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
  - Heaton: $10k (UW:$2k/EdCC: $8k)
  - Intec: $9k (UW)
  - Recent mat'l donations from Cytec and Toray not yet included)

- Total: $2,487k

AMTAS – Future

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)

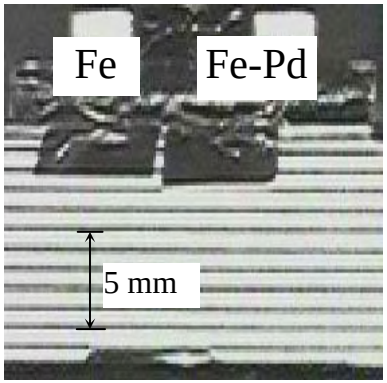
Challenges:

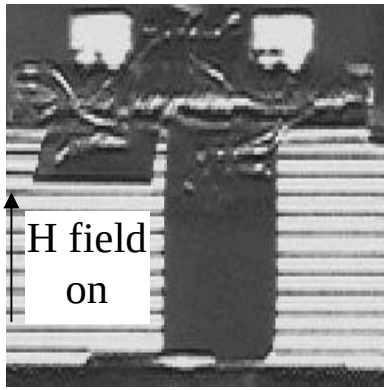
- Well-established competitors (within US and abroad) receive substantial support from federal/national/local governments
- UW lab infrastructure/facilities non-competitive
- Must expand funding base beyond FAA and Boeing
- Research directions dictated by FAA - frustrating

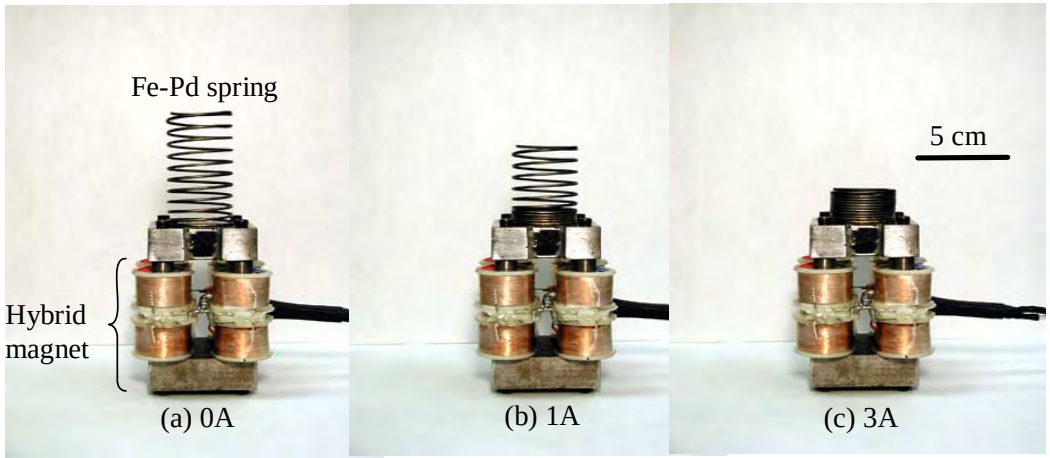
Center for Intelligent Materials and Systems (CIMS)

- Established in 2000.
- Participating faculty: Taya (ME), Xu(ME) and Kuga(EE).
- Annual research expenditure: increasing from $500K(2000) to $1.2M(2005).
- Researchers supported annualy(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 !!!

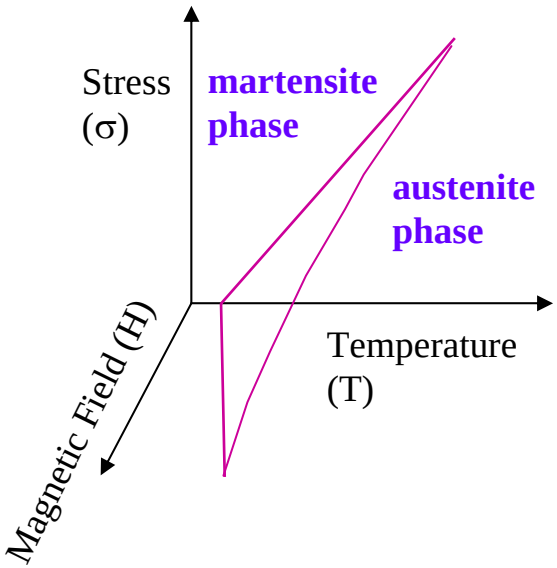
New Actuator Material : shape memory alloy (SMA) and Ferromagnetic SMA

