cells

PI: Dr. Paras Prasad, University at Buffalo (SUNY)



Hybrid nanostructured PbS-TiO_2 quantum dot-sensitized solid state solar cell incorporating a polymer layer (PCE=2.6%)



Solution based Polymer/CIS(Se) hybrid solar cell with spraying method (PCE=3.3%)

Technical Objectives:

- To develop new hybrid photovoltaic device structures using quantum dots (QDs) and hole-transporting polymer for high efficiency performance by low cost processing
- To develop improved IR spectral response of photovoltaic devices using low bandgap polymers with fine-tuned energy levels and NIR absorption

Approaches:

- Fabrication of all solid state IR-sensitized QD hybrid solar cells incorporating PEDOT for enhancing hole-transporting and electron blocking function
- Synthesis of low bandgap polymers based on the fused thiophenes (cyclopentadithiophene and dithienopyrrole) with tuned energy levels for bulk heterojunction with QDs
- Investigation of multi-layered QDs interfacing to enhance light-harvesting efficiency by cascading electron transfer

Accomplishments/Payoffs

- Developed nanostructured PbS-TiO_2 QD-sensitized hybrid cell with PEDOT polymer layer, showing 2.6% PCE (NIR contribution (>715nm) = 24%)
- Enhanced PCE (3.3%) of solution-processed multi- layered CIS PV cells with electron blocking polymer layer (NIR contribution (>715nm) = 27%)
- Fabricated NIR light harvesting hybrid solar cell based on bulk heterojunction of low bandgap polymer and PbS QDs

Nano-interfacial engineering of highly efficient polymer tandem solar cells

Yang Yang, Materials Science and Engineering, UCLA

Targets:

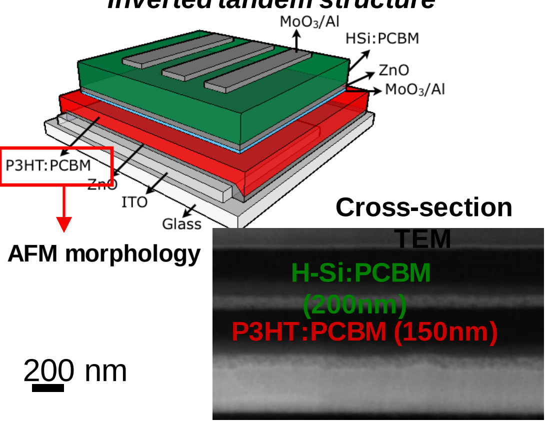
This project is to address the nano-scientific and engineering issues in design principles, conformation, and operation mechanism of high-performance polymer-based tandem solar cells for compact power.

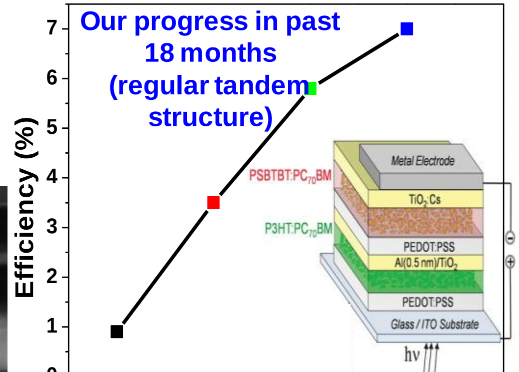
- Investigating and controlling nanophase separation of solution processed polymer-based tandem solar cells.
- Exploring a nano-sized interconnection layer with good electric, optical and mechanical properties for the tandem solar cells.
- Manipulating the nano-scale thickness of each constructing layer for the optimal optical field distribution in the tandem solar cells.
- Build high efficient tandem solar cell with both regular and inverted structure.

Approaches:

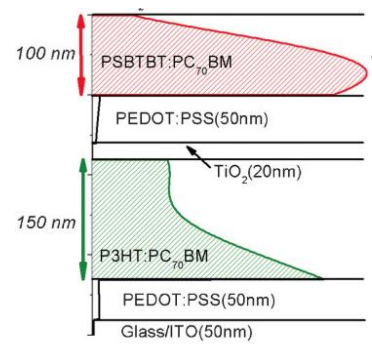
- Nano scale phase separation control to optimize the performance of each bulk heterojuncion subcells.
- Nano-interfacial engineering to improve the surface wettability and electrical properties.
- Tuning the nanometer thick films thickness to balance the optical absorption of each polymer layer.
- Investigation of recombination mechanism of connection layer between two sub-cells.

