Information Storage Device Physics

- Energy localization
- Storage materials
- Hysteretic phenomena
- High frequency switching

**Heat Assisted Magnetic Recording**

![Diagram showing heat assisted magnetic recording](image_url)

**Graph showing voltage vs. current**

- Perovskites
- Magnetic Marks
- Field Emission
- STM Tip

**Magnetic Medium**

- SrTiO₃
- SrRuO₃
- Cr-SrZrO₃

**probe Recording**

**Courses:**

- 18-416: Information Storage Systems
- 18-517: Information Storage Systems Design

**Professor**

James A. Bain

Department of ECE
Data Storage Systems Center
http://www.ece.cmu.edu/~jbain

jbain@ece.cmu.edu
ECE Advising:
Getting Your Questions Answered
James A. Bain

The Oracle at Delphi
Outline

- Logistics of the advising and mentoring process
- Objectives of the advising and mentoring process
- Advising summary
- Data storage technology overview
Logistics of Advising Process

• Fall Sophomore Year
  – Take 18-200: Emerging Trends in ECE
  – Receive advisor assignment
  – Complete advising preparation worksheet
  – Meet with advisor (possibly more than once)
  – Select classes for Spring 05

• Spring Sophomore Year
  – Meet with advisor (possibly more than once)
  – Request/select a faculty mentor
  – Meet with faculty mentor
  – Select classes for Fall 06

• Junior and Senior Years
  – Meet with faculty mentor as desired
  – Select classes for each semester
  – Plan for post-graduation:
    internships, jobs, fellowships, grad schools, etc.
ECE Undergraduate Advising Committee

Prof. Shawn Blanton
Prof. Tsuhan Chen
Prof. Dave Greve
Prof. José Moura
Prof. Priya Narasimhan
Prof. Dave O'Hallaron
Prof. Dawn Song
Prof. Peter Steenkiste
Prof. Tom Sullivan
Prof. Don Thomas
Prof. Elias Towe
Janet Peters
Undergraduate Program Staff

Susan Farrington - sfarring@ece.cmu.edu
HH 1118, 8-6955
Director of Alumni and Student Relations
Structures relationships with students during and after ECE, student organizations, profession societies, alumni events

Janet Peters- impeters@ece.cmu.edu
HH 1110, 8-3666
Assistant for Undergraduate Education
Monitors student academic progress, handles procedural and policy information and information on Co-op, IMB, Double Majors and Minors, Career Center, Health Center, etc. Coordinates advising process

Leona Kass-O'Rourke- lkass@andrew.cmu.edu
HH 1109, 8-2496
Educational Program Assistant
Assists associate department head in class scheduling, waitlists, etc.
Preparing for your first advising appointment

When meeting with your faculty advisor for the first time, it is essential that you be as prepared as possible to make the most of your advising session. The preparation can be divided into three categories: **Think**, **Investigate**, and **Plan**.

Bring this completed sheet to your first appointment!

**Think**
- What are your areas of interest? ______________________________________________________________________________________ ______________________________________________________________________________________
- Are you thinking of completing an Additional Major/Minor? Y N If Yes, What? ____________________________________
- Are you thinking of doing any internships? Y N If yes, When? ______________________________________________
- Are you thinking of doing a Co-Op? Y N If Yes, When? ______________________________________________
- Are you thinking of Studying Abroad? Y N If Yes, where and for how long? ________________________________
- What are your post-graduation goals? IMB MS elsewhere PhD Industry Other ______________________________
- What time constraints are you facing (work, extra-curricular activities, family, friends, etc.) ____________________________________________________________

**Investigate**
- Look at the requirements and options for the ECE degree at [http://www.ece.cmu.edu/users/shared/primer/index.php](http://www.ece.cmu.edu/users/shared/primer/index.php)
- Find out what the requirements are for any Additional Major(s)/Minor(s)

**Plan**
- List all requirements for ECE and any Additional Major(s)/Minor(s) in the boxes below
- Fill out plan for remaining semesters
- See if plan is reasonable, given constraints you face
- Modify plan as necessary (go back to **Think** stage if needed)
# Academic Plan

**Name:** __________________________  **Date:** __________  **Advisor:** __________________________

<table>
<thead>
<tr>
<th>1st Year Fall</th>
<th>1st Year Spring</th>
<th>Sophomore Fall</th>
<th>Sophomore Spring</th>
<th>Junior Fall</th>
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<th>Senior Fall</th>
<th>Senior Spring</th>
<th>5th Year Fall</th>
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**Units Carried:**

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**Summer Plans:**

Updated 09/04, JP & SLM
18-200 Fall 2005

The Emerging Trends in Electrical and Computer Engineering

Hosting instructor: Prof. Jimmy Zhu, Time: Thursdays 3.30-4.20pm, Location: DH 2210