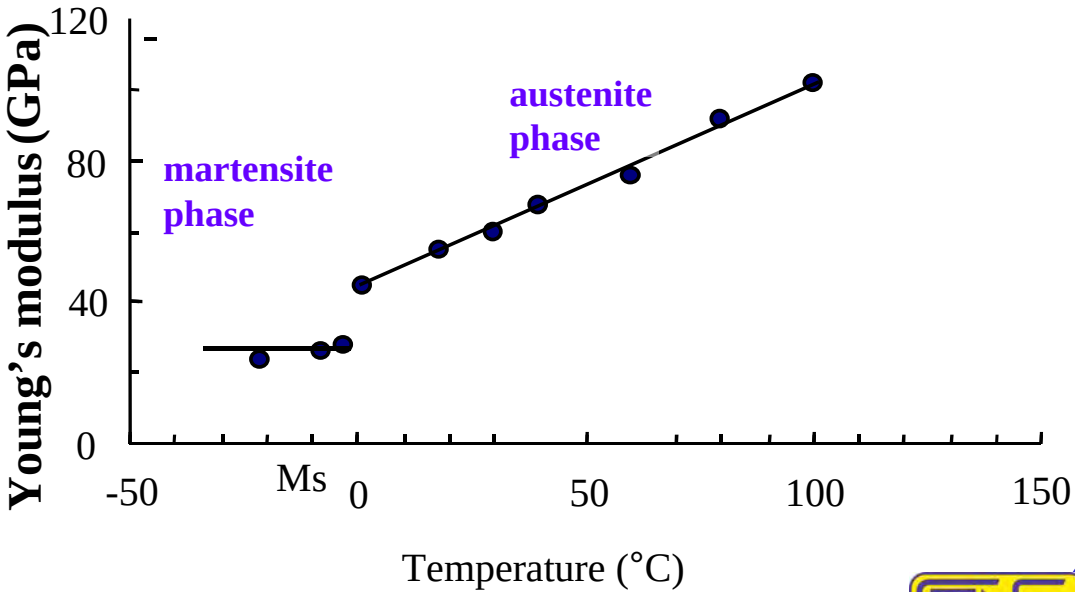






3D-phase diagram





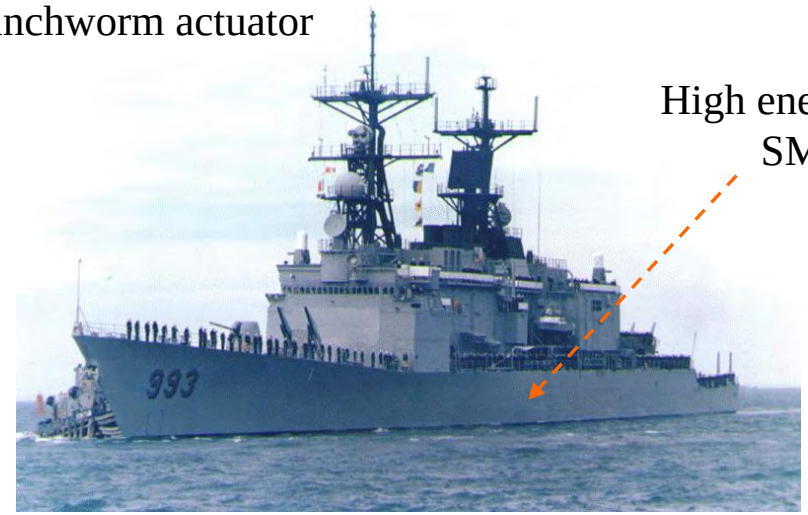
Applications for SMA / FSMA

FSMA composite synthetic jet actuator

High temperature SMA actuator/sensor

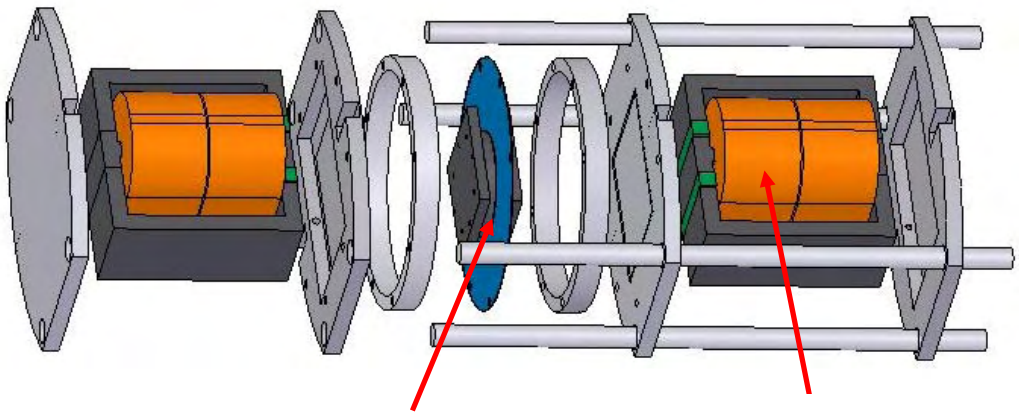
FSMA composite linear inchworm actuator

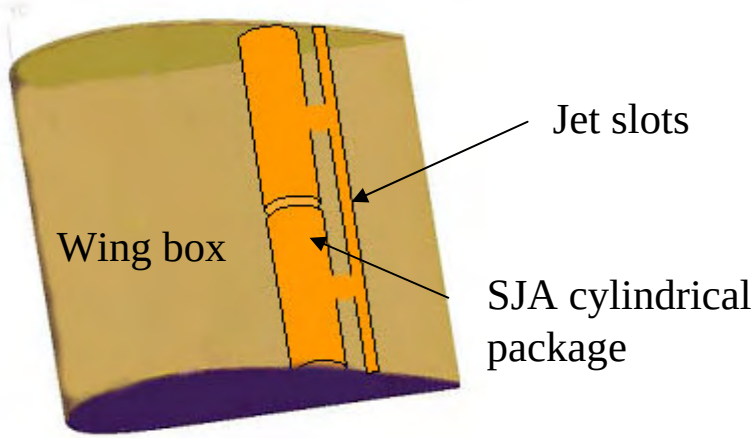
Bio-inspired flight

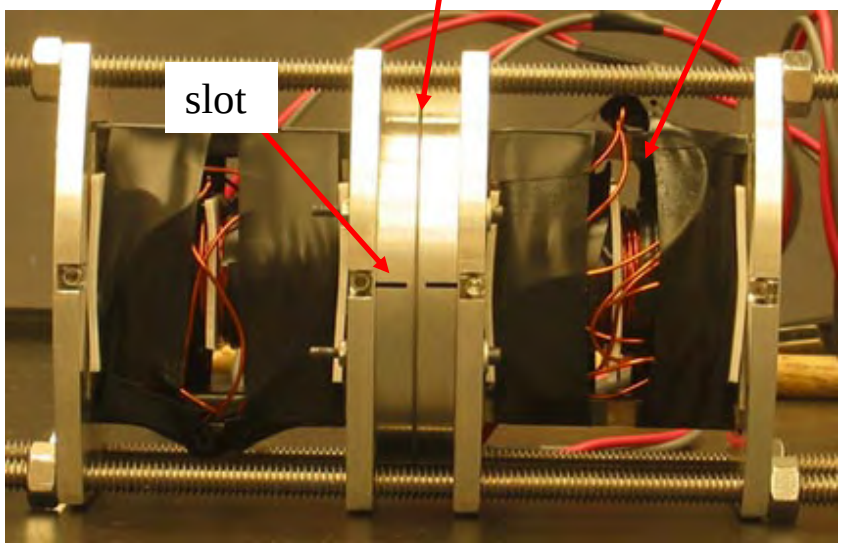


