iNEMI Flexible Electronics Roadmap

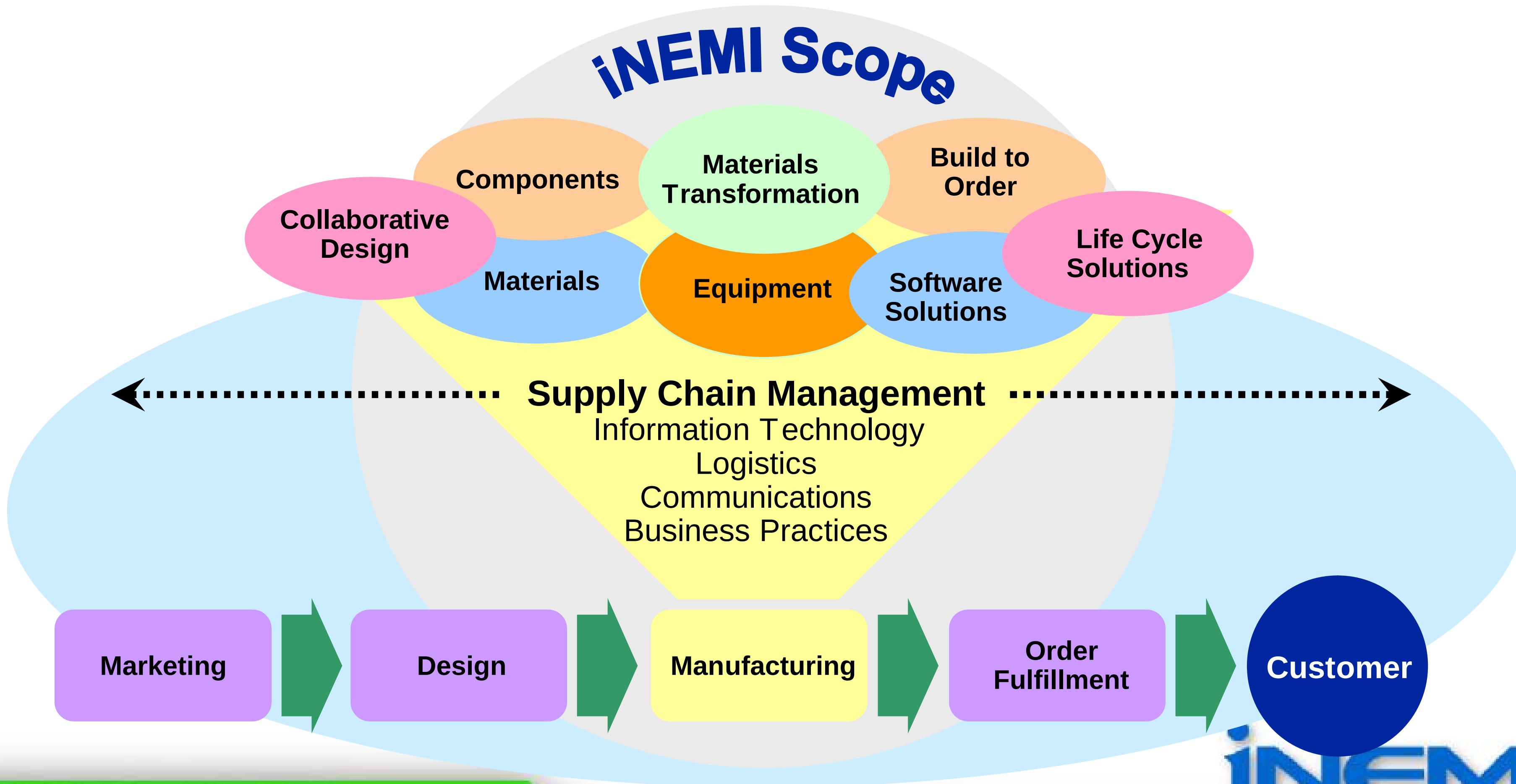
From Concept to Product

… many routes can be taken and a roadmap simplifies the process

Daniel Gamota, Chair
Margaret Joyce, Co-Chair
Jie Zhang, Co-Chair

iNEMI Mission

Assure Leadership of the Global Electronics Manufacturing Supply Chain for the benefit of members and the industry



What Does iNEMI Do?

Leverage the combined power of member companies to provide industry leadership

- iNEMI roadmaps the global needs of the electronics industry
  - Evolution of existing technologies
  - *Prediction of emerging/innovative technologies*
- iNEMI identifies gaps (both business & technical) in the electronics infrastructure
- iNEMI stimulates research/innovation to fill gaps

What Does iNEMI Do?

- iNEMI establishes implementation projects to eliminate gaps
- *<u>iNEMI stimulates worldwide standards to speed the introduction of new technology & business practices</u>*
- iNEMI works with other organizations to ensure that government policy recommendations are aligned with our mission

Why do Companies Participate?

- *Excellent opportunity to "test the iNEMI collaboration waters" without committing to membership.*
- The experience leads to a better understanding of the "state of the art" in those areas of participation.
- *Early access to the roadmap chapter's technical and business information for the participating company.*
- Opportunity to shape the industry's future priorities concerning R&D.

Why do Companies Participate?

- Opportunity to impact iNEMI's future direction through "technology gap" identification and solutions most important to your company.
- Those who participate in the Roadmap creation get a broad view of the supply chain landscape from customers, competitors and suppliers.
- *Roadmaps can become "self-fulfilling prophecies" as many within industry focus on the identified challenges and benchmark their company against the user needs.*
- As General Dwight D. Eisenhower was fond of saying, "It's not the plan (that is created) but the planning (process) that provides maximum insight."

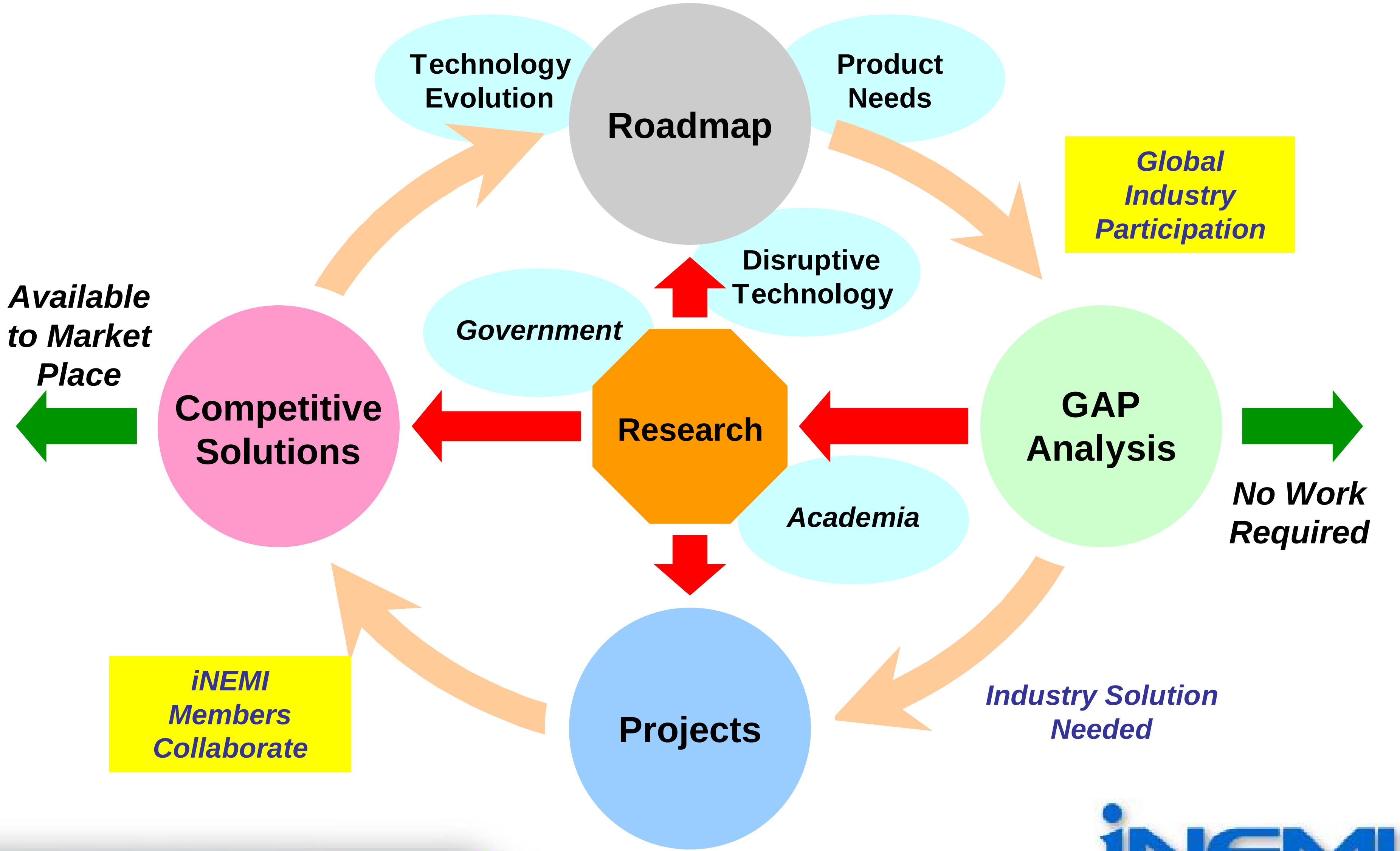
iNEMI Members

OEM/EMS, Suppliers, Government, & Universities

ALCATEL
Cisco Systems
DELPHI
DELL
intel
Celestica
GUIDANT
hp invent
IBM
Foxconn
Jabil Circuit
Medtronic
Microsoft
Lucent Technologies
Plexus
StorageTek
Nortel Networks
Sanmina-SCI
Solectron
Sun microsystems
symbol
EIA Electronic Industries Alliance
AMR Research
AeA
IPC Association Connecting Electronics Industries
Coherent
Cookson Electronics
Endicott Interconnect
3M
Dover
ECI
E2open
Asymtek
Henkel
Indium Corporation of America
Kester
ERSA
FCI
Heraeus
MatrixOne
Nihon Superior Co., Ltd.
PTC
NanoDynamics
PCN
Rohm and Haas Electronic Materials
Senju Comtek
Speedline Technologies
Teradyne
Texas Instruments
Total Parts Plus
tyco Electronics
Universal
Vectron International
Vitronics Soltec
CMAP Centre for Microelectronics Assembly and Packaging
IEEC
MetaGroup
Georgia Tech
MIT
ncms
NIST
Développement économique et régional Québec
Virginia's Center for Innovative Technology
iNEMI

