High Rate Electrochromic Coatings (EC): DE-EE0003838

DOE Windows Roadmap Meeting, Minneapolis, MN, USA
06/28/2012

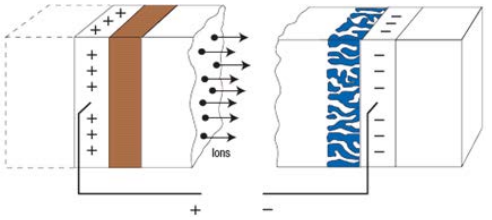
Team:

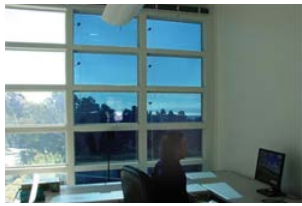
Applied Materials CTO-Advanced Technologies Group

& Lawrence Berkeley National Laboratory

EC Program: Background, Purpose & Objectives

- **Background**:
  - Market application of EC windows are limited by
    - Low value proposition (performance/cost)
    - High manufacturing cost
    - Insufficient advantage in energy savings vs. high efficiency low-e glasses





- **Project Purpose**:
  - Improve this value proposition by developing novel HVM technologies and methods to reduce cost.

- **Objectives**:
  - Concept and Feasibility (C&F) demonstration of Novel HVM equipment technologies;
  - Develop fundamental models and methods to simulate EC devices
  - C&F demonstration of laser based patterning methods (amended objective)

"C&F to Scaling" is demonstrated core strength of Applied Materials

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Scope of Work and Cost Breakdown

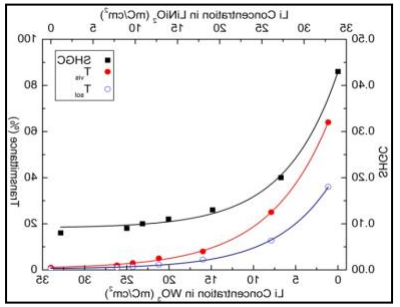
- Scope of work
  - C&F demo of cost reducing HVM equipment technology
    - Novel deposition technologies for higher throughput manufacturing
      - Dielectric oxide deposition: Multiple Frequency Sputtering
      - Li deposition: linear deposition source
  - Development of fundamental device models and methods
    - Optical, electrical and electrochemical characteristics
  - C&F demo of laser based device fabrication methods
    - Laser/process selection based on optical/thermal properties
    - Fabricate using blanket depositions and laser

- Total cost of project (government and private shares)

	Cost Share	Gov. Share	Total
Applied	2,000,000	1,600,000	3,600,000
LBNL	0	400,000	400,000
Total			4,000,000

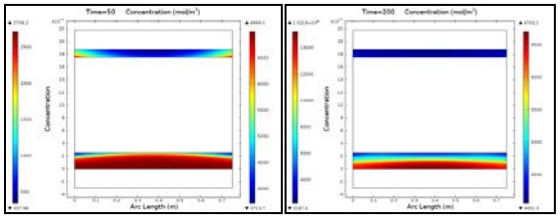
Accomplishments to Date

- Dielectric oxide deposition: Multiple Frequency Sputtering
  - Hardware **completed**
  - Higher deposition rate (> 45% higher at same power) and better layer quality (higher ionic conductivity, smoother & fewer pinholes in thinner film) **demonstrated**

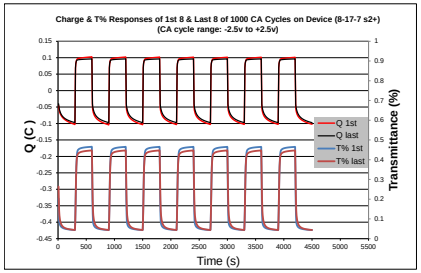


- Li deposition: linear deposition sources
  - Hardware **completed** for 1st concept; Larger linear source **designed**

- Device models and simulation methods
  - Fundamental model and simulation methods **completed**
    - 2um thick device with lateral dimension up to 1m long (for electrical)
  - Validation of the models and simulation methods **completed**.