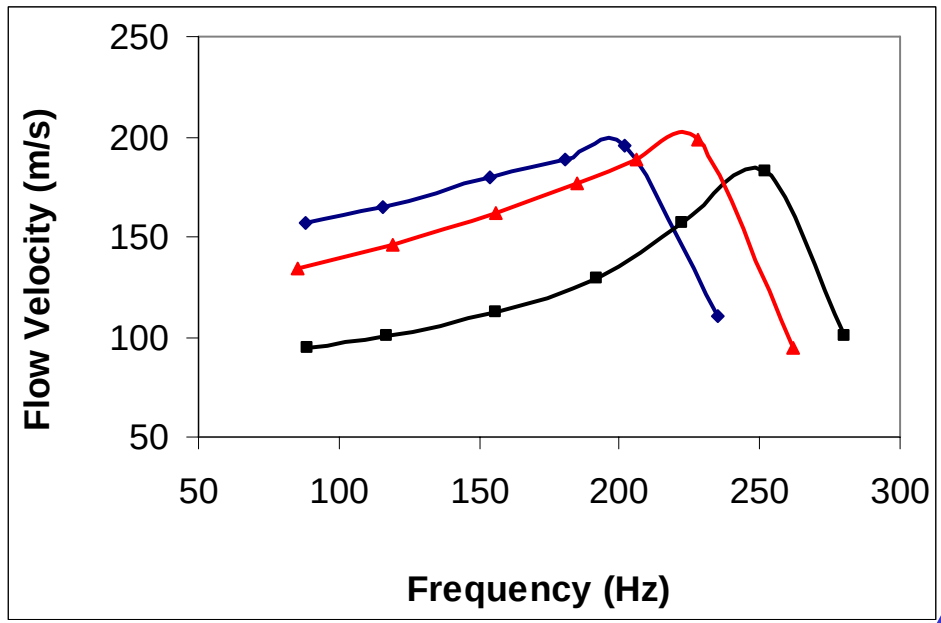
High energy absorbing SMA foam

UW design of Synthetic Jet Actuator (SJA) for control of unstable low Mach number flight

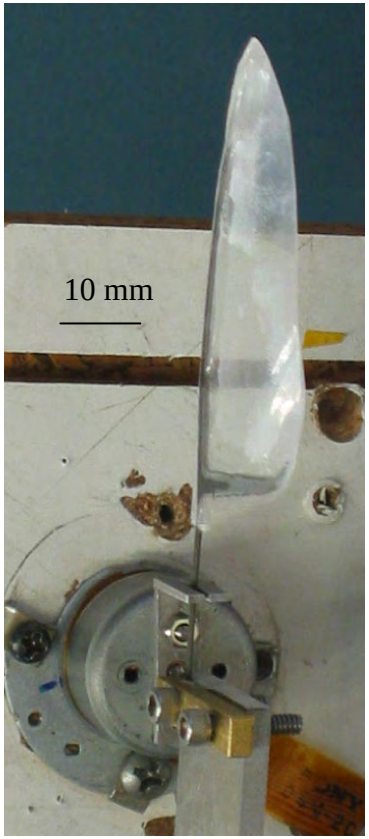




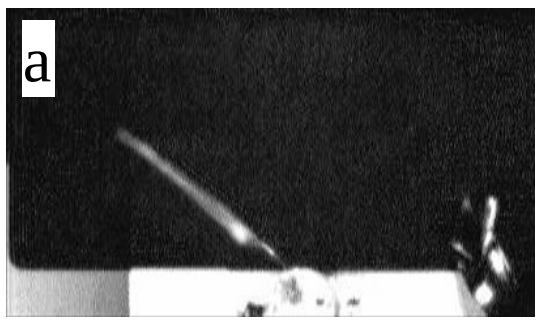


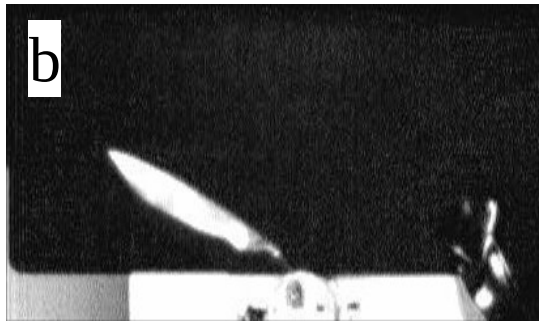


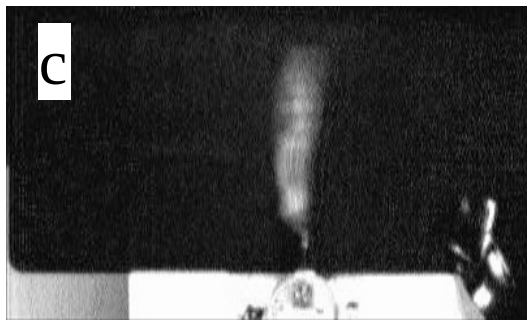
Flapping motions of a FSMA composite wing for MAV