Advancing manufacturing technology

Methodology

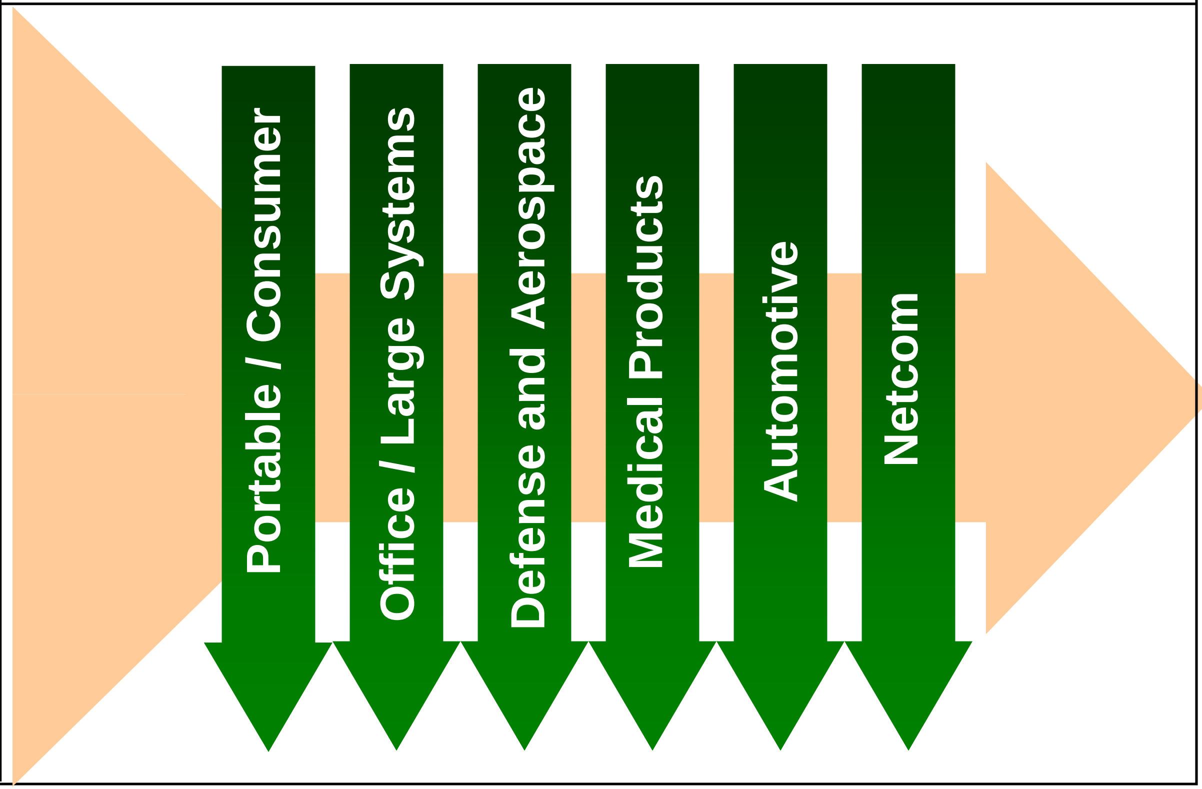


Statistics for the 2009 Roadmap

- > 550 participants
- > 250 companies/organizations
- 18 countries from 4 continents
- 20 Technology Working Groups (TWGs)
  - New roadmaps on Solid State Illumination, Photovoltaics and RFID Item-Level Tag
- 5 Product Emulator Groups (PEGs)
- > 1400 pages of information
- Roadmaps the needs for 2009-2019

Roadmap Development

Product Sector Needs Vs. Technology Evolution

TWGs (21 total)	**Product Emulator Groups**
Semiconductor Technology	
Business Processes **Prod Lifecycle Information Mgmt.**	
Design Technologies Modeling, Thermal, etc.	
Manufacturing Technologies Board Assy, Test, etc.	
Comp./Subsyst. Technologies Large Area Flexible Electronics, Displays, Packaging, etc.	

Flexible Electronics Roadmap History

09/2005 – iNEMI Stakeholders identify Flexible Electronics as Future Growth Market and authorize formation of TWG

01/2006 – Flexible Electronics TWG formed (25 participants)

09/2006 – 1st Edition submitted for final editing

01/2007 – 1st Edition iNEMI Roadmap released to public

01/2009 – 2nd Edition iNEMI Roadmap released to public (67 participants)

09/2010 – 3rd Edition submitted for final editing

1st Edition Released at APEX 2007

iNEMI Large Area Flexible Electronics Roadmap

2011 Roadmap Submitted for Final Editing

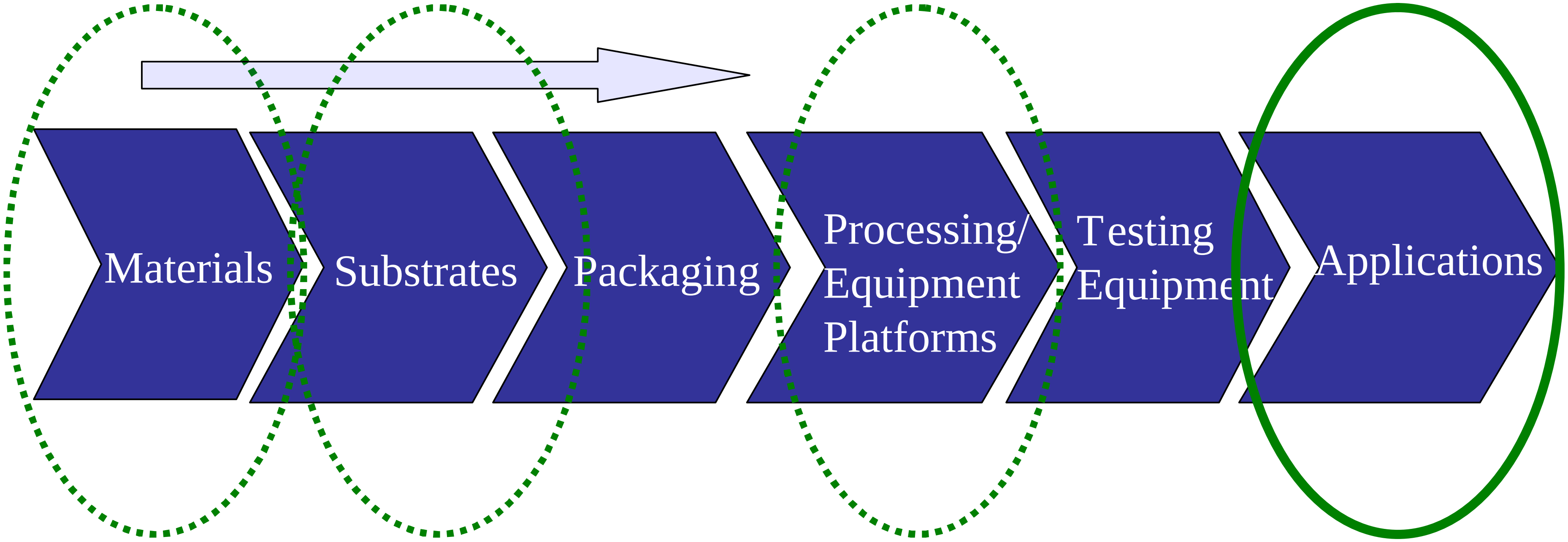
LARGE AREA FLEXIBLE ELECTRONICS

Contents

Tables

Shift in Roadmap Topic Participation

– Movement Along Supply Chain



2007 Roadmap greatest participation -"Materials".

2009 Roadmap greatest participation shifted "Substrates" and "Processing Equipment".

2011 Roadmap greatest participation shifted "Processing Equipment" and "Applications".

iNEMI Roadmap Format

Situation Analysis

Substrates

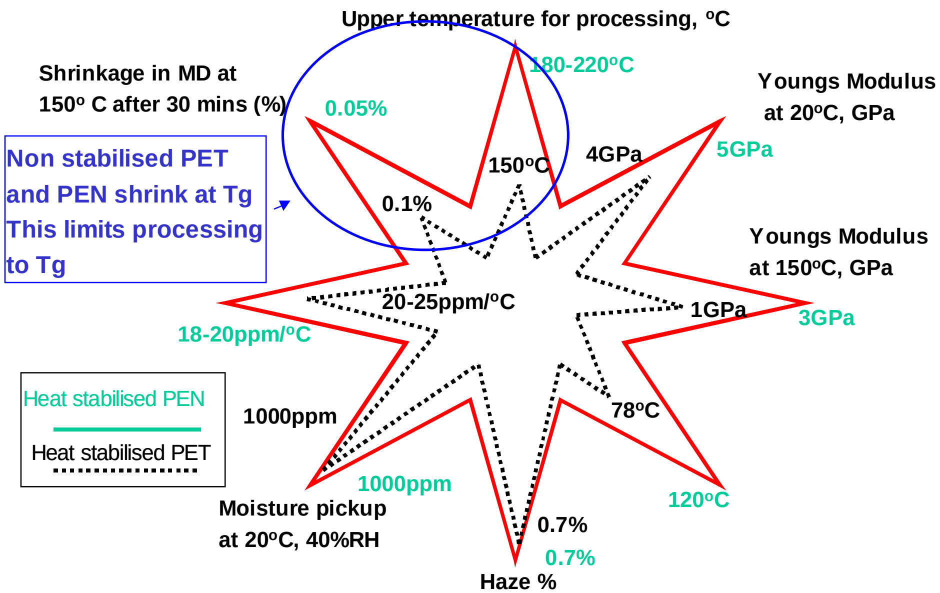
Status and Current Developments

Polymer Films

Polyesters: Applications

Properties

Major Past and Current Developments



Roadmap Format (continued)

