Academic MEMS Goes Fabless: The Masdar Institute Perspective

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Abu Dhabi, UAE
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• Who Are We?
  – Abu Dhabi, UAE
  – Masdar Institute (MI)
  – Microsystems
• Our Partnerships
• MEMS at MI
  – Going Fabless
• Coming of Age
The Abu Dhabi Context

- $15B investment in semiconductors
- 6000 patents
- 15,000 patents (IBM Micro)
The Abu Dhabi Semiconductor Hub

Vision

• **Become one of the world’s leading research hubs in microsystem technology**

• **Serve as an R & D hub for Abu Dhabi’s emerging semiconductor ecosystem**

The World’s First Truly Global Foundry

Global Manufacturing Operations

- Fab 1: Leading-edge 300mm manufacturing campus, Dresden, Germany
- Fab 7: Mainstream 300mm manufacturing campus, Woodlands, Singapore
- Fab 8: Future leading-edge 300mm manufacturing campus, Saratoga County, NY
- Fab 2, 3, 3a, 5, 6: Mainstream 200mm manufacturing campus, Woodlands, Singapore, Singapore

ATIC Advanced Technology Investment Company

- $15B investment in semiconductors
- 6000 patents
- 15,000 patents (IBM Micro)
Investment Portfolio

- Semiconductor Technology: 27% ($14.5bn)
- Corporate / Acquisitions: 12% ($12.9bn)
- Oil, Gas & Energy: 7% ($3.9bn)
- Info & Comm Technology: 7% ($3.8bn)
- Aerospace: 7% ($3.8bn)
- Real Estate & Hospitality: 6% ($3.7bn)
- Industry: 5% ($3.3bn)
- Renewable Energy: 5% ($2.9bn)
- Infrastructure: 5% ($2.6bn)
- Healthcare: 5% ($1.1bn)
- Service Ventures: 2% ($0.5bn)

Percentages based on balance sheet asset value

Source: Mubadala H1 2012 financial statement.
Masdar Institute (MI)
A Research Driven University

- Independent, private, non-profit and established in collaboration with MIT
- Graduate level (MSc & PhD)
- Focused primarily on advanced and sustainable technologies
- Dedicated to capacity development
  - **Human Capital**: manpower for economic development
  - **Intellectual Capital**: knowledge and technology development and transfer
MI’s Academic Programs
Graduate Education as a Foundation for Research

2009
- MSc Engineering Systems and Management
- MSc Mechanical Engineering
- MSc Material Science and Engineering
- MSc Computing and Information Science
- MSc Water and Environmental Engineering

2010
- MSc Electrical Power Engineering
- MSc Microsystems Engineering

2011
- MSc Chemical Engineering
- PhD program
- Practicing Professionals

2012
- MSc Sustainable Critical Infrastructure
- MSc Geomechanics

2013

2014+

- MSc Sustainable Critical Infrastructure
- MSc Geomechanics

ACADEMIC DEPARTMENTS
- Department of Engineering Systems and Management
- Department of Electrical Engineering and Computer Science
- Department of Mechanical and Materials Engineering
- Department of Chemical and Environmental Engineering

FACULTY
- 90+

STUDENTS
- 450+

4
Institute Center for Microsystems

Fast Facts

• Total Faculty Involved: 11 core faculty and 8 affiliated faculty from other academic programs (ME, Mat. Sc., CIS)
  – Attracting top talents from all over the world

• Number of Externally Sponsored Projects: 40+
  – Organized under three research centers with international partnerships

• Number of Students: 50 MS and 16 PhD
  – UAE Nationals: 20 MS and 4 PhD.