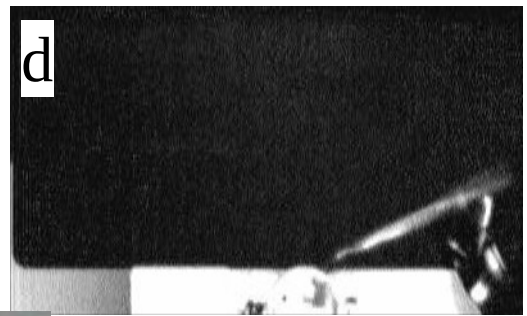


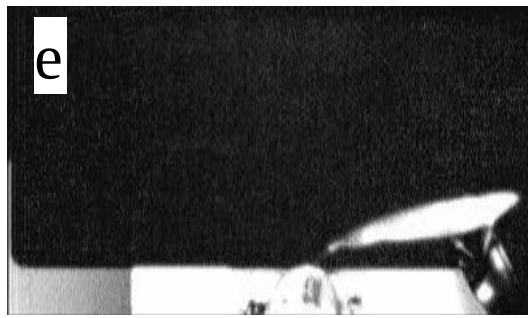
Power input: 5V, 0.9A
Flapping frequency: 19Hz
Flapping angle = 115°

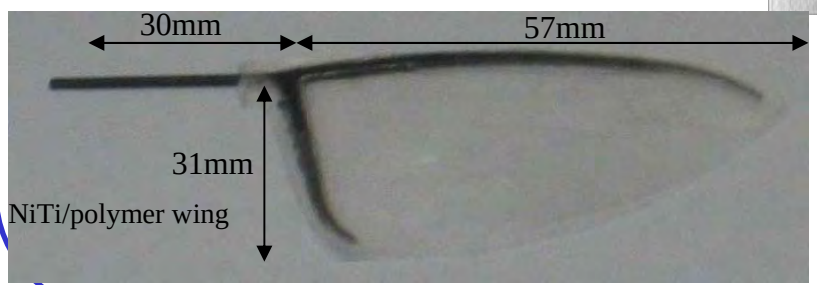






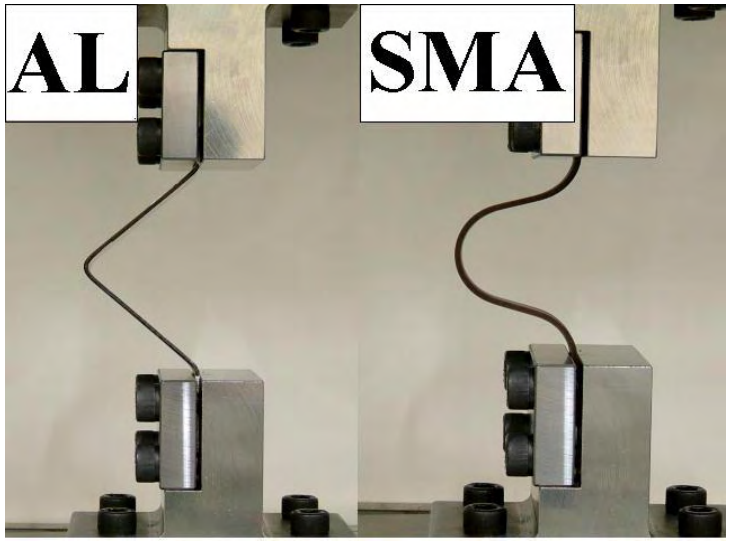


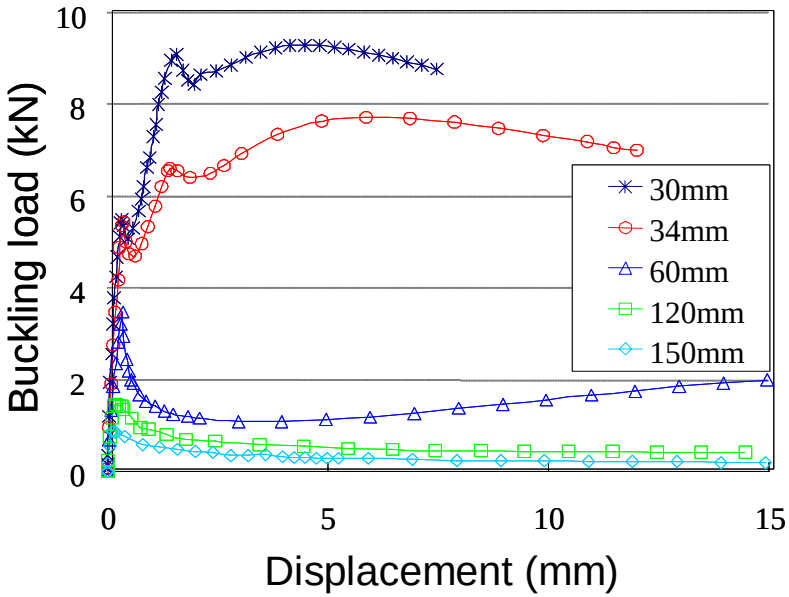