Roadmap of Key Technology Needs for Substrates

Roadmap of Quantified Key Attribute Needs, Gaps, and Showstoppers

Substrates

Polyester

Technology Requirements

Needs, Gaps, and Showstoppers

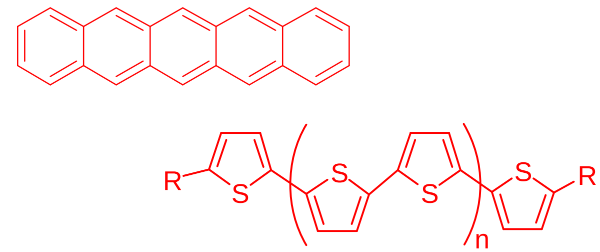
State of the Art (2009)	Mid term (2014)		Long term (2019)	
Attributes	**Attributes**	**Technology needs**	**Attributes**	**Technology needs**
Surface morphology: roughness – bare foil 50nm RMS	15 nm RMS	Development of advanced foil manufacturing technologies	5 nm RMS	Development of advanced, yet low cost, polishing technologies
Flatness (per 500mm of length): 2.0mm	1.0mm	Development of advanced foil manufacturing technologies	0.5mm	Development of advanced foil manufacturing and inspection technologies
Coefficient of thermal expansion: 10ppm/°C	<5ppm	Development and scale-up of alternative materials	<5ppm	Development and scale-up of alternative materials

Functional Inks

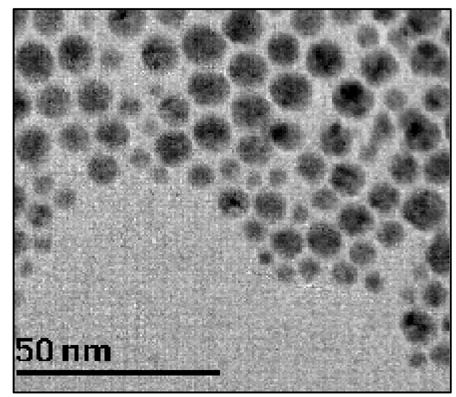
<u>Attributes</u>

- High performance
- Long shelf life and pot life
- Solution processable
- Compatibility with other functional inks (chemical and electrical interfacial integrity)
- Robust synthesis/formulating routes
- Materials and device stability in-air
- Compatible with large area scalable processing platforms