Inverted tandem structure

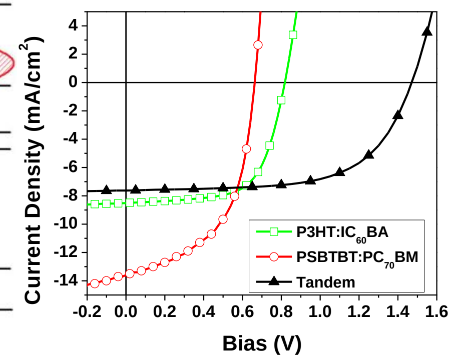




Theoretical simulation and optical design of regular tandem structure



Highly efficient regular tandem solar cells, PCE = 7.0 %

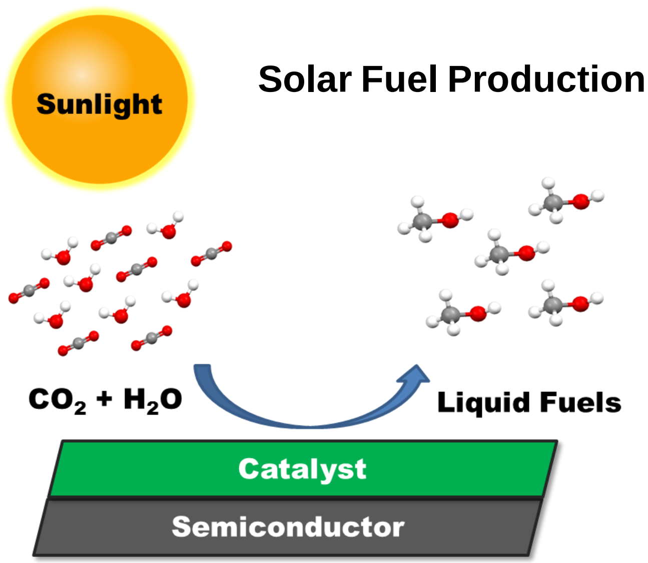


Research highlight

- Polymer tandem PV cells of 7.0 % efficiency have been achieved via solution process;
- An versatile and robust interconnection layer consisting of a p^+-n junction was realized;
- A deeper insight into the interconnection layer revealed that it acted as a metal-semiconductor contact, which is responsible for Voc adding-up.

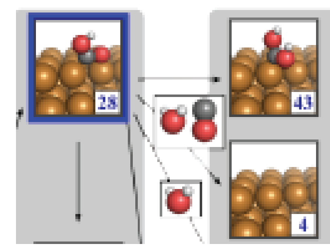
Novel Catalytic Mechanisms for the Chemical Reduction of Carbon Dioxide To Energy-Dense Liquids

Clifford Kubiak, Andrew Bocarsly, Emily Carter,
Nathan Lewis, Anders Nilsson and Jens Nørskov



Objectives

- Develop efficient catalysts for the production of liquid fuels from CO_2, water and sunlight.
- Determine molecular mechanisms for the catalytic chemical reduction of CO_2 to energy-dense liquids.



Approach

- Theoretical studies of CO_2 reduction
  - Metal and semiconductor surfaces
- In-situ spectroscopic studies of intermediates in the catalytic chemical reduction of CO_2
  - Synchrotron radiation, structure determination
  - Photo-electrochemical studies
- New catalysts for the efficient reduction of CO_2
  - Robotics for combinatorial discovery

Payoff

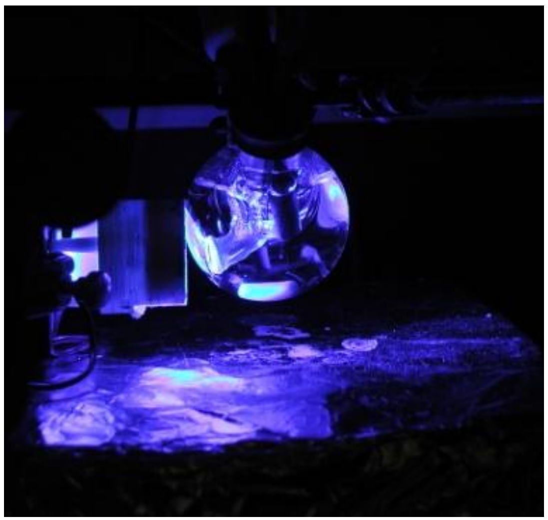
- Understanding of mechanisns of the reduction of carbon dioxide to energy dense liquid fuels
- New semiconductor materials and catalysts (homogenous and heterogeneous) for the efficient solar reduction of CO_2
- Secure and sustainable path to methanol and higher hydrocarbon fuels (directly or, for example, by the Mobil process using ZSM-5).