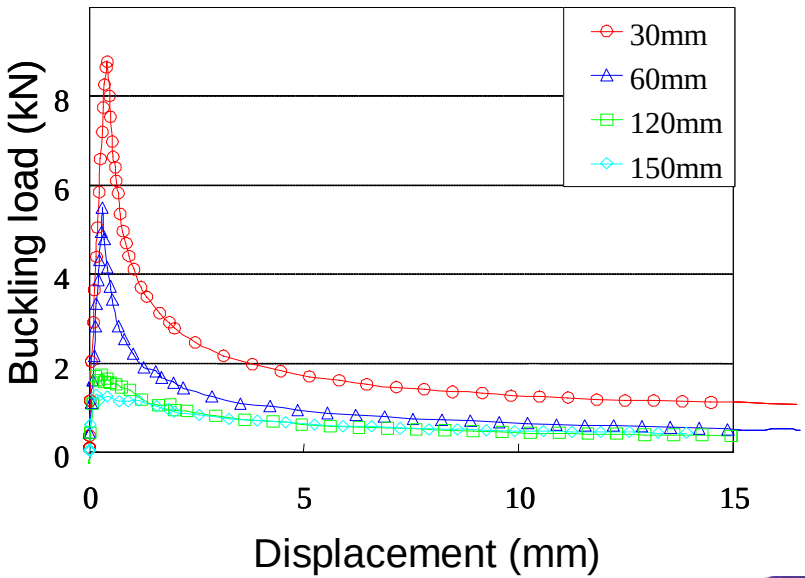


NiTi wing frame:
thickness = 0.3mm
width ranging from 2.2mm to 0.5mm
(depending on location)

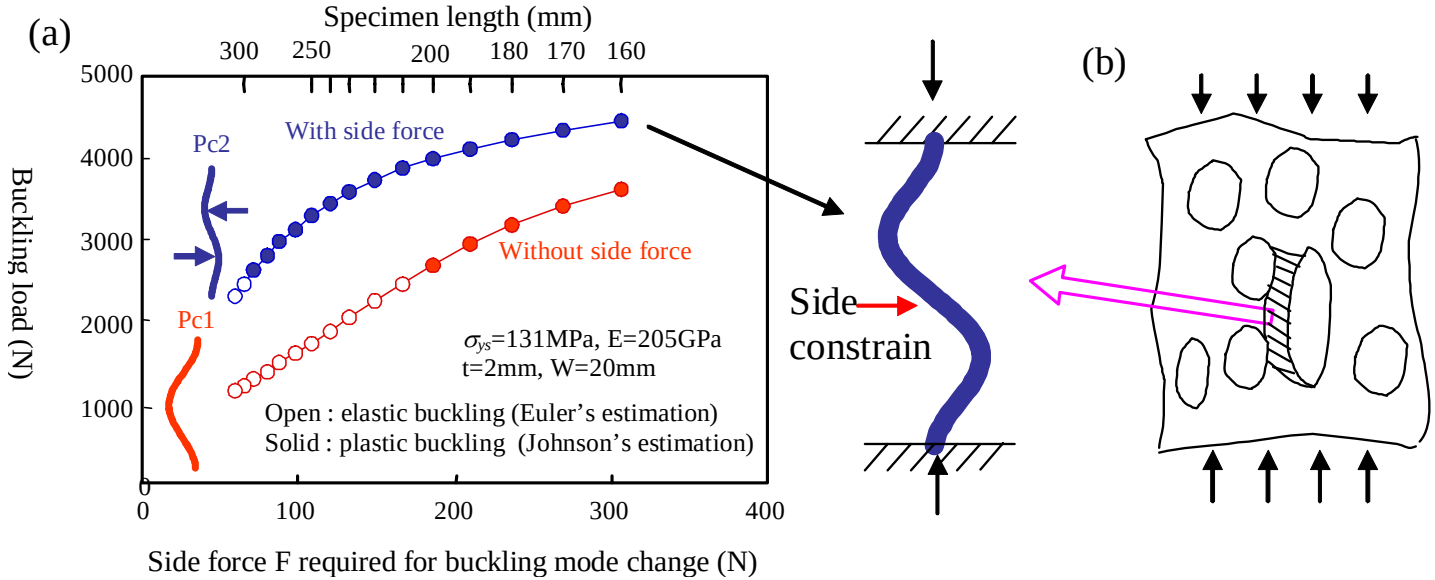
High energy absorbing SMA for use in protecting human against blast loading and collision

