Advanced Materials

1. FAA Center of Excellence: AMTAS (Prof. Mark Tuttle)
2. Center for Intelligent Materials and Systems (CIMS) (Profs. Minoru Taya and Chunye Xu)
   • Actuator and sensor materials
   • Electro-chromic window technology
   • MURI 2006 Project on Energy Harvesting and Storage System
3. Fracture Mechanics and Fatigue (Prof. M. Ramulu)
4. Multifunctional Materials (Prof. Jiangyu Li)
5. Multifunctional composite (Prof. Jae Chung)
FAA Center of Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS)

- Joint Advanced Materials and Structures (JAMS) Center announced by FAA in Dec ‘03 with two co-lead universities:
  - UW: Center for Advanced Materials in Transport Aircraft Structures (AMTAS)
  - WiSU: Center of Excellence for Composites and Advanced Materials (CECAM)

- UW/AMTAS Administrative Personnel:
  - Mark Tuttle, Director, ME Department
  - Kuen Lin, Co-Director, A&A Department
  - Ellen Barker, Assistant to Director, ME Department

- Detailed website:  http://depts.washington.edu/amtas/
AMTAS Participants

Academic Partners

- University of Washington (UW; ME, AA, MSE Depts)
- Washington State University (WSU)
- Oregon State University (OSU)
- Edmonds Community College (EdCC)

Eleven industrial partners (large & small), all with significant presence within the greater Puget Sound Region. Most active and engaged is Boeing-Commercial
AMTAS Funding Levels

Summary of total funding levels to date (8/2006):

- **FAA Cash:** $1,257k
  - UW: $958k/WSU: $104k/EdCC: $195k

- **AMTAS Match:** $1,230k
  - Cash:
    - Boeing: $200k
    - UW: $200k
  - In-Kind:
    - Boeing: $811k
    - UW: $573k/WSU: $27k/EdCC: $211k
    - Intec: $9k (UW)
    - Heaton: $10k (UW:$2k/EdCC: $8k)
    - Recent mat’l donations from Cytec and Toray not yet included)

- **Total:** $2,487k
Initial 3-yr Phase I funding expires Sept ‘07. Phase II funding likely

Intend to evolve AMTAS into regional center for composite-advanced mat’ls and manufacturing, supporting multiple industries (aerospace, automotive, trucking, marine, energy, bio, etc)

Possible links to (or collaborations with) Advanced Materials Center being developed by Alex Jen and announced Spring ’06 not yet explored

International collaborations evolving (e.g., with U. of Manchester)

Challenges:
• Well-established competitors (within US and abroad) receive substantial support from federal/national/local governments
• UW lab infrastructure/facilities non-competitive
• Must expand funding base beyond FAA and Boeing
• Research directions dictated by FAA - frustrating
Center for Intelligent Materials and Systems (CIMS)

- Established in 2000.
- Participating faculty: Taya (ME), Xu(ME) and Kuga(EE).
- Researchers supported annually(2005): one research faculty, 5 post docs, 5 RA students.
- Funding sources: NSF, AFOSR, ONR, Darpa, Army, Boeing, Honda, Noastec Foundation, Hitachi Powdered Metals, TGIF.
- Objectives: Research on design, synthesis of active and sensing materials and their devices.
- CIMS researchers are ranked among top 1-5 inventors of the year in UW-OTT report in 2004 and 2005.
- New research starting on May 2006: AFOSR- MURI on Energy Harvesting and Storage for Future AF vehicles. $6M budget for five years (2006-2011)
- Threat: Lab space currently in Fluke Hall is not semi-permanent, threatened to move out !!!

UW - Center for Intelligent Materials and Systems
New Actuator Material: shape memory alloy (SMA) and Ferromagnetic SMA

3D-phase diagram

Stress ($\sigma$) vs. Temperature (T) vs. Magnetic Field (H)

- martensite phase
- austenite phase

Graphs:
- Young's modulus (GPa) vs. Temperature (°C)
- Temperature vs. Martensite Phase ($Ms$ vs. Temperature (°C))
Applications for SMA / FSMA

- Bio-inspired flight
- FSMA composite synthetic jet actuator
- High temperature SMA actuator/sensor
- FSMA composite linear inchworm actuator
- High energy absorbing SMA foam

UW - Center for Intelligent Materials and Systems
UW design of Synthetic Jet Actuator (SJA) for control of unstable low Mach number flight

- FSMA composite diaphragm
- Electromagnet
- Jet slots
- Wing box
- SJA cylindrical package

Graph showing flow velocity (m/s) vs. frequency (Hz):
- Flow velocity decreases as frequency increases.