University of California San Diego, California Institute of Technology, Stanford University, and Princeton University

Carbon-Neutral Fuels: Converting Carbon Dioxide to Fuels

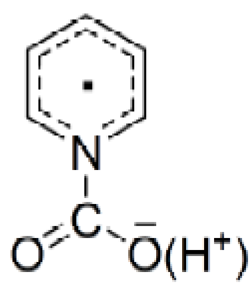
Objective:

- Produce energy dense hydrocarbons and alcohols using CO_2 as a feedstock



Blue light (465 nm) is used to convert CO_2 to alcohols with a substituted pyradine catalyst and a p-GaP electrode

Key intermediate in pyridinium catalysis of CO_2 reduction



Approach:

- Develop new electrocatalysts to efficiently <u>produce alcohols and carbon-carbon bonded products</u> from CO_2 and sunlight feedstocks
- Identify key mechanisms and dynamics related to the necessary multielectron processes.

Payoff:

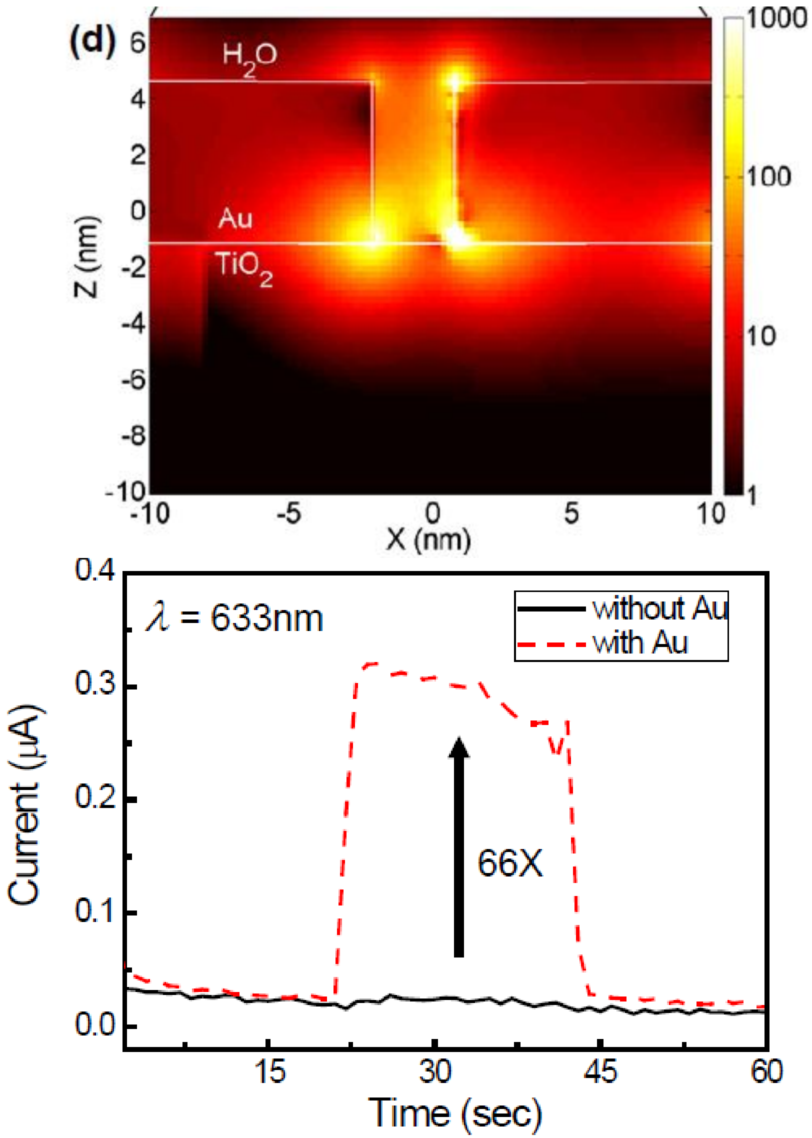
- A secure and sustainable source of liquid fuels for aircraft use
- A carbon neutral fuel – CO_2 produced in combustion is offset by using CO_2 as a feedstock

Solar fuels store the energy from the sun in energy-dense chemical bonds for use as transportation fuel.