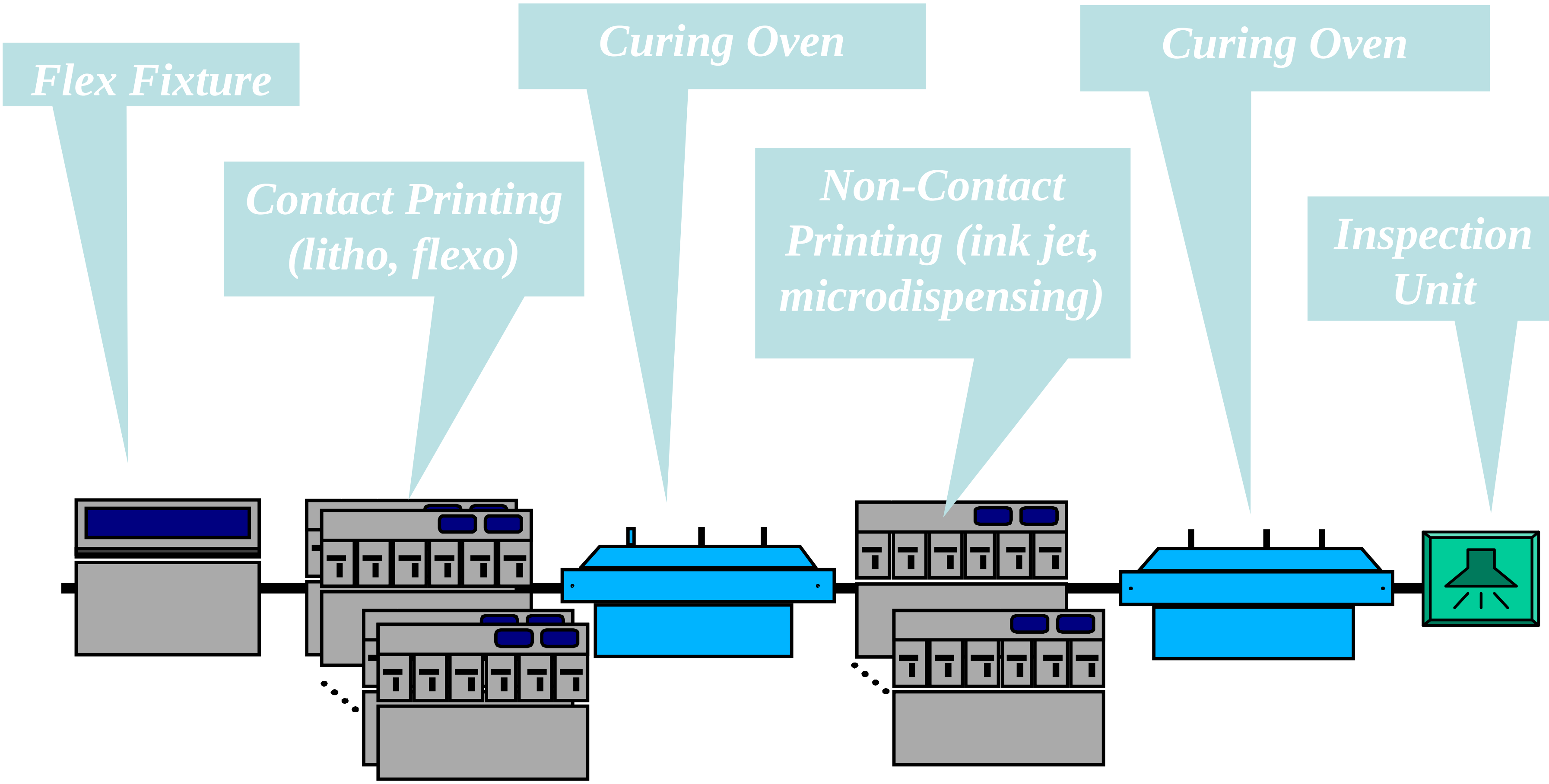
Semiconductor Inks



Silver Nanoparticle Conductive Inks



Manufacturing Platforms and Processing Equipment

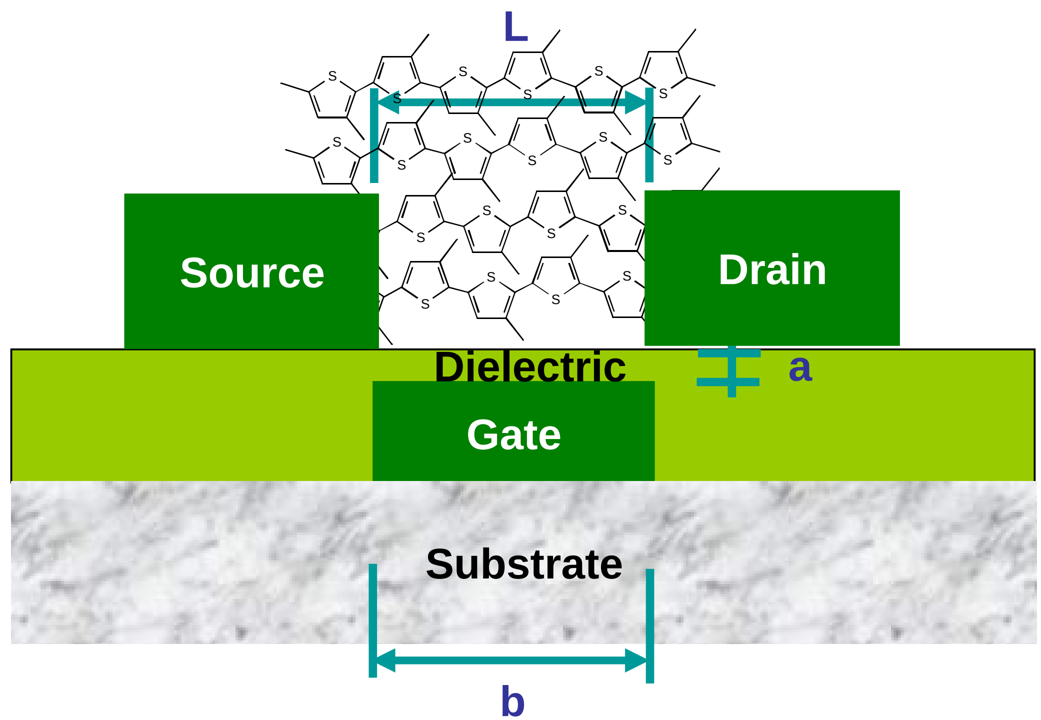


- *Highly integrated hybrid system for high throughput and scalability*

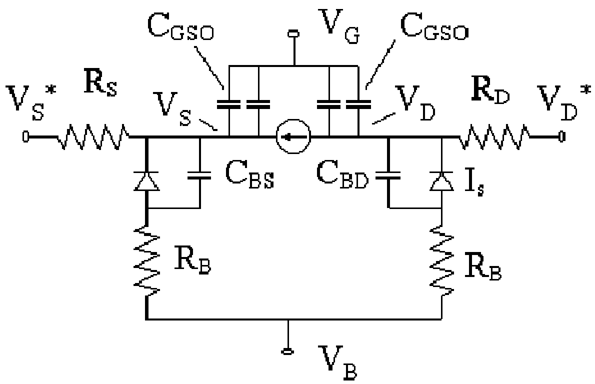
In-Line/Off-Line Characterization Tools

Critical Parameters

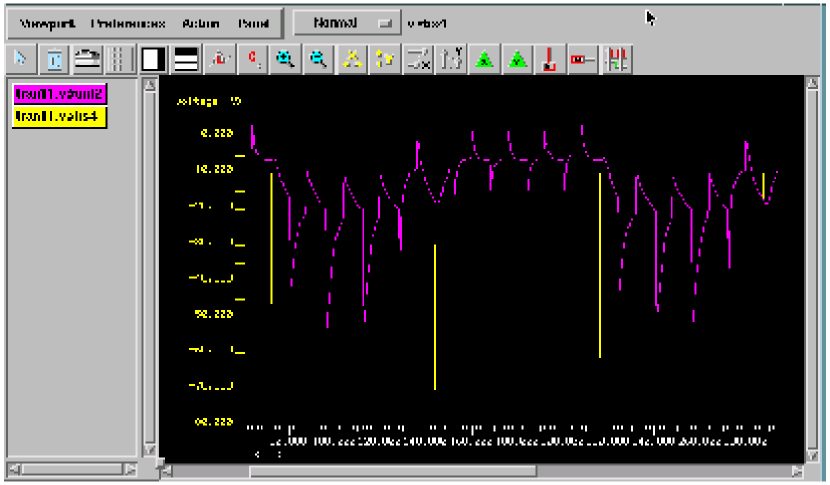
- Resolution
- Registration
- Layer thickness
- Orientation of features
- Dimensions of features
- Processing conditions
- Material quality (pot life)
- In-process electrical testing
- Final product electrical testing



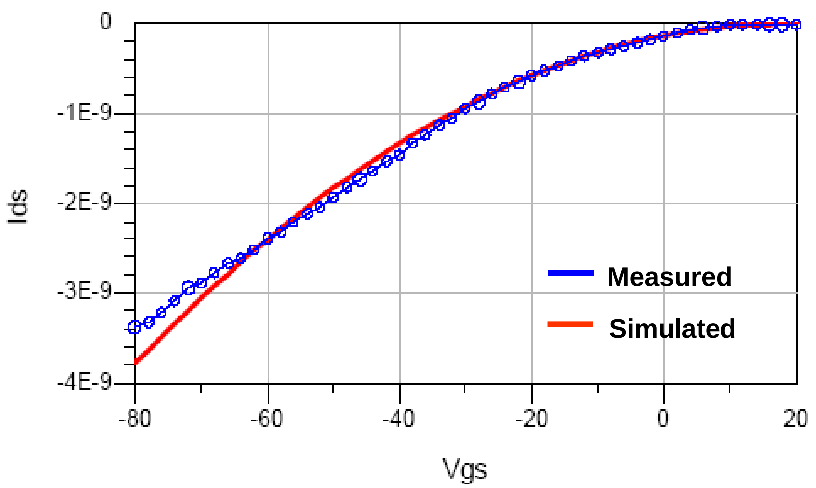
Electrical Design, Layout, and Simulation Tools



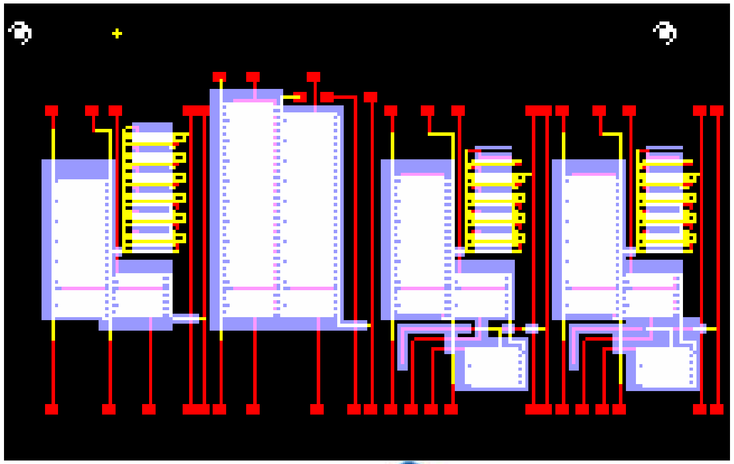
Circuit Design



Circuit Simulation



Confirmation of Experimental to Simulation



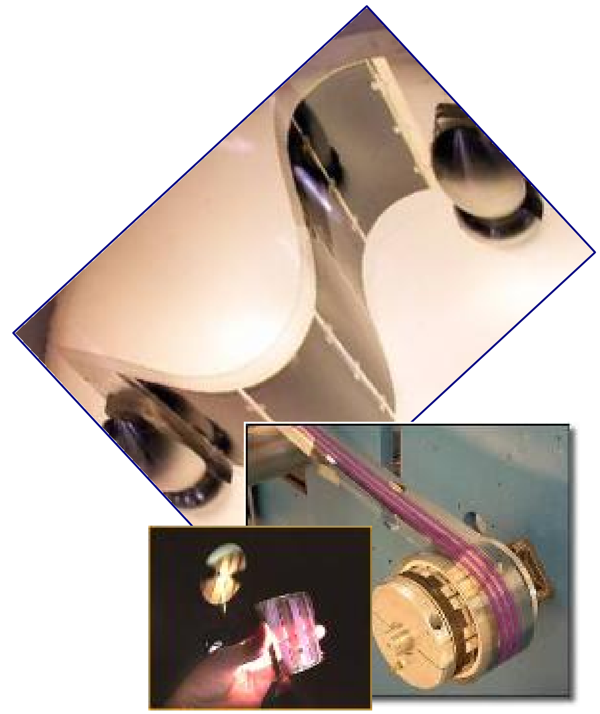
Circuit Layout

Products and Applications

Lighting & Displays

RF Enabled Sensors

Photovoltaics



Reliability Testing Methods and Equipment

Reliability Testing Parameters

- Air to air temperature cycling (-20°C to +60°C, 30 min dwell)
- Liquid to liquid thermal shock (-20°C to +60°C, 5 min dwell)
- Flexure (30 degree off-axis bend)
- Humidity exposure (60°C at 90% R.H.)
- Oxygen exposure
- Solvent resistance (Bleach, water, ammonia, etc.)
- Tearing, crumpling, crushing

➤ ***Reliability is application specific***

Standards

IEEE Printed and Organic Electronics Working Group 1620™ Established in 2003

1620-2004™ → **1620.1-2006™** → **P1620.2**

Device Level Test
http://grouper.ieee.org/groups/1620/1/

Approved in 2004 ü

2008 update complete and IEEE-SA approval received

Ring Oscillator Test
http://grouper.ieee.org/groups/1620/1/

Approved in 2006 ü

RF Sub-System Test

Assembling Working Group ?

Need for printed RF measurement standard

Flexible Electronics "*Top Four*" Needs and Gaps

- #1 In-line inspection and testing equipment
- #2 Higher performance inks (semiconducting, OLED, PV active, etc.)
- #3 Simulation and design tools
- #4 Robust manufacturing platforms

www.inemi.org

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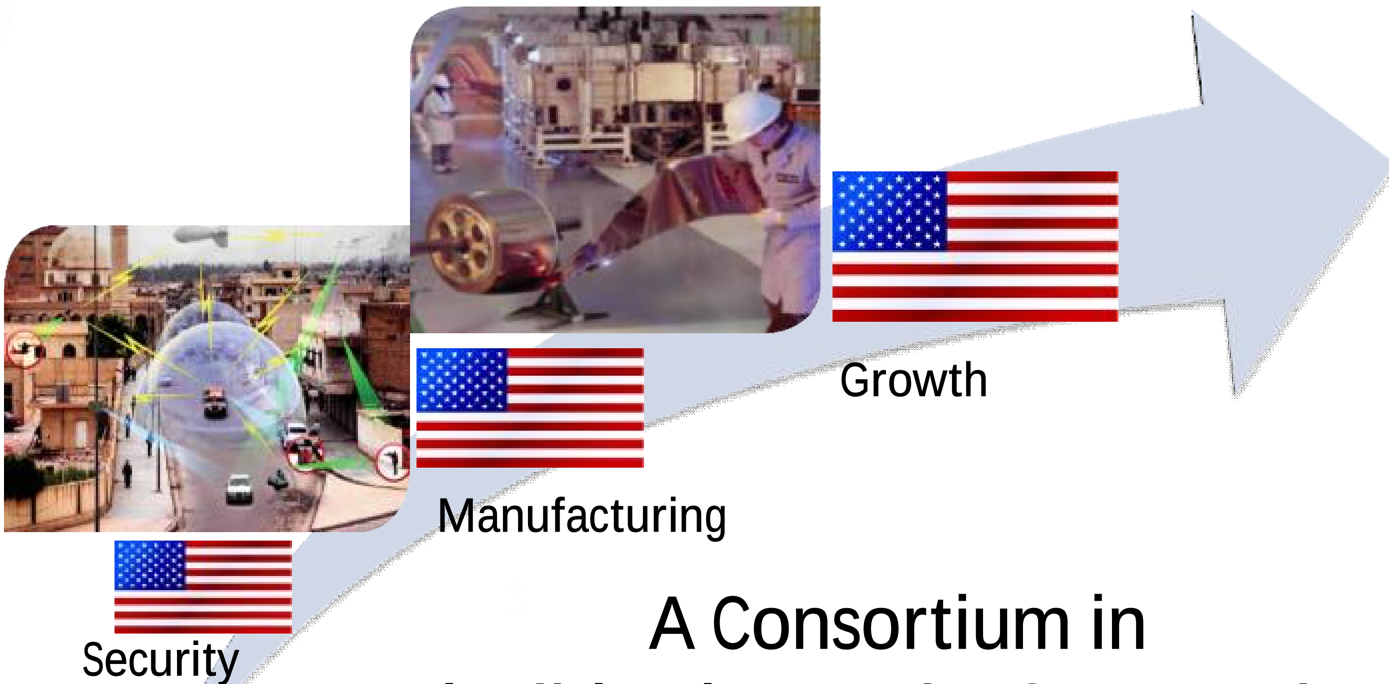
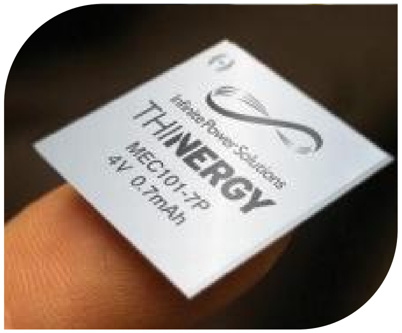


A Consortium in Flexible Electronics for Security, Manufacturing and Growth in the U.S.