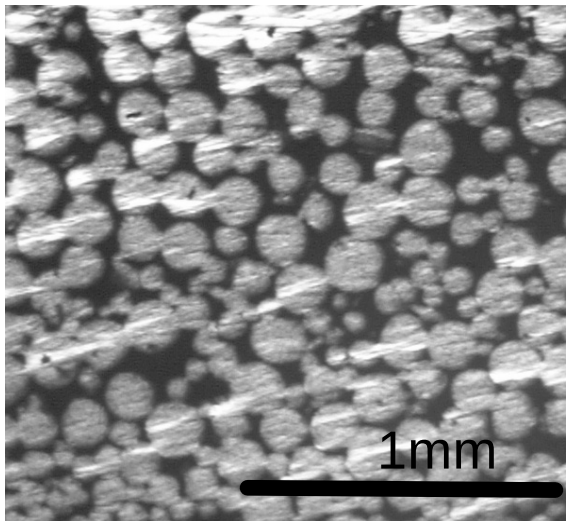


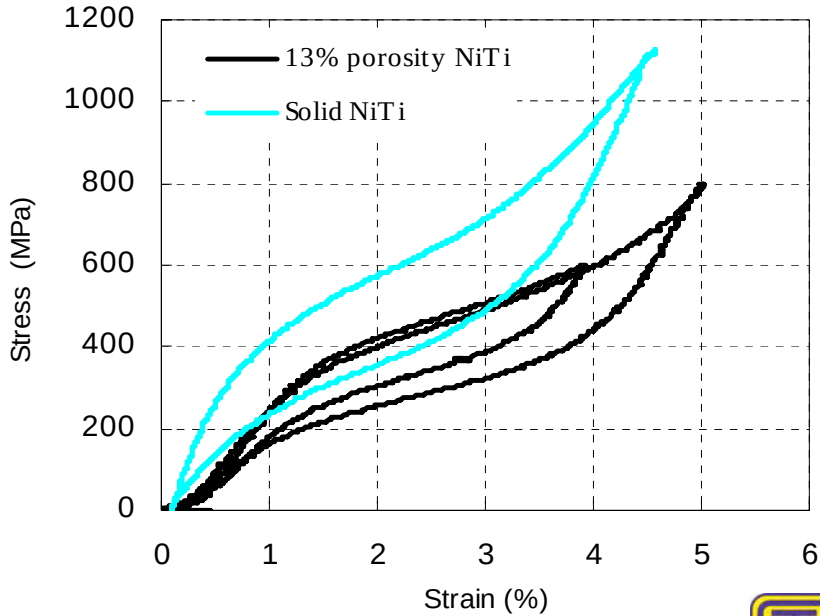




High energy absorbing SMA foam

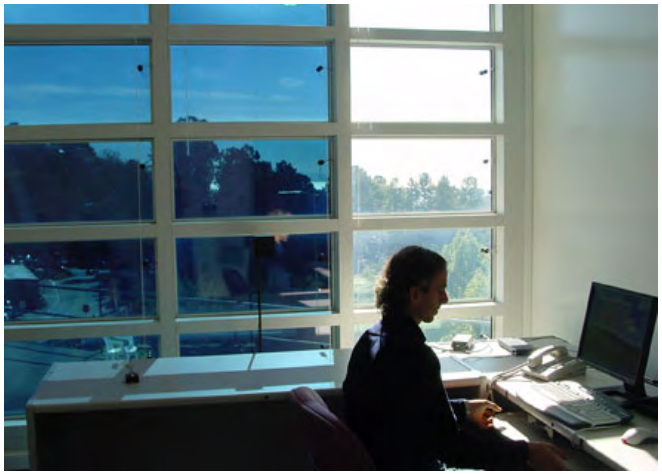






Electrochromic Windows

- Enlarge size
- Scale down



http://www.sage-ec.com/pages

ECW
of aircraft

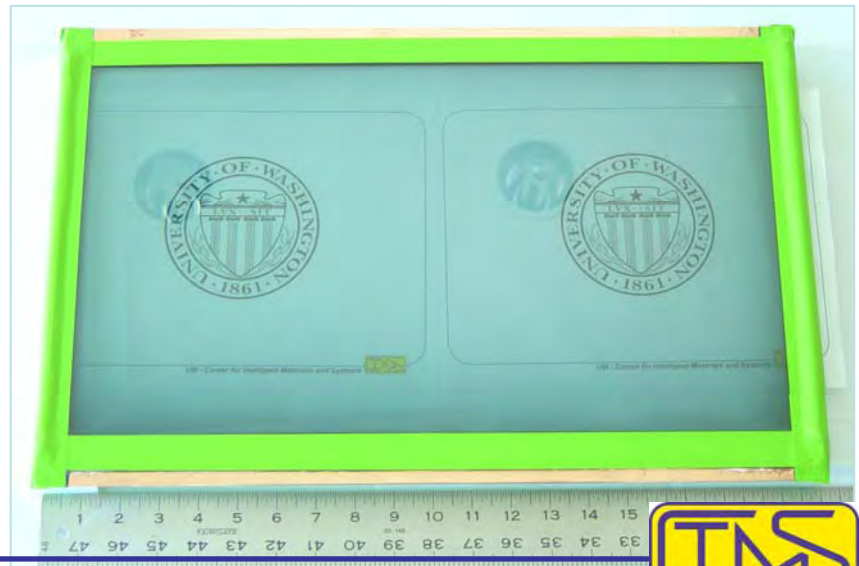
welding shields

Xu, C., Kong, X., Liu, L. Su, F., Kim, S. and Taya, M., “Smart Glass Based on Electrochromic Polymers” Smart Structures and Materials, *Proc. SPIE*, Vol. **6168,** pp.61681N, 2006

ECWs in Various Scales

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

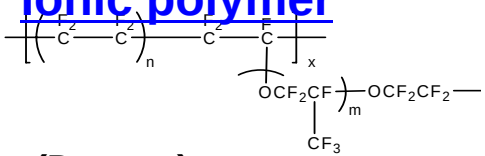
12 x 20 inch
(30.5 x 50.8 cm)