Prof. A. Bocarsly

PRINCETON UNIVERSITY

Plasmon-Resonant Enhancement of Photocatalytic Water Splitting



- Photodriven splitting of water to H_2 and O_2 on TiO_2 substrates is greatly enhanced (x66) by the presence of Au nanoparticles.
- Use highly catalytic TiO_2 with highly plasmonically active Au nanoparticles
- Local E-field enhancement near the TiO_2 surface increases electron-hole pair generation at the surface of the TiO_2
- Larger enhancement factors possible if this mechanism can be optimized.

Cronin, U Southern California
Nanoletters, 2011

Aligned Carbon Nanotubes for Highly Efficient Energy Generation and Storage Devices

Liming Dai

Case Western Reserve, University and University of Dayton

Aligned Carbon Nanotubes and Graphene Sheets for Energy Generation and Storage

STATUS QUO

Vertically-aligned Carbon Nanotubes and Graphene

• Vertically-aligned multiwalled, single-walled and superlong carbon nanotubes (VA-CNTs) were synthesized by various CVD methods • Graphene sheets were also prepared by CVD and exfoliation of graphite

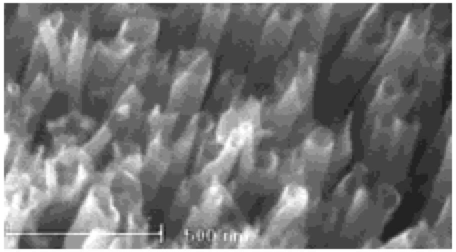
Research in Functionalization

•Functionalization of VA-CNTs and graphene sheets by plasma and solution chemistry

NEW INSIGHTS

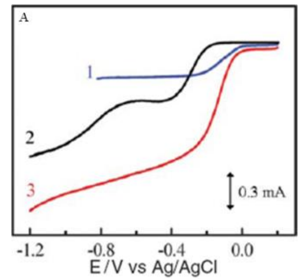
Energy –related Electrodes

• Tip-opened VA-CNTs and graphene sheets, with and without functionalization, as electrodes of a large surface area



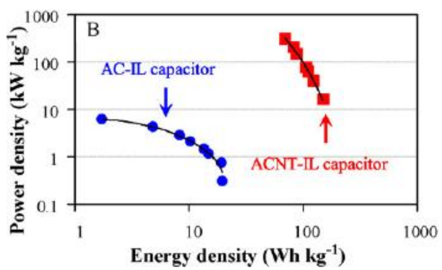
Photograph of the tip-opened VA-CNT array

MAIN ACHIEVEMENTS:



ORR in 0.1 M KOH (air) at the Pt (curve 1), VA-CCNT (curve 2), and VA-NCNT (curve 3)

• VA-NCNTs provides a four-electron pathway for the ORR with 3 time more active than Pt (*Science* **2009**, *323*, 760).



Ragone plots for the VA-CNT and AC (activated carbon) electrodes

HOW IT WORKS:

• N-atoms in the CNT plane positively charge adjacent C-atoms to facilitate electron transfer for ORR • Tip-opened VA-CNTs provide large surface for charge storage (*J. Power Sources* **2009**, *189*, 1270).

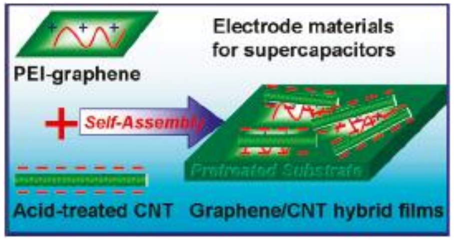
ASSUMPTIONS AND LIMITATIONS:

• Low-cost production of VA-CNTs is necessary for commercialization.

QUANTITATIVE IMPACT

Current Impact

• 3 time increase in the catalytic activity for oxygen reduction and order of tens fold increase energy density compared to typical fuel cell and supercapacitor, respectively.



CNT and graphene hybrid films of nanopores are promising electrodes (*J. Phys. Chem. Lett.* **2010**, *1*, 467).

END-OF-PHASE GOAL

Planned Impact

• VA-CNT and graphene hybrid systems for low-cost energy generation and storage devices

Research Goals

• Completion of the proposed objective • Discovery of new low-cost electrodes for energy devices in collaboration with Dr. Michael Durstock at AFRL.