<table>
<thead>
<tr>
<th>Date</th>
<th>Lecturer</th>
<th>Lecture Contents</th>
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<tbody>
<tr>
<td>L01</td>
<td>Prof. T.E. Schlossinger</td>
<td>The forefront of new paradigm in technology</td>
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<tr>
<td>L02</td>
<td>Prof. Bruce Krogh</td>
<td>ECE undergraduate curriculum</td>
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<tr>
<td>L03</td>
<td>Prof. James Bain</td>
<td>Student advising</td>
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<td>L04</td>
<td>Prof. Diana Marculescu</td>
<td>Ambient intelligent systems</td>
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<td>L05</td>
<td>Prof. Ken Gabriel</td>
<td>Akustics</td>
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<td>L06</td>
<td>Dr. Marlos Savides</td>
<td>Biometrics</td>
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<td>L07</td>
<td>Prof. Dan Stancil</td>
<td>Wireless communication</td>
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<td>L08</td>
<td>Prof. David Lambeth</td>
<td>Advanced sensor systems</td>
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<tr>
<td>L09</td>
<td>Prof. Jim Hoburg</td>
<td>Magnetic levitation</td>
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<tr>
<td>L10</td>
<td>Prof. Phil Koopman</td>
<td>Embedded systems</td>
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<tr>
<td>L11</td>
<td>Prof. Yi Luo</td>
<td>Nanotechnology and nano-electronics</td>
</tr>
<tr>
<td>L12</td>
<td>Prof. Ille Nourakhsh</td>
<td>Robotics</td>
</tr>
<tr>
<td>L13</td>
<td>Prof. Shawn Blanton</td>
<td>Testing of Integrated Circuit</td>
</tr>
<tr>
<td>L14</td>
<td>Prof. Mike Reiter</td>
<td>Cyber Security</td>
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</table>
Myths about meeting with your advisor

• Myth I: Advisors are judging you, so don't say anything stupid... ...even if that means that you say nothing

• Myth II: Advisors have all the answers

• Myth III: Advisors are looking to criticize your performance... ...so avoid them if things aren’t going well

• Myth IV: Advisors are looking to criticize your performance... ...so you don’t need to see them if things are going well
Objectives of Advising Process

Treat students such that they would **ENTHUSIASTICALLY** advise their loved ones to enroll in ECE at CMU
Top 10 Reasons for Intensive Advising

1. Our students sometimes need some questions answered
2. Our students sometimes need some reassurance
3. Our students want to feel heard and connected
4. Our students may not know all the questions they have
5. Our students are not aware of all of their opportunities
6. Our students don’t know all of the faculty members
7. Our students benefit from thinking and planning ahead
8. Our students have varying ways in which they want to receive information
9. Our students are human beings who need preparation for life
10. We want to know our students
Why look to your advisor for answers ...

or

Galadriel

or

Alex Trebek

or

Donald Trump

or

Galadriel

or

Gandalf
Actually, advisors give ADVICE not answers...

The Oracle at Delphi

Know Thyself
Think of advising as a resource

Think, Investigate, Plan

- Initiate contact
- Be patient but persistent with your advisor
- Come prepared with questions
Summary

• The ECE advising system is designed to provide you with resources

• Advisors are assigned and will help connect you with mentors

• Mentors will be in one area of your interest and will guide you as juniors and seniors

• The more we know about you and the more you know about the department, the more effectively we can help you find answers

• Ultimately, YOU are going to provide your own answers NOT get them from someone else
Introduction to
The Information Storage Technology at CMU

James A. Bain, Associate Director, DSSC
Jimmy Zhu, Director, DSSC
Applied Physics Courses

- Fundamentals of Electromagnetics
  - 18-300
  - 18-401
  - 18-410
  - or
  - Physical Sensors Transducers and Instrumentation
    - 18-412
    - Field Effect Devices & Technology
  - 18-415
  - Optical Comm. Systems
  - 18-310
  - 18-416
  - Information Storage Tech.
  - 18-517

- Field Effect Devices & Technology
  - 18-412
  - 18-415
  - 18-416

- Optical Comm. Systems
  - 18-415
  - 18-416

- Information Storage Systems Design
  - 18-517
Data Storage Technologies

Heat Assisted Magnetic Recording
- Optical Waveguide
- Optical Fiber
- Cylindrical Lens
- Slider
- Waveguide Solid Immersion Lens

Digital Tape Recording

Hard Disk Drives

Nonvolatile RAM (MRAM, FLASH, etc.)