Malcolm J. Thompson Ph.D
Chairman and CEO
RPO, Inc.

New Rules, New Manufacturing, New Jobs

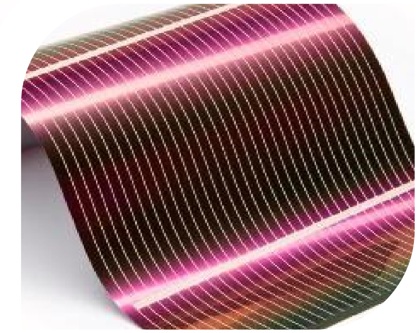


Electronics Industry Helps Drive U.S. Economy

- Moore's Law in silicon electronics drives to smaller features, higher density and complexity
- Large multi $B manufacturing facilities – but many overseas

Future Electronics Opportunity

- Flexible (and potentially printed) electronics enables *human scale* products
  - Conformable and portable PV – Energy Impact
  - Wearable health monitors – Health Care & Battlefield Impact
  - Sensors – Homeland Security, Healthcare, Consumer Products & Battlefield Impact
  - Flexible displays & e-books - Education, Training and Communications Impact
- New, distributed manufacturing
  - Printing electronics – customized diversified products manufactured closer to the end user – analogous of move from print shop to the home office – more accessible to large and small manufacturers

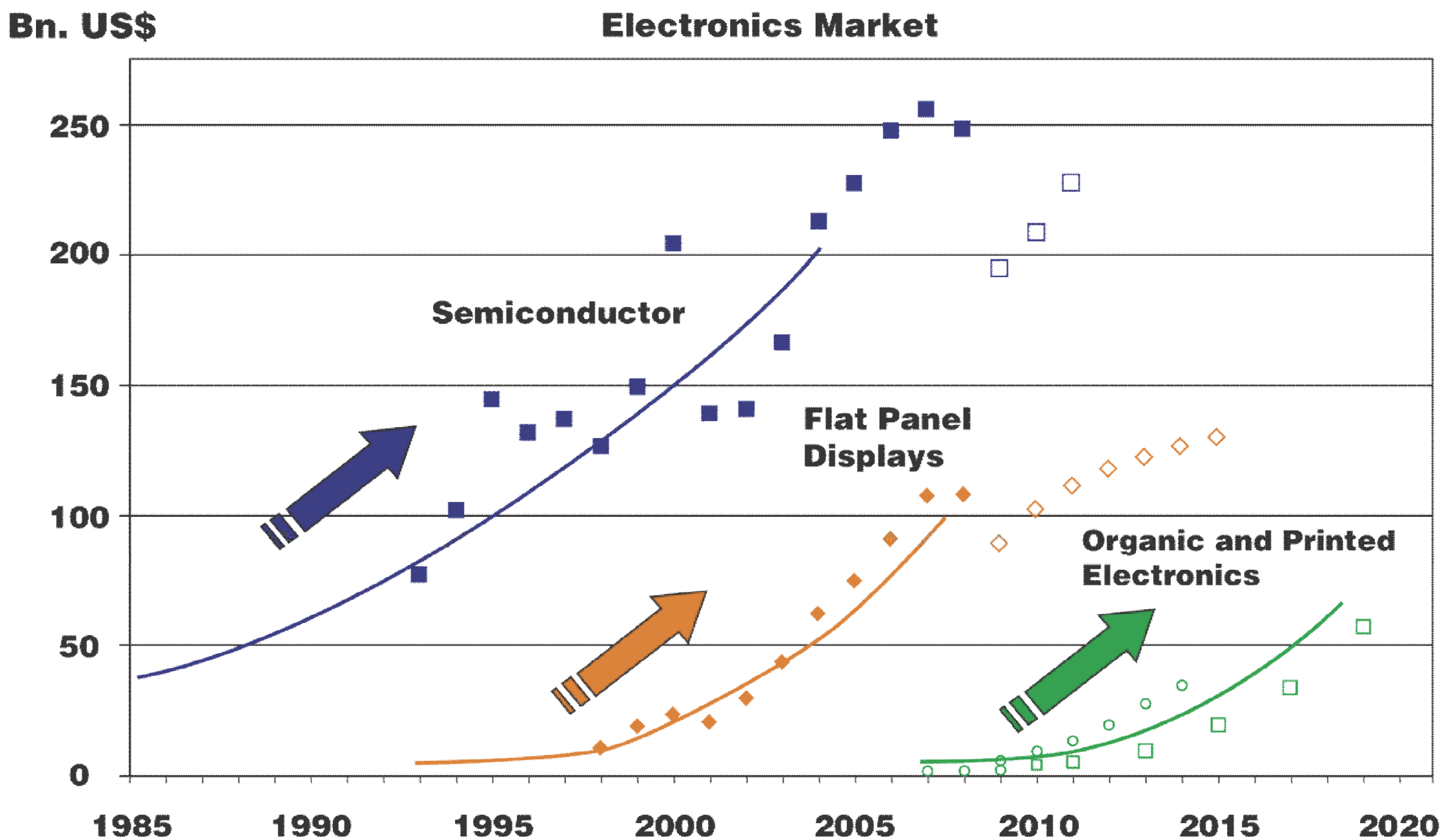


Global Trends and Comparisons

EAST ASIA 600 ORGANIZATIONS	NORTH AMERICA 750 ORGANIZATIONS	EUROPE 775 ORGANIZATIONS
•Most work in Japan (Korea moving fast, may overtake) •Strong government backing in most aspects •Few startups but many giants involved •Defending the massive display business – buying those in the West e.g. Eink, CDT etc. (OLED displays, OLED lighting, e-paper etc) •Developing transistors for display backplanes and other applications	•Weak government backing outside of military •Many startups involved. Giants often slow/unfocussed •Strong in materials and process development (inorganic and organic) •Usually successfully large user market (Amazon Kindle reader, Hasbro/Tink games, skin patches)	•Most effort in Germany. Holland, UK, Sweden also hot •Strongest government backing in most aspects (Germany) •Many large and small companies involved. Few startups •Strong in materials and process development (mainly organic) •Strong in PV manufacture (but losing ground)

Source: IDTechEx

Flex Electronics Could Follow Similar Growth Path of ICs and PFDs



Source: SEMI, WSTS, DisplaySearch, NanoMarkets

Why Flexible Electronics?

An entirely new industry will impact many sectors from consumer to defense and security

Power
-Batteries
-Photovoltaic

Lighting
-Point Source
-Large Area

Sensors
-Defense
-Health & Medical
-Infrastructure

Communications
-Displays
-Signage

Opportunity for Job Creation and Development of Manufacturing Skills & Equipment

Why a Flexible Electronics Consortium?

To Combine Multiple Interests & Mitigate Limitations

Government	Industry	Academia
Interests •Job creation •National security •National competitiveness •Economic growth •Cost of government services	Interests •Profit •Revenue •Market dominance •Product leadership •Intellectual property •Start-up environment	Interests •Educating and training students •New Innovative R&D •New materials and processes
Issues •Don't like picking winners & Losers •Pre-competitive R&D •Each government department has narrow focus	Issues •Cannot exist alone no matter how big the company •Need complete new industry supply chain •Have fewer R&D $ •Few big R&D centers left like Bell Labs, etc.	Issues •Less R&D funding •Relevance •Needs better connection with industry

Why a Flexible Electronics Consortium?

- Materials, equipment and processes cut across many research and manufacturing areas
  - Beyond any single company
- Allows collaboration to overcome common challenges
  - Research is pre-competitive
  - Processes will reach across applications
  - Capable of broad adoption
- Allows identification of technology gaps
  - Through roadmapping and technology assessment
- Allows for coordination to minimize technical overlap and increase research efficiency

Why a Flexible Electronics Consortium?

- Galvanize industry and government interest
- Promote cooperation and collaboration in a time of limited economic resources
- Align interests of end product manufacturers to tools and materials suppliers
- Address pressing needs
  - e.g., product integrity and lower energy costs
- Adapt to changing U.S. manufacturing dynamics
  - *how is printing industry affected by rise of e-books, printed PV, low cost medical sensors?*

Why a Flexible Electronics Consortium?

Lessons learned from past consortia

- Timing is crucial: worldwide competitors not static
- Broad scope and constant re-thinking
- Provide sufficient funding
- Success can't be predicted
    - e.g., Corning is the most profitable company in the FPD industry

... apply them to future consortia

- Provide leadership and best practices to industry
- Foster synergy and collaborations
- Address dual-use requirements
- Create IP policy that encourages innovation and commercialization
- Focus on U.S. based companies and jobs

Why a Flexible Electronics Consortium?

Government and Electronics Industry Interests Are Intertwined

- Defense and Homeland Security are dependent on a U.S. (and worldwide) electronics industry
- Future procurements and legacy systems are huge issues for DOD
- Electronics industry is a jobs creator
- Shared support for R&D is a responsibility

"…industrial policy works best when a government is dealing with areas where it has natural interest and competence, such as military technology or energy supply."