Light-driven Synthetic Catalyst Splits Water for Use in Producing Fuels (Nocera, MIT)

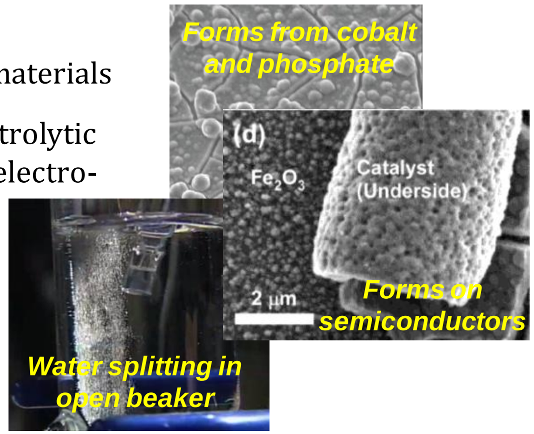
1. An In-Situ Water-Splitting Catalyst

Spontaneously self-assembles from water on any conducting surface

Made of earth abundant materials

Can operate under electrolytic (indirect) or photoelectro-chemical (direct) solar-to-fuels conditions

Efficiencies of >80% achieved at 100 mA/cm^2 of current



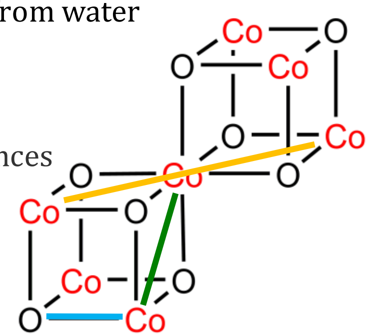
2. ...that Duplicates Photosynthesis

Has the structural and functional elements of the Oxygen-Evolving Complex (OEC)

Self-Assembly: a metal-oxo cubane from water

Structure: Photosynthesis has a manganese-oxo cube with the same metal-metal and metal-oxygen distances as the Co-OEC

Repair: Photosynthesis self repairs the OEC; Co-OEC is the first self-repairing catalyst



3. ...that Operates Under Benign Conditions and in Any Water Source

$$2H_2O \rightarrow O_2 + (4H^+ + 4e^-)$$

Catalyst takes output of photovoltaic or semiconductor and splits water:

- at room temperature
- in open atmosphere
- in neutral water
- has permitted Pt to be removed on H_2 production side

4. ...that is Simple to Engineer

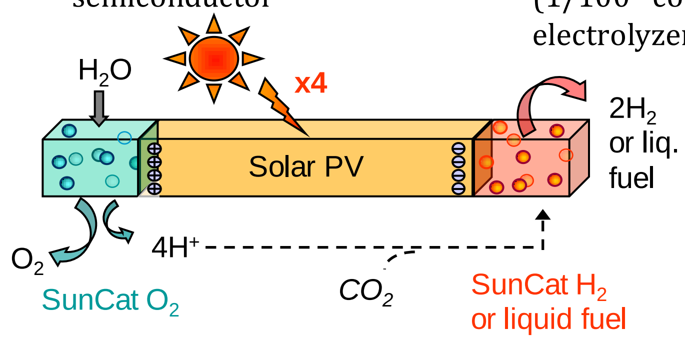
Low balance of systems cost for direct and indirect:

Direct Fuels Production

Catalyst works with direct output from a semiconductor

Indirect Fuels Production

Catalyst lends itself to high-through-put manufacturing (1/100 cost of commercial electrolyzers)



A Rich Set of Fundamental Issues

- Electron/hole transport and loss dynamics
- Electron transfer, charge separation
- Proton-coupled electron transfer (PCET)
- Dye-sensitized solar cells
- Plasmonics
- Materials for flexible solar cells
- Protective coatings
- Catalysis
  - Mechanisms, Earth abundant materials
  - Small Molecule Activation
  - Lifetimes, efficiency
  - Imaging
- Engineering, Manufacturing

Research Funding Opportunities at AFOSR

- Core Program – AFOSR Broad Agency Announcement
- Multidisciplinary University Research Initiative (MURI)
- Defense Univ. Rsch. Instrumentation Program (DURIP)
- Young Investigator Program (YIP)
- DOD Research and Educational Program (HBCU/MI)
- Small Business Technology Transfer (STTR)
- Summer Faculty Fellowship Program (SFFP)
- Graduate and Postdoctoral Fellowship Programs
- National Security Science and Engineering Faculty Fellowships (NSSEFF)

Concluding Remarks

AFOSR continues to *discover, shape, and champion basic science that profoundly impacts the future Air Force*

- **Supporting world-class basic research**
- **Educating tomorrow's scientific leaders**
- **Providing meaningful transitions now**
- **Filling pipeline for future transitions**

"There are those who say we can't afford to invest in science, that it's a luxury at a moment defined by necessities. I could not disagree more. Science is more essential for our prosperity, our security, and our health, and our way of life than it has ever been." – President Obama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