- Functional devices and flow **completed**
  - Cycled (continuing) to 1000 cycles with minimal changes



- Laser based device fabrication methods
  - Layer properties characterization **completed**

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Additional Accomplishments

- Conference Presentations
  - Spring Meeting, MRS 2011: Nuclear Reaction Analysis (NRA) of Li
  - 9th International Conference on Coated Glasses (June 2012): Optical modeling and simulation of Electrochromic devices (accepted for oral presentation)
  - International Meeting on Electrochromics 10: Electrical and optical modeling of Electrochromic devices (Planned - 2012)

- Journal Publications
  - Optical Modeling work: *Solar Energy Materials & Solar Cells* (submitted)
  - Electrical Modeling work: *Journal of Electrochemical Society* (submitted)

- Patent Applications
  - Deposition methods for dielectric/ceramic materials
  - Novel Li deposition sources
  - Novel integration schemes and methods using laser based technologies
  - New materials for device performance improvement

Expected Outcome and Next Steps

- **Expected Outcomes**
  - Novel HVM technology will improve the EC value proposition by lowering the cost and increasing the manufacturing energy efficiency
    - Higher CapEx efficiency (factory capacity and throughput per CapEx $)
    - Simple creation of broader product portfolio
      - Multiple devices from single large substrate (by laser patterning) as in the Display industry
  - Fundamental Device Model will help industry create better EC devices
    - Optimization of device structure and performance with existing materials data
    - Optimization of materials & device structure etc. to meet desired device performance specification

- **Next steps**
  - Complete the remaining few tasks of the program
  - Determine market viability of the resulting EC window technology
  - Seek vertically integrated consortium in the window manufacturing chain to collectively address the emerging market

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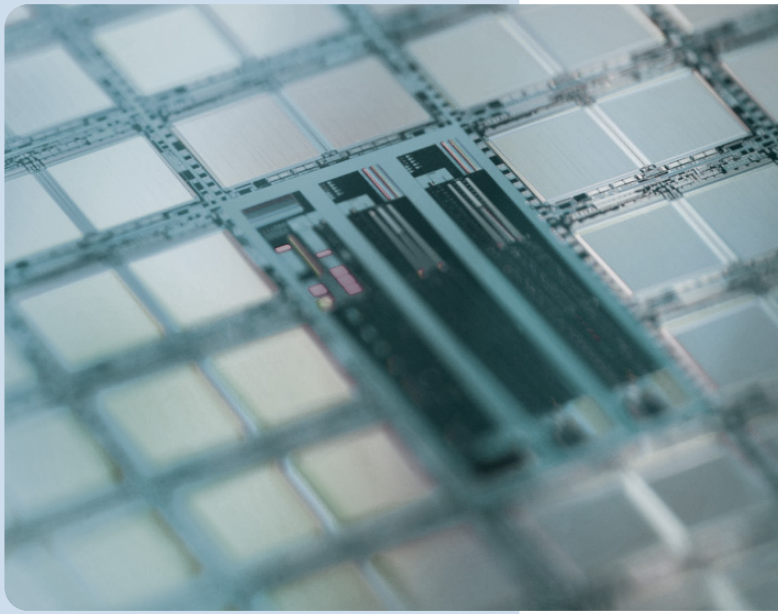
into industries.™

Supplemental / For Reference

Applied Materials® Corporate Overview

Turning Innovations into Industries™



B. Leo Kwak, Ph.D.

Distinguished Member of Technical Staff

Corporate CTO Office, Applied Materials

June 4, 2012

VISION

We apply nanomanufacturing technology to improve the way people live.

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WHAT WE DO

We make the **equipment** that makes the components that change the world.

