## MAE Research Matrix

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<thead>
<tr>
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<tbody>
<tr>
<td>Advanced Aerospace Systems</td>
<td>Dapino, Kahraman, McNamara, Öz, Parker, Shen</td>
<td>Kahraman, Parker</td>
<td>Chen, Dapino, Dunn, Haldeman, Kahraman, McNamara, Öz, Parker, Shen, Singh, Yedavalli</td>
<td>Adamovich, Benzakein, Bons, Chen, Dunn, Freuler, Gaitonde, Gregory, Haldeman, Kahraman, Lempert, McNamara, Samimy, Subramaniam, Sutton, Yu, Zhuang</td>
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<td>Energy and Environmental Quality</td>
<td>Ghosh, Kahraman, McNamara, Öz, Shen</td>
<td>Denning, Kahraman, Walter</td>
<td>Blue, Canova, Cao, Guezennec, Kahraman, McNamara, Öz, Parker, Rizzoni, Singh, Utkin, Wang, Yedavalli</td>
<td>Benzakein, Bons, Canova, Denning, Gaitonde, Gregory, Guezennec, Heremans, Kahraman, Lempert, Mazumder, McNamara, Moran, Prakash, Samimy, Selamet, Sun, Sutton, Zhuang</td>
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<td>Nuclear Energy</td>
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<td>Blue, Cao, Smidts, Yedavalli</td>
<td>Aldemir, Cao, Denning, Sun</td>
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Tumor metastasis: A force journey

(a) Primary tumor growth

(b) Angiogenesis

(c) Local invasion

(d) Intravasation

(e) Survival in circulation

(f) Arrest at secondary sites and extravasation

(g) Angiogenesis and metastatic outgrowth

Ma & Weinberg 2008
Working Principle of AFM Imaging
Tapping-Mode Imaging

Gently taps
Mechanical Property Mapping of Cells
(Menq and Jhiang)

Operation freq. : 5 kHz; Scanning speed : 0.5 Lines/sec; Image resolution: 256x256 pixels

Bright field image

Height image (AFM)

Damping coeff. map

Stiffness map

Histogram for one image (map)
What we (mainly) do: Synthesize and characterize thermoelectric materials

solid state heat converters generate electricity directly from heat

The relation of a thermoelectric converter to a classical heat engine is like that of a transistor to a vacuum tube:
• All solid state
• No moving parts
• Almost no maintenance
• Almost infinite lifetime
• 100 - 1000x higher power density
• lower efficiency
Research: increase efficiency

Enhancement of Thermoelectric Efficiency in PbTe by Distortion of the Electronic Density of States
Joseph P. Heremans, et al.
Science 321, 554 (2008);
DOI: 10.1126/science.1159725

End-product: exhaust waste heat thermoelectric generator
5.5% increase in mpg
Materials for other temperature ranges...

Cooling – Room Temperature
Automotive HVAC

Cooling – Extremely Low Temperature
Night vision

Provides cooling with electrical power heated/cooled seats in mid- and full luxury autos

... and have begun working on thermodynamics of spins
(for anyone more interested in physics)

Visit us! W490
Chris Jaworski.15
Joseph Heremans.1
mecheng.osu.edu/TML

Observation of the spin-Seebeck effect in a ferromagnetic semiconductor

C. M. Jaworski¹, J. Yang², S. Mack³, D. D. Awschalom³, J. P. Heremans¹, and R. C. Myers²,⁴
Ignition and flameholding of high-speed flows by low-temperature plasmas

- Conventional “point source” ignition methods (spark plugs, high-temperature arcs) are ineffective in high-speed flows: cooling occurs more rapid than heating. Imagine lighting and holding a match in a hurricane wind! Plasma ignition demonstrated to Mach 1 (350 m/sec) in lean ($\phi = 0.5$) in H$_2$–air and 100 m/sec in ethylene-air.

- Low-temperature plasma produced by repetitive nanosecond duration pulses: large-volume, stable, generates chemically active radical species (O and H atoms, OH) efficiently

- Reactions between fuel and radicals start at low temperatures and result in large-volume (rather than a point source) ignition, complete combustion

- After ignition, plasma serves as a flameholder; without it flame is blown off by a high-speed flow

- Applications: combustion in jet engine afterburners, supersonic combustion in scramjet engines

- Support: Air Force, NASA
Plasma temperature in cavity and burned fuel fraction vs. flow velocity and static pressure

- Open symbols: air; closed symbols: ethylene-air
- Air plasma temperature in the cavity: $T=200-400^\circ$ C; stable and diffuse plasma
- Ethylene-air plasma temperature: $T=500-900^\circ$ C (significant temperature rise)
- Flame blows off when air-fuel plasma temperature falls below $T\approx 500^\circ$ C
- Flame blow-off velocity considerably increases at higher static pressures (12 m/s at 70 torr, 20 m/s at 100 torr, 50 m/sec at $P=150$ torr, >65 m/sec at $P=200$ torr)
How Does This Work?