The Economist - Aug. 5, 2010

Impact of a National Flexible Electronics Consortium

The National Consortium

- Will not be the biggest part of this new industry but will be the most critical part
- Will ensure the supply chain is complete

National Consortium Proposal

- U.S. Government should join with industry to support a national consortium which focuses on technology commercialization and works across markets
- Include a focus on supply-chain and infrastructure development to develop and sustain U.S. –based flexible manufacturing
- Sponsor academic and industry R&D for new manufacturing materials, equipment and processes
- USG funding of $350M-$650M over 5 years with a ramped industry cost-share to attract significant industry participation


Thank You

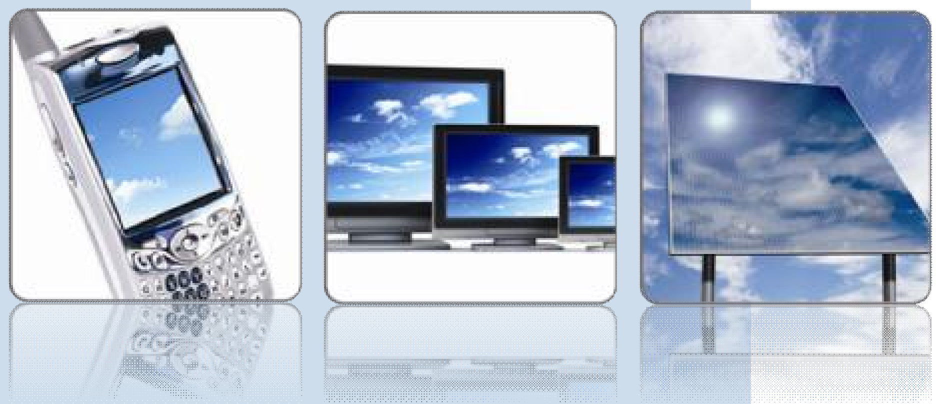
APPLIED MATERIALS®

Cooperating on the Manufacturing Challenge

Tom Edman

Vice President

Corporate Business Development and
Global Corporate Affairs & Marketing



September 24, 2010

Agenda

Applied Materials introduction

The power of partnerships

Safe Harbor

This presentation may contain forward-looking statements, including those regarding Applied's performance, opportunities, products and industry outlooks. These statements are subject to known and unknown risks and uncertainties that could cause actual results to differ materially from those expressed or implied by such statements, including but not limited to: the level of demand for Applied's products, which is subject to many factors, including uncertain global economic and industry conditions, end demand for electronic products and semiconductors, government renewable energy policies and incentives, and customers' new technology and capacity requirements; Applied's ability to (i) develop, deliver and support a broad range of products and expand its markets, (ii) align its cost structure with business conditions, (iii) plan and manage its resources and production capability, (iv) implement initiatives that enhance global operations and efficiencies, and (v) attract, motivate and retain key employees; and other risks described in Applied's SEC filings. All forward-looking statements are based on management's estimates, projections and assumptions as of August 18, 2010, and Applied undertakes no obligation to update any forward-looking statements.

Who We Are

- World leader in nanomanufacturing technology™ solutions
- #1 equipment supplier in semiconductors, LCD displays and PV solar
- Expanding into the next wave: energy and environmental solutions

1970+
Computing

1990+
Communications

2010+
Energy and Environment

At A Glance

Applied Materials solar energy system at its campus in Sunnyvale, CA, is one of the largest corporate solar power installations in the U.S.

Ticker:	Nasdaq: AMAT
Market Cap*:	$17.4 billion
Fiscal 2009 Revenue:	$5.0 billion
Fiscal 2009 R&D:	$934 million
Founded:	November 10, 1967
Headquarters:	Santa Clara, California
Global Presence:	93 locations in 22 countries
Manufacturing:	China, Germany, Israel, Italy, Singapore, Switzerland, Taiwan, United States
Employees:	~13,000 worldwide
Patents:	8,024 issued

* As of Oct. 25, 2009 (Fiscal Year-End)

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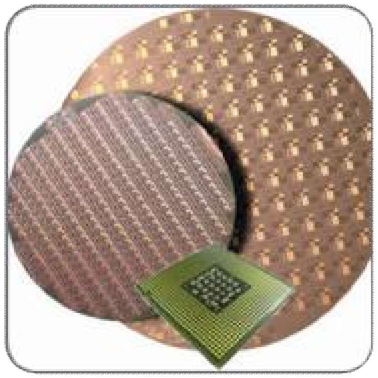
Delivering Manufacturing Scale Drives Low Costs

FIRST	THEN	NOW
		
Cost Per Transistor	**Cost Per Area**	**Cost Per Watt**
20,000,000x cost reduction over 30 years[1]	20x cost reduction over 15 years[2]	Toward grid parity

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

External Use

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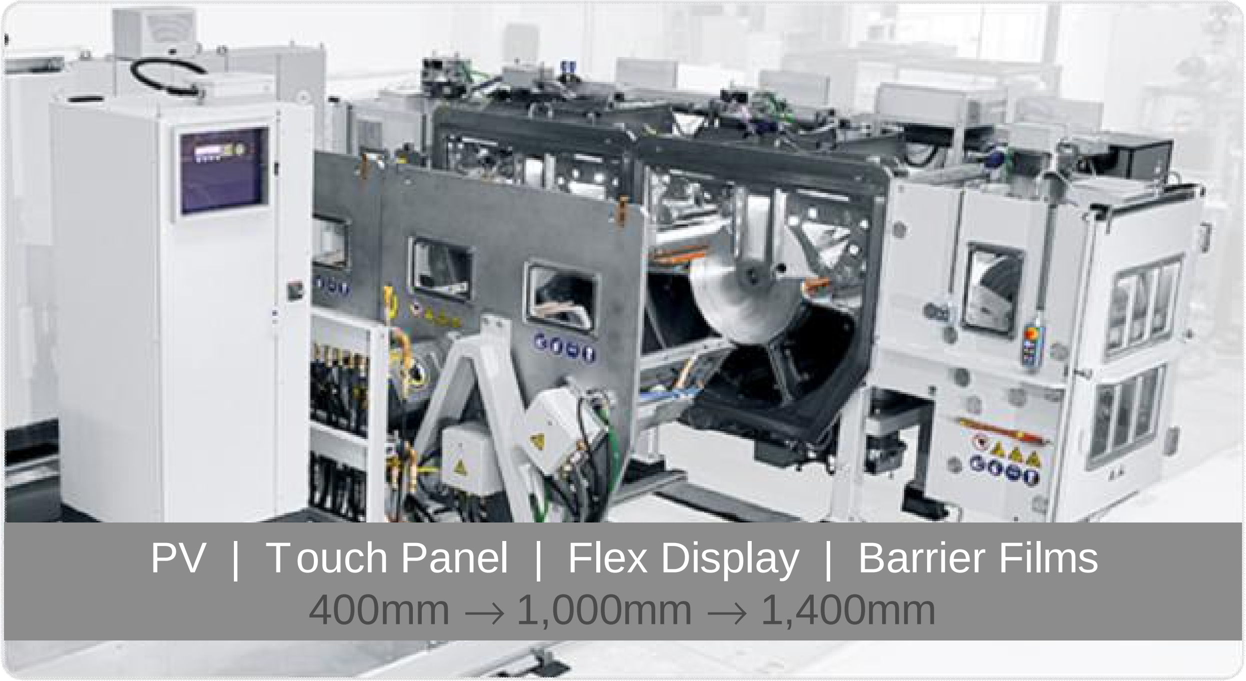
SmartWeb™ Well-Suited to Flex Electronics



- High volume manufacturing at lowest cost of production
- Modular architecture maximizes output for virtually any application
- Technical performance provides superior results

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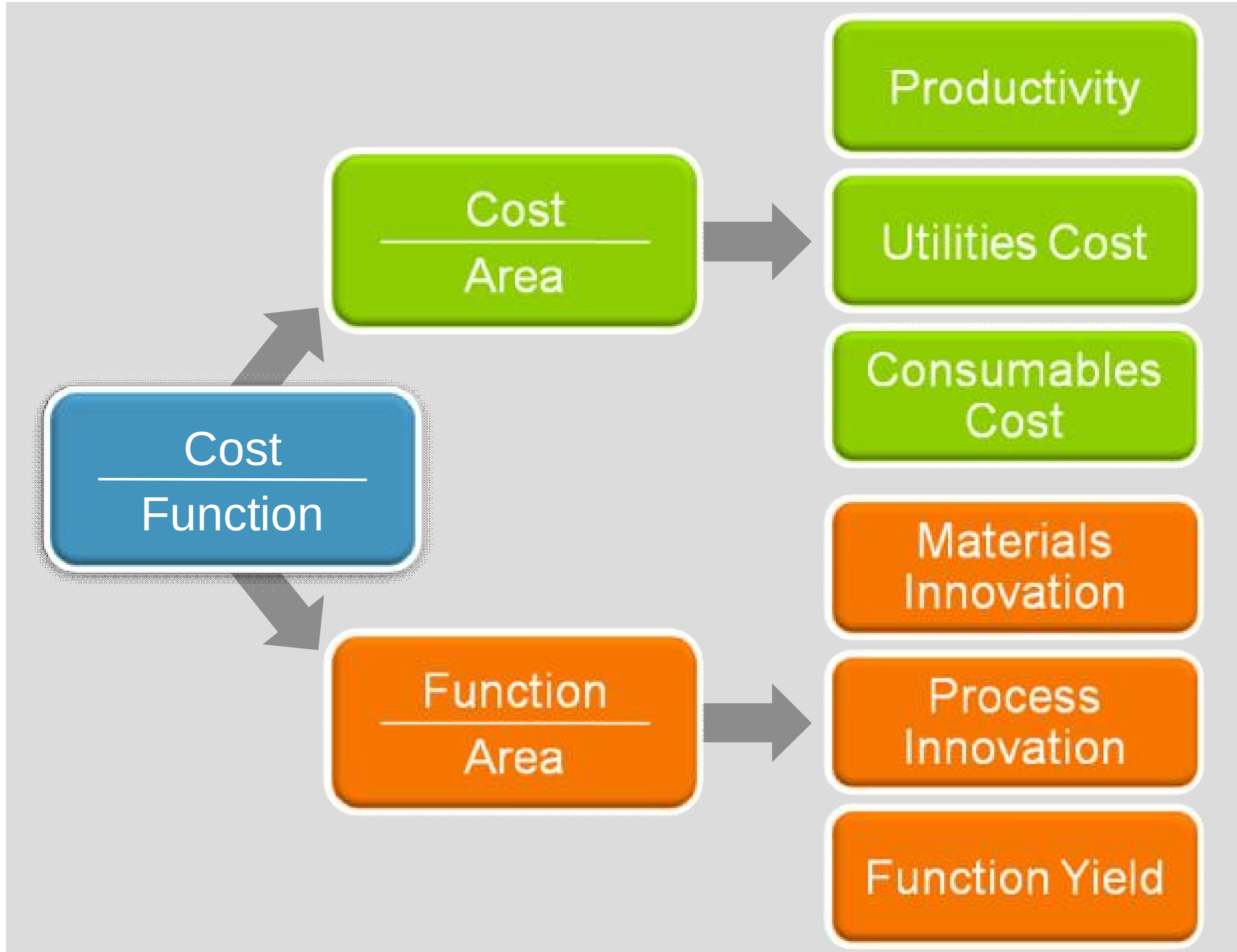
Driving Cost Down for Flex Electronics