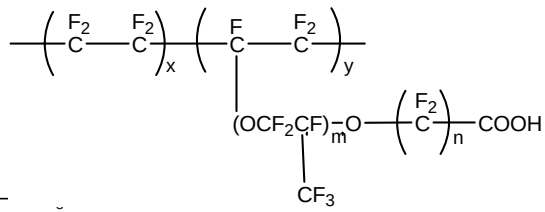
Xu, C., Liu, L., Legenski, S. E., Ning, D., and Taya, M., "Switchable Window Based on Electrochromic (EC) Polymers", *Journal of Materials Research*, Vol.**19**, No.7, pp. 2072-2080, 2004

Electroactive polymer for Bio-sensors and actuators

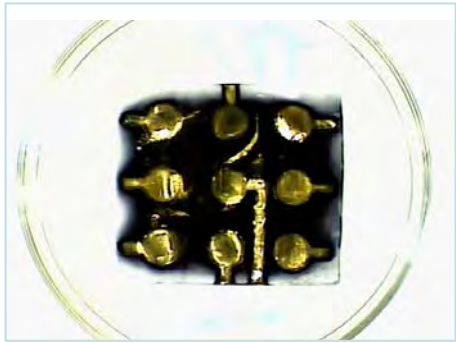
Ionic polymer



Nafion (Dupont)



Flemion (Asahi Glass)

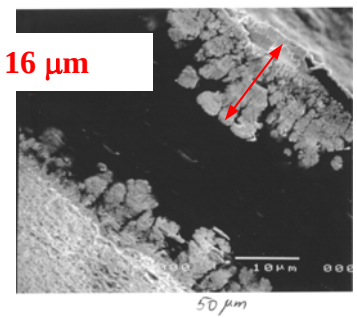


3x3 array actuator

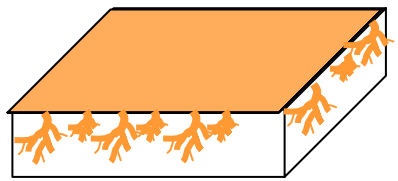
Compliant Electrode key technology for durable use

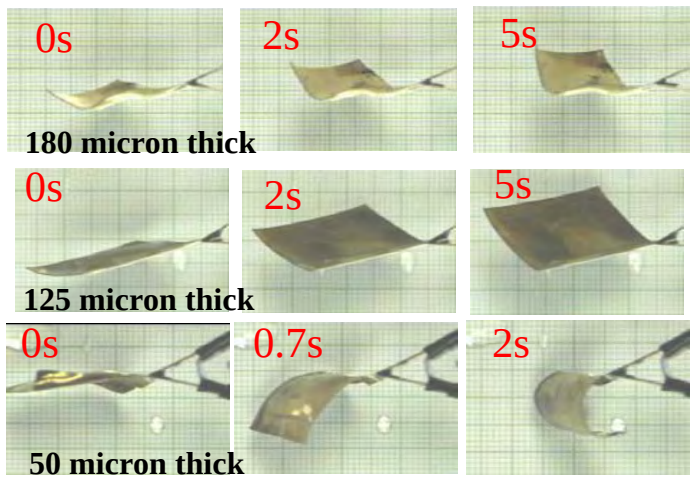
Gold plating by impregnation reduction

Cross section



Scheme





Fish fin

Solvent and counter ion

Alkali metals, alkaline earth metals, alkyl ammonium

Le Guilly, M., Xu, C., Cheng, V., Taya, M., Lucien Opperman and Yasuo Kuga, "Flemion Based Actuator for Mechanically Controlled Microwave Switch", Smart Structures and Materials, *Proc. SPIE*, Vol. **5051**, pp.362-371, 2003

MURI on Energy Harvesting and Storage Systems (EHSS)

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

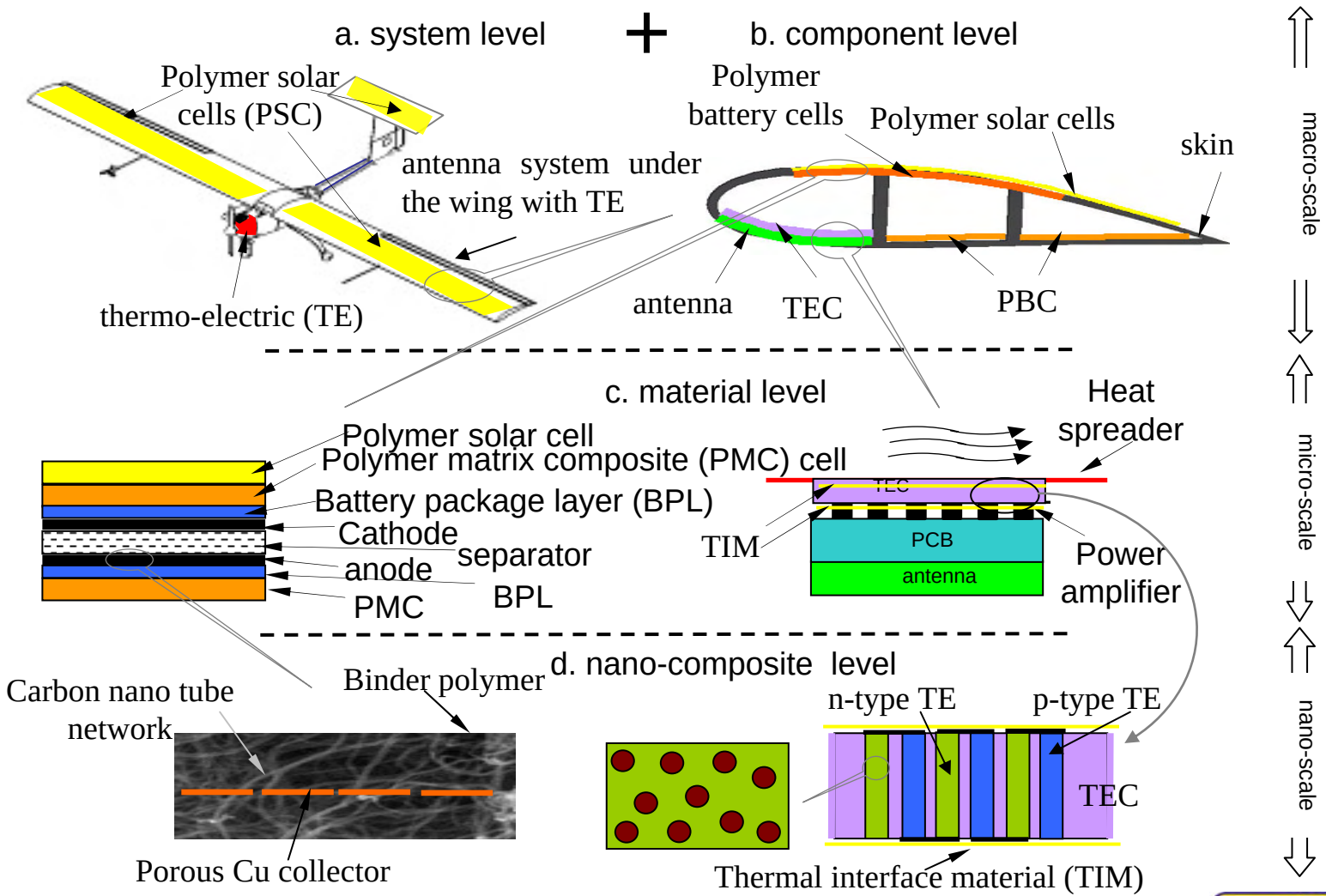
Researchers:
Minoru Taya, PI of the entire team
UW: Chunye Xu (ME), G. Cao(MSE),
S. Jenekhe(ChemE), Y. Kuga(EE)
CU: M. Dunn, K. Maute, R. Yang
UCLA : T. Hahn, S Ju
VPI : D. Inman