- At OSU we utilize specialized pulsed discharge plasma devices, some of our own design and fabrication.
- These “pulsers” create high voltage (~20 kV) short duration (~10 nsec) plasmas at repetition rates as high as 100 kHz.
- Each pulse creates a large pool of radical species, in particular O and H atoms, which initiate combustion reactions at low temperature (~300 K). In ordinary combustion the fuel must be heated to ~1500 K in order to create this initial radical pool (This is what a spark plug does). In addition, this radical pool is created in a large volume, rather than in “filaments”
Fundamental Kinetic Studies

We also perform a large variety of fundamental kinetic studies using advanced laser diagnostic methods.

- Atomic Oxygen and Hydrogen by Two Photon Laser Induced Fluorescence.
- OH and NO by Single Photon Laser Induced Fluorescence.
- Temperature by Coherent Anti-Stokes Raman Spectroscopy (CARS).

Temperature, determined by CARS, as Function of Number of Discharge Pulses at 40 kHz repetition rate.

Discharge Test Section
- Electrode dimensions
  65 mm(l) x 14 mm(w)
- Quartz cell dimensions
  220 mm(l) x 22 mm(w) x 10 mm(h)
A Comparative Analysis of Energy Management Strategies for Hybrid Electric Vehicles

L. Serrao, Ph.D. ME, 2009, currently at IFP, Paris, France
S. Onori, Sr. Research Associate, CAR
Giorgio Rizzoni, Professor, MAE, and Director, CAR
Hybrid Electric Vehicles

• By definition, HEVs include two energy storage devices on board:
  – fuel tank
  – rechargeable energy storage systems (RESS), such as battery, supercapacitors, flywheels etc.

• Wheels are powered by engine and/or electric motors

• Advantages:
  – energy recuperation during braking (regenerative braking)
  – more flexibility in engine operation improves efficiency

• Flexibility implies need for power split control (energy management)

(Courtesy of Toyota Motor Sales USA, Inc.)
The energy management problem in HEVs

In a generic hybrid electric powertrain, there is at least one degree of freedom in the way power is delivered to the wheels → possibility of power split optimization
Case study: EcoCAR

- Competition among universities to build plug-in hybrid vehicles
- OSU vehicle uses a dual-mode architecture, series or parallel (clutches are used to switch between modes)
- Only series configuration is considered here
- This vehicle can be charge-sustaining or charge-depleting
Generic optimal control problem

Objective is to find a control $u(t)$ defined in the time interval $[t_0, t_f]$ that minimizes the cost function:

$$J = \phi(x(t_f), t_f) + \int_{t_0}^{t_f} L(t, x(t), u(t)) dt$$

while satisfying:

- the system dynamic equation $\dot{x} = f(t, x, u)$
- the instantaneous state constraints $G(x) \leq 0$
- the instantaneous control constraints $u(t) \in U(t)$
- the initial conditions $x(t_0) = x_0$
- the final conditions (if defined) $x(t_f) = x_f$
This hybrid architecture has one degree of freedom: one between RESS and generator power must be chosen such that

\[ P_{\text{req}}(t) = P_{\text{ress}}(t) + P_{\text{gen},e}(t) \]

(the other will be determined by difference with the total power request)

The form of this power balance equation is a characteristic of the specific architecture
Connecting DP, PMP, and ECMS

**Dynamic Programming**
Optimal solution
Not implementable
Long computations

→ **Use i-ECMS as an implementable optimal strategy**

**ECMS**
Easy implementation
need for tuning
Sub-optimal

1. The optimal solution can be found using PMP under suitable problem definition

2. ECMS and PMP are equivalent if the equivalence factors are time-varying and properly defined

3. **Minimum principle**
*Necessary* conditions for optimal solution
Gives sufficient conditions and unique optimal solution in some cases
The energy management problem for hybrid electric vehicles has been formalized and studied in detail.

Two optimal control techniques (DP and PMP) have been applied to the HEV case showing that a typical energy management technique, ECMS, can be seen as an implementation of a formal optimal control solution.

Simulations corroborate the theoretical results.

The theoretical equivalence of ECMS with the optimal solution and the relation with the minimum principle can be used to improve ECMS implementation and propose new methods of adaptation.