The Global Strength of Applied

Stock Ticker:	**Nasdaq: AMAT**
Market Cap:	**$16.8 billion**
Fiscal 2011 Revenue:	**$10.5 billion**
Fiscal 2011 R&D:	**$1.1 billion**
Founded:	**November 10, 1967**
Headquarters:	**Santa Clara, California**
Global Presence:	**87 locations in 19 countries**
Fortune 500 Ranking:	**259**
RD&E and/or Manufacturing Centers:	**China, Germany, Israel, Italy, Singapore, Switzerland, Taiwan, United States**
Employees:	**~14,600 worldwide**
Patents:	**~9,500 issued**

* Information as of Q1'12 except FY'11 amounts
Fiscal year-end October 30, 2011

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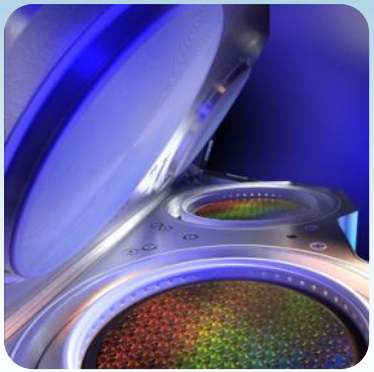
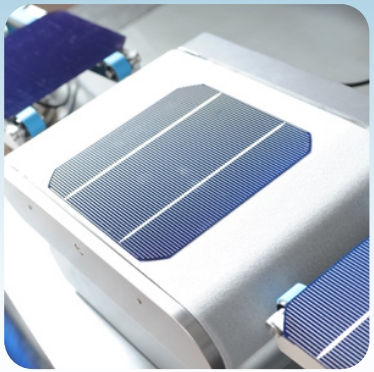
Business Segments

Semiconductor



Display

Energy and Environmental Solutions



Applied Global Services

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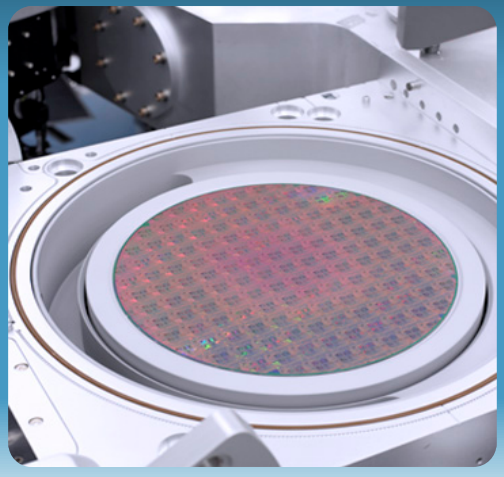
Semiconductor

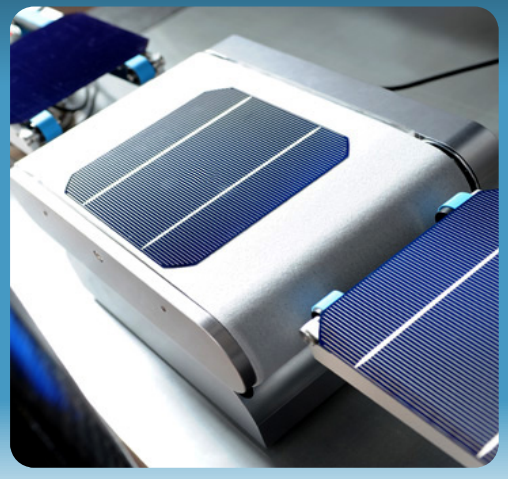


20,000,000x
reduction in
COST PER TRANSISTOR
in 30 years[1]

Display

20x
reduction in
COST PER AREA
in 15 years[2]

Solar



5x
reduction in
COST PER WATT
in 4 years[3]

At 1976 transistor prices,
an iPod® would have cost $3.2B

1 Source: SIA, IC Knowledge LLC
2 Source: Display Search, Nikkei BP, Applied Materials
3 Source: Photon Consulting 2012

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Enabling and Accelerating Innovation

Applied Materials is the global leader providing innovative equipment, services and software to the semiconductor, flat panel display and solar photovoltaic industries

OUR STRENGTHS

Thin film engineering

Commercializing sophisticated systems

Global reach

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