Collaborating Industry, Boeing, etc.

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

April 7, 2006

Multi-scale approach to design of energy harvesting aircraft systems



Multifunctional Materials Laboratory

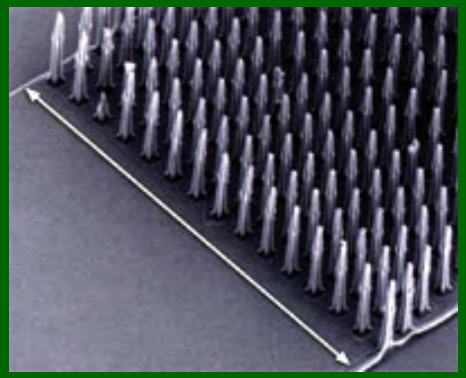
PI: Jiangyu Li

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

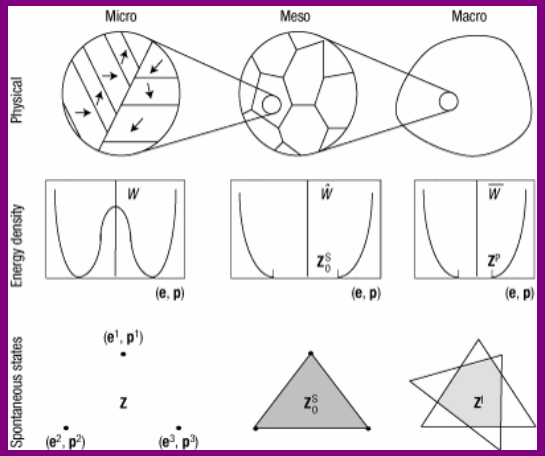
Experiment

Microcompounding



Nanoimprinting

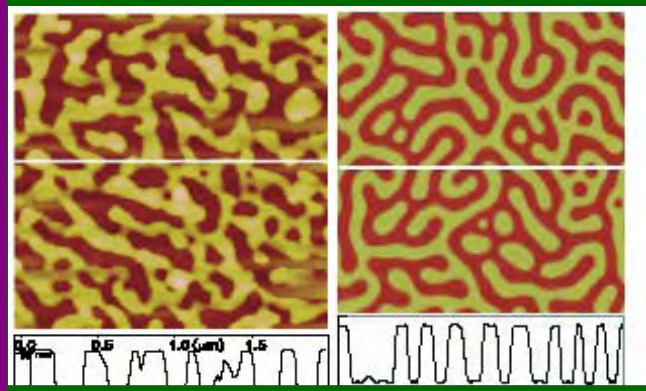
Theory



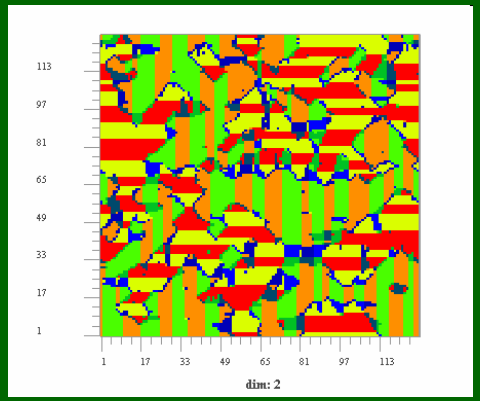
Multi-scale Theory of Ferroelectrics

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

Computation



Nanostructure Formation



Domain Configuration

Key Publications in Nature Materials, Physical Review Letters, Applied Physics Letters, JMPS

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.