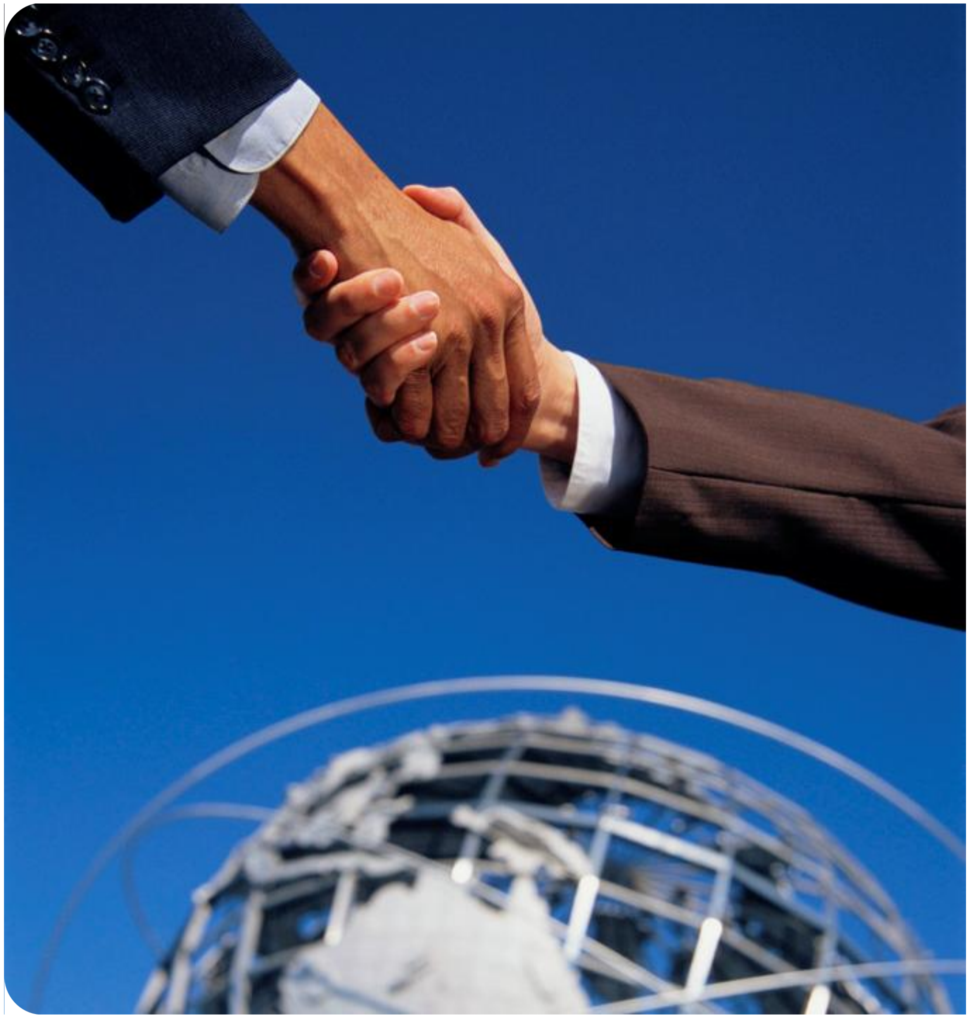
Cost Down = High Performance + Low Cost Production ($/m²)

The Power of

Partnerships

The Reason for Partnerships

- § Our markets
  - – Capital intensity falling
  - – End market growth slowing, but technology needs accelerating
  - – Markets shifting to Asia (low cost and speed to market)
- § Competitive intensity
- § Time to market
- § R&D treadmill



Types of Partnerships

Joint development programs
Partner with individual vendors/customers in adjacent spaces to speed time to market

Applied Ventures investments
Window into new technologies and markets which offer commercialization avenues

Major research institute collaboration

University collaboration

Externally funded RD&E programs
Government partnerships

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Applied Ventures Portfolio Companies

Solar Equipment, Services & Software	iosil ENERGY; KOTAK; WAKONDA TECHNOLOGIES; Fat Spaniel TECHNOLOGIES; Solaicx; [e] enphase ENERGY; SunEdison simplifying solar
Solid State Lighting	illumitex; GROUP IV SEMICONDUCTOR
Energy Storage	ClearEdge POWER; ActaCell; Infinite Power Solutions
Display & Glass, Materials	Liquavista; PLEXTRONICS; SAGE ELECTROCHROMICS, INC; TERA-BARRIER
Semiconductors, Memory, Sensors	SEMPRIUS; adesto TECHNOLOGIES; Transfer Devices, Inc.; GRANDIS
DFM , Test, Packaging	Takumi TECHNOLOGY; TESSOLVE test is our passion; AI Advanced Inquiry Systems
Photonics/Optical	INNOLUME; infinera; GLIMMERGLASS; devicescape; enara NETWORKS

External Use

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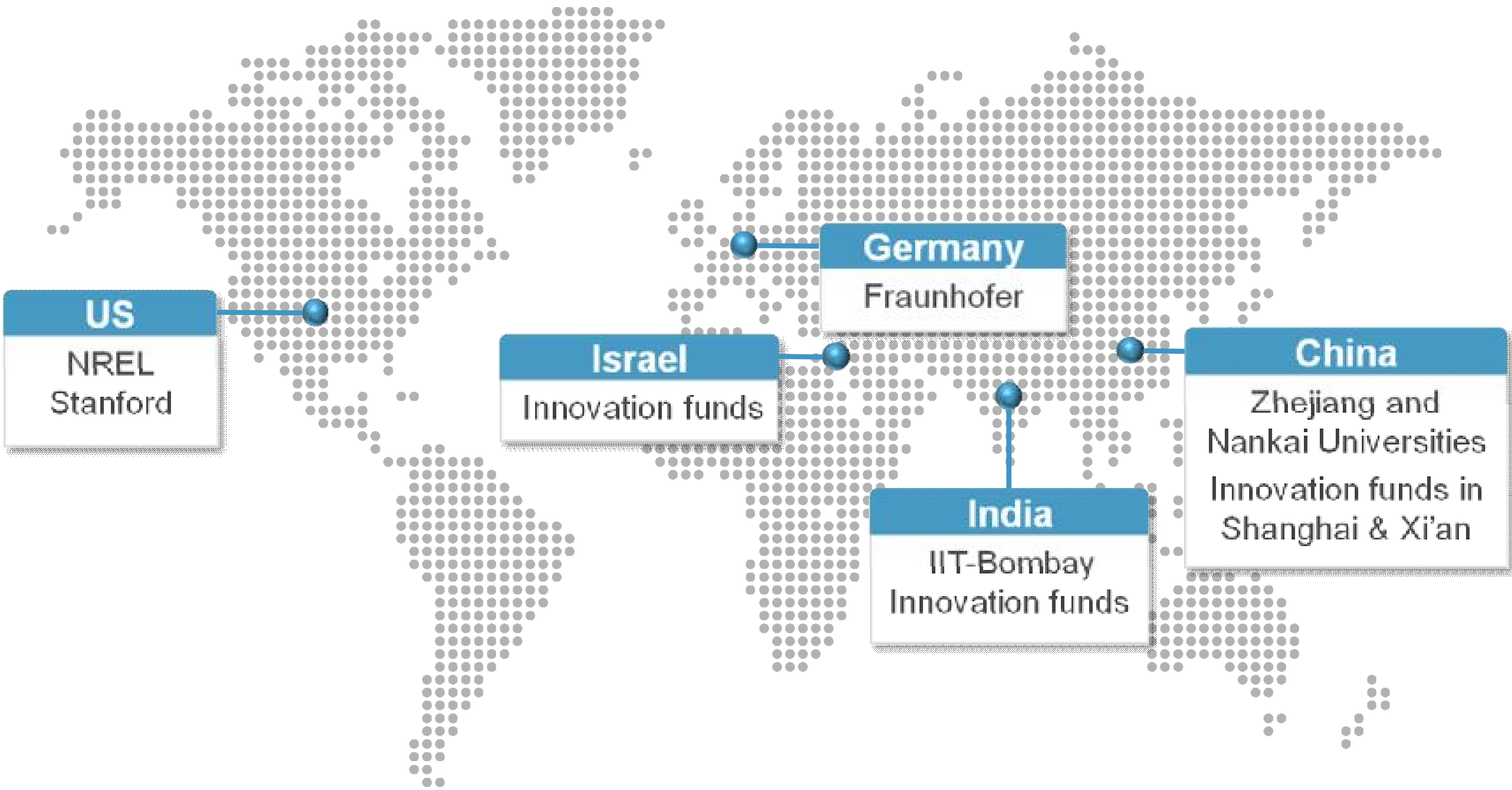
Applied Materials Global Partnerships



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Global University Investments

Vision:

Be the preferred partner with leading global universities and research institutes to spur innovation through nanomanufacturing research in electronics, display, energy and environment

Mission:

Lead Applied's investment strategy in global university research and ensure good ROI in the 3 R's Research, Recruiting, and Relationships)

Strategies:

- Collaborate on disruptive research ideas for defining new nanomanufacturing markets and products
- Collaborate on educating best students in Nanomanufacturing technologies and attract them to Applied Materials
- Where appropriate, collaboratively leverage external funds for turning nanomanufacturing inventions into innovations
- Speed time to market

Examples:

IIT Bombay, UCB, Stanford

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Externally Funded RD&E Programs

External funding – Why now and what for?