UW - Center for Intelligent Materials and Systems
Flapping motions of a FSMA composite wing for MAV

Power input: 5V, 0.9A
Flapping frequency: 19Hz
Flapping angle = 115°

NiTi wing frame:
thickness = 0.3mm
width ranging from 2.2mm to 0.5mm
(depending on location)
High energy absorbing SMA for use in protecting human against blast loading and collision.
High energy absorbing SMA foam

(a) Specimen length (mm)

- With side force
- Without side force

$\sigma_s = 131$ MPa, $E = 205$ GPa
$t = 2$ mm, $W = 20$ mm

- Open: elastic buckling (Euler’s estimation)
- Solid: plastic buckling (Johnson’s estimation)

(b) Side constrain

Side force $F$ required for buckling mode change (N)

- $P_{c1}$
- $P_{c2}$

Side constrain

Buckling load (N)

- $13\%$ porosity NiTi
- Solid NiTi

Stress (MPa)

- 0 1 2 3 4 5 6
- 0 200 400 600 800 1000 1200

Strain (%)

- 0 1 2 3 4 5 6
- 0 100 200 300 400 500 600

UW - Center for Intelligent Materials and Systems
Electrochromic Windows

- Enlarge size
- Scale down

ECW of aircraft

Welding shields


http://www.sage-ec.com/pages
ECWs in Various Scales

1x1, 3x3, 6x6, 12x12 inch

12 x 20 inch
(30.5 x 50.8 cm)

Electroactive polymer for Bio-sensors and actuators

**Ionic polymer**

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\end{align*}
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Flemion (Asahi Glass)

Nafion (Dupont)

**Compliant Electrode** key technology for durable use

Gold plating by impregnation reduction

Cross section

Scheme

Solvent and counter ion

Alkali metals, alkaline earth metals, alkyl ammonium

MURI on Energy Harvesting and Storage Systems (EHSS)

Period: May/2006-May/2011
Funding: $6M
Funding Agency, AFOSR

Researchers:
Minoru Taya, PI of the entire team
UW: Chunye Xu (ME), G. Cao(MSE),
S. Jenekhe(ChemE), Y. Kuga(EE)
CU: M. Dunn, K. Maute, R. Yang
UCLA : T. Hahn, S Ju
VPI : D. Inman

Collaborating Industry, Boeing, etc.

Goal : To develop a set of energy harvesting materials and systems for future AF vehicles

April 7, 2006

UW - Center for Intelligent Materials and Systems
Multi-scale approach to design of energy harvesting aircraft systems

a. system level
- Polymer solar cells (PSC)
- Antenna system under the wing with TE
- Thermo-electric (TE)

b. component level
- Polymer battery cells
- Polymer solar cells
- Antenna
- TEC
- PBC

Polymers & matrix composite (PMC) cell
- Battery package layer (BPL)
- Cathode
- Anode
- Binder polymer
- Porous Cu collector
- Carbon nano tube network
- Porous Cu collector
- Power amplifier
- Thermal interface material (TIM)

C. material level
- Polymer solar cell
- Polymer matrix composite (PMC) cell
- Battery package layer (BPL)
- Cathode
- Anode
- Binder polymer
- Porous Cu collector
- Carbon nano tube network

D. nano-composite level
- n-type TE
- p-type TE
- TEC
- Porous Cu collector
- Carbon nano tube network
- Binder polymer
- Porous Cu collector

UW - Center for Intelligent Materials and Systems
Multifunctional Materials Laboratory

PI: Jiangyu Li
Postdoc: L. Zhang; Graduate Students: Q.G. Du, Y.F. Ma, L.J. Li, B. Walsh

Sponsors: NSF/DMI/DMR, ONR/UNL, ACS PRF, UW RRF

Mission: to Analyze, Design & Optimize Multifunctional Materials/Structures
Systems: Ferroelectrics, Magnetics, Multiferroics, EAP, Nanocomposites...
Applications: Sensing, Actuation, Energy Harvesting/Storage, Information Processing, etc

Multifunctional carbon nanotube composite
Chung; nanomanufacturing lab.

Objective: multifunctional carbon nanotube composite for extreme specific-strength, toughness, high thermal stability, excellent mechanical damping properties and high electrical conductivities. Carbon nanotube weaver to fabricate CNT texture by capillary reaction with dielectrophoresis.