• Number of Staff: 1 Research Scientist, 5 Postdocs, and 6 Research Engineers
• 15+ chip tape-outs in 180nm, 65nm, and 28nm technologies

• UAE first GF 28nm chip tape-out (Shabra, Elfadel)

• UAE first Si-photonics chip tape-out (Khilo and NOOR)

• UAE first organic solar cell printed at MI (Dahlem and Mejd AlSari – UAE national)

• Two cycles of MEMS Tape-outs in Gyros, Accelerometers, Piezoelectric energy harvesters, piezoelectric ultrasound transducers, and optical MEMS
Institute Center for Microsystems
Awards and Recognition

• Best Paper Award, International Symposium on Circuits Systems – Biomedical Track, May 2015, Portugal Lisbon
• Runner-up for Best Student Paper Award, International Symposium on Circuits Systems – Biomedical Track, May 2015, Portugal Lisbon
• Best Transactions Paper Award, March 2014, IEEE Transactions on Computer-Aided for Integrated Circuits and Systems, Awarded every year by the IEEE Council on Electronic Design
• IEEE Circuits and Systems Committee on Sensor Systems
• IEEE Circuits and Systems Committee on Biomedical Circuits and Systems
• Associate Editor, IEEE Transactions on Very-Large Scale Integration
• Numerous Technical Program Committees for top IEEE Conferences
iMicro’s Local & Global Partnerships
MEMS TwinLab Singapore

- Project Launch on May 1, 2014: 12 faculty and 13 projects
  - IMU, pMUT, EH, optoMEMS, MEMS CAD
- MI funding: US$6M over 3 years
- Close collaboration with Singapore’s Institute of Microelectronics (IME) acting as MEMS foundry
- 3 Steering Committee Meetings held in Singapore on Aug 29, 2014, Jan 30, 2015, and Oct 16, 2015
- Almost daily meetings with IME and GLOBALFOUNDRIES (ultimate MEMS platform provider).
The Key to the Kingdom

Foundry

PDK

Design

CAD
The Key to the Kingdom

- Foundry (IME)
- PDK
- Design (Masdar)
- CAD
  - Coventor, Cadence, etc
MEMS Old Way: One Process = One Device

Siddharth Chakravarty, GLOBALFOUNDRIES
MEMS Right Way: One Process = Many Devices

Siddharth Chakravarty, GLOBALFOUNDRIES
MEMS Industry Transformation

Siddharth Chakravarty, GLOBALFOUNDRIES
MEMS Industry Transformation

- PDK
- CAD reference flows
- IC/MEMS reference flows
New MEMS devices in volume in 2018?
- 9-axis combo
- Pressure + Humidity + T° combo
- More microphones!
- Silicon timing for XO / TCXO / 32kHz clock
- Antenna switching
- Gas / biochemical sensors
- Autofocus
- MEMS mirrors
- Micro speaker
- Touch screen
- Finger Print
- IR Sensor
- IR Imager

Energy harvesting?
- UV sensor?
- LIDAR?
- Ultrasonic sensor?
- Radiation sensor?
- Joystick?
Model-to-Hardware Correlation for EH

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Importance of the IC/MEMS Reference Flow

Materials and process data

MathWorks

Matlab/Simulink for Piezomechanics

Damping

Verification and detailed analysis

CoventorWare Analyzer

Device simulation

Co-Simulation of Harvester and circuit

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Modes of Butterfly EH Device
Optimal Electrode Placement for EH

Stress maps from TED enabled Harmonic analysis in CW

CW stress map guides parameterized electrode placement in MEMS+

Parameters:
1. Gap size: $g_s$
2. Gap location: $g_l$

Power Model
- MEMS+ Charge
- MATLAB: Power and Voltage
- OR
- CADENCE

Optimization
- Boundaries
- Cost

Specs
- Geometric constraints

Performance Criteria
- Maximum power

Optimized design
Review

Integrated sensors, MEMS, and microsystems: Reflections on a fantastic voyage

Kensall D. Wise*

Engineering Research Center for Wireless Integrated MicroSystems, Department of Electrical Engineering and Computer Science, The University of Michigan, Ann Arbor, MI 48109, USA

Received 19 September 2006; accepted 5 February 2007
Available online 20 February 2007
• The university was the fab.
• It all started at Bell Labs but the MOSFET and the MEMS took very different paths.
• Perhaps now they will come back together again!
Acknowledgements & Thanks

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  • The Masdar Institute of Science and Technology, Abu Dhabi, UAE
  • Institute of Microelectronics, Singapore
  • GLOBALFOUNDRIES, Singapore
Thank You