Probe Based Storage

Optical Recording

Carnegie Mellon
30 Faculty Members in
- Electrical and Computer Engineering
- Material Science and Engineering
- Mechanical Engineering
- Physics
- Chemical Engineering
- Chemistry

15 Postdocs and Visiting Researchers

45+ Graduate Students (PhD and MS)

60+ DSSC Research Projects
DSSC Industrial Affiliates: 13 (+2)

agere systems

Advanced MicroSensors

Headway Technologies

imation

maxell Worldwide

Maxtor

Quantum

Seagate

SHARP

Showa Denko

STORAGETek

WD Western Digital

Fujitsu
Year 2005 Research Funding

Total Funding: $5 Million

- DSSC Affiliates Membership: $1.6 Million
- US Government Funding: $2.2 Million
- Other Industrial Funding: $1.0 Million
- INSIC: $0.2 Million
Targeted New Affiliates

ALPS
FUJIFILM
IBM®
Hitachi Global Storage Technologies
HOYA
TOSHIBA
TEIJIN
TORAY®
TDK®
KOMAG
SAMSUNG
Notable laboratory facilities

- **Materials fabrication**
  - Extensive deposition facility (13 machines)
  - Tape fabrication system
  - Langmuir-Schafer trough for nanoparticle arrays
  - Electrodeposition
  - Sputtered Tape Coating Facility

- **Device Fabrication**
  - Optical lithography (1 um)
  - E-beam lithography (35 nm)
  - Focused ion beam (35 nm)
  - Chemical mechanical polishing (CMP)

- **Materials analysis**
  - Magnetometry
  - TEM (extensive)
  - X-ray
  - Various chemical analysis

- **Device testing**
  - Drag tester
  - Tape Drum Tester
  - Scanning Kerr microscope
  - HAMR spin stand
  - Scanned probe microscope (w/ conducting AFM)
Developing a Storage Industry Cluster in Pittsburgh, Pennsylvania

April 26, 2005
Storage technology progress

- Longitudinal demos
- Perpendicular demos
- Products

- Historical demos: 40%/yr
- 1999 demos: 190%/yr
- Recent demos: 30%/yr
- Recent products: avg: 30%/yr
- Products 1998-2002: 100%/yr

- millipede demos
- INSIC goal


Gbits/sq. in: 1, 10, 100, 1000
Beyond 1 Tbit/in²

- At 1 Tbit/in² you can save a picture of every man, women and child on earth on a disk the size of a Compact Disk.

- 750 byte 30 x 30 pixel 8 bit grayscale .jpeg image

- 25 nm
Measuring magnetic marks
Y. Zhou (Zhu)

Perpendicular recording
SV Readback
Size: 13 X 13 $\text{um}^2$
Write: 75 nm x 75 nm pix.
Read: 10 nm x 1 nm

Recorded footprint of a single pole head on a perpendicular medium
Heat Assisted Recording
L. Zhou, E. Black, B. Knight
(Bain, Stancil, Schlesinger)

- Heating medium locally and temporally to enable data writing.
- The data retention time is significantly increased.
Mode Index Lenses
L. Zhou, (Bain, Schlesinger)

- Materials deposition
- Optical design
- Fabrication
- Testing
- Integration
Experiment:

Very small aperture lasers

Advanced “aperture” and resonant structure design

Metrology at the nanoscale

AND

Theory/Modeling
Nonvolatile: data retention without power.

Enables “instant-on” feature for computers.

Enables single chip computer systems.

A universal memory with potential to replace SRAM, DRAM, FLASH, and partially disk drives.
Probe Storage

- **Array of micro-actuated probe heads**
  - 80 x 80 array
  - 7-50 GBytes capacity

- **Magnetic probe recording**
  - 10 nm by 10 nm bits
  - 8 mm by 8mm media
Resistance change oxides
S Choi/H Lee (Bain/Salvador)

- Material results only
- Resistance change phenomenon demonstrated by several groups
- Potentially low power
- No engineering model of behavior yet ...

Electromagnetic actuation, IBM
Aggeliki Pantazi, et al

- Power levels meet product specifications
- Shock tolerance addressed
- Maximum displacement and rates are acceptable
- Extensive systems integration

Carnegie Mellon
Detailed understanding of physics has been developed
- Stability has been examined and is not a showstopper
- 10 Tbits/in² is feasible
**MISC-IC Technology**

**Memory Intensive Self-Configuring IC’s**

### Gen I Technology: Reconfigurable Logic (0-5 yrs)
- Probe reconfigurable interconnect (non-volatile)
- Probe configurable logical blocks (non-volatile)

### Gen II Technology: Integrated Probe Storage (4-7 yrs)
- Large non-volatile memory with access time < 500 us

### Gen III Technology: Integrated nanodevices (7-10 yrs)
- Probe activation of self-organized nanofabric
Summary

- DSSC has a broad spectrum of research in materials, devices and applied physics
- Information storage is a rich field of application with a lot of participation from ECE faculty
- $100 Billion storage industry can make of wide spectrum of ECE graduates in applied physics areas as well a signal processing