- Energy business is policy driven
- DARPA (and now I-ARPA) continue to fund game changing disruptions in Semiconductor/Microelectronics area
- Urgency to commercialize nascent technologies

Strategies

- Establish a roadmap driven discipline to the product planning and product development phases
- Create partnerships with key customers, suppliers, end users and research institutions to drive roadmap aligned technologies/products
- The external funding and the associated partnerships accelerate or strengthen Applied's pathway to commercialization and lead to creation of domestic manufacturing jobs

Government Funded R&D Projects

Project	Lead (Partners)	Federal $	AMAT $ (Cost-Share)	Comments
Advanced Epi tools for GaN light emitting diode devices	AMAT/AEP	$4.0 M (AMAT)	$4.2 M	Contract date: June 1, 2010 (2 years)
Novel high energy density Li-ion cells, manuf. modules, and integrated separator	AMAT/AEP A123 and LBNL	$3.1 M (AMAT) $1.3 M (others)	$ 4.3 M	Contract date : July 1, 2010 (2.5 years)
Development of high rate coating technology for low cost electrochromic dynamic windows	AMAT/ATG LBNL	$1.6 M (AMAT) 0.4 M (LBNL)	$2 M	Contract date : Sept 1, 2010 (1.5 year)
Market viable, dual-use, advanced energy storage solutions development program	AMAT/ATG Primet, Cornell and SUNY-Bing	$2.5 M (AMAT) $1.1 M (others)	$2.5 M (est)	Contract date: Sept 2010 (1 year)
High-volume manufacturing development for thin-film Li- stack battery technologies	AMAT/ATG	$0.7 M	$0.4 M (est)	Expected Contract date: Sept 2010 (1 year)

Major Research Institute Collaboration

Strategies:

- Link tools to adjacent process steps to gain learning on integrated process performance
- Lower required investment
- Speed time to market
- Opportunity to develop partnerships

Examples:

- Examples: IMEC, MTC, Albany Nanotech, Fraunhofer

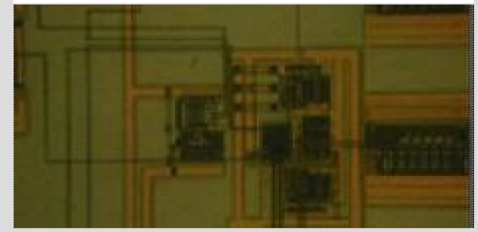
Flex Related Collaboration

CAMM
The Center for Advanced Microelectronics Manufacturing

Flexible TFT backplanes

- R2R devices on PEN

UNIVERSITY OF CAMBRIDGE
Department of Engineering

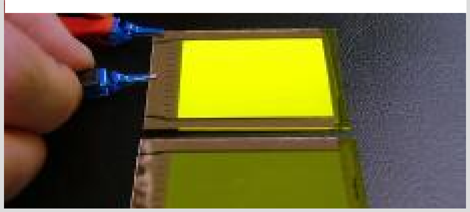


Semiconductor Characterization

- a-Si:H/µc-Si:H for PV

APPLIED MATERIALS
Web Group

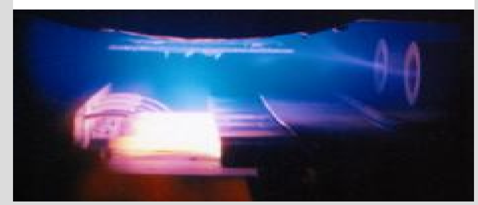
LTFN IVV ISC



Flexible TFT backplanes

- “Flexonics” project
- Barrier for OLED/PV

Fraunhofer
FEP



Barriers, Packaging

- Dev. of hollow anode
- Clear Al_2O_3 barriers

Conclusion

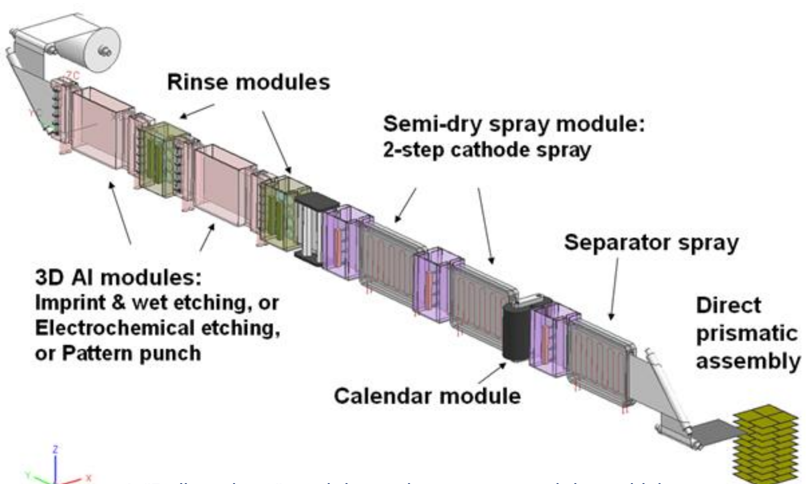
- Applied Materials is well-positioned as a present and future capital equipment partner for the commercialization of technologies
- Partnerships of all types are an essential time to market tool for the future
- Government/Industry partnerships very helpful in path toward commercialization
  - Early identification of strategic industries
  - Assistance across the path of commercialization very attractive
- Flex applications at a critical stage
  - Multiple applications emerging (touch panel, display, solar, battery)
  - Active government/industry partnerships could determine final winners
  - Applications have moved beyond the lab so commercialization assistance will be critical

Turning innovations
into industries.™

WIN: $4.37M from ARPA-E for Advanced Li-Ion Battery Manufacturing

Technology Summary

This project addresses the challenges of power performance of high capacity loading electrodes to enable high capacity cell design with a **novel electrode architecture with tailored porosity, optimal particle size distributions and 3D current collecting capability**. To simplify manufacturing processes and to **reduce battery cell material cost**, the **separator is deposited directly onto the electrodes**.



A "Roll-to-sheet" modular tool prototype modules, which will be constructed at Applied Materials during the project to fabricate novel electrodes and integrated separator stacks. Roll-to-sheet tool platform can lead to direct prismatic cell assembly approaches.

Key Personnel

Applied Materials (Lead, PI – Connie Wang), A123 Systems, Lawrence Berkeley National Lab

Program Summary

Period of performance: 30 months

ARPA-E funds: $ 4,373,990
Cost-share: $ 4,373,990
Total budget: $ 8,747,980

	Key Milestones & Deliverables
Year 1 (2010)	§ Multi-layer semi-dry spray using 1-sided auto R2R prototype
Year 2 (2011)	§ 3D Al structure fabrication and select approaches
Year 3 (2012)	§ Design, build R2R prototype to fabricate separator on electrode

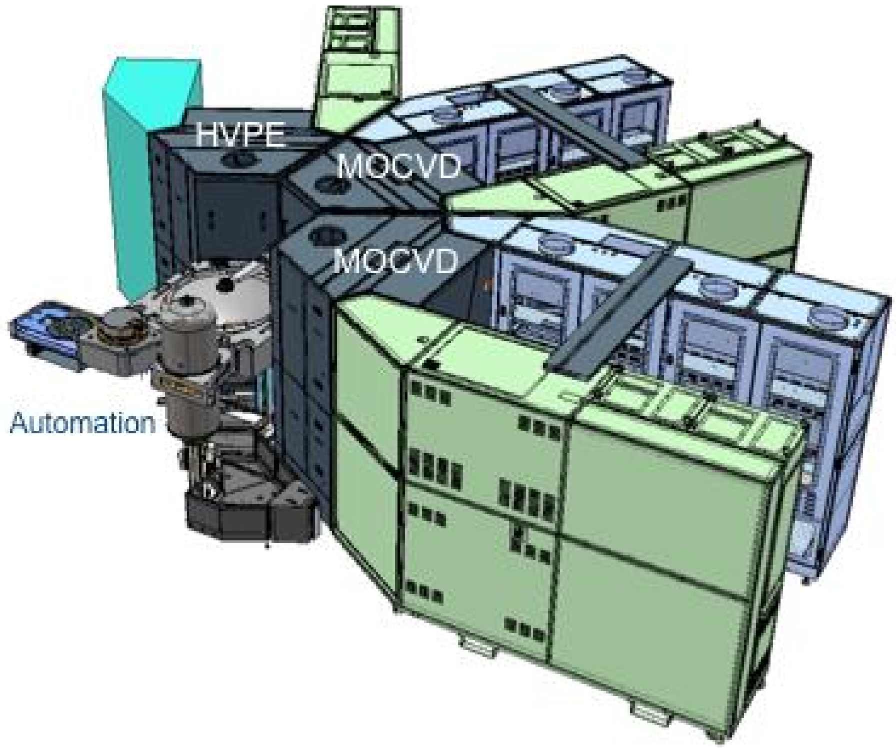
Technology Impact

A roll-to-sheet prototype process tool modules will be demonstrated to fabricate the novel cathode electrode-separator stack using innovative semi-dry spray processes. Cycling performance of the novel stack will also be demonstrated. The tool is flexible to incorporate most advanced active materials to meet energy density targets, manufacturers' high throughput requirements, and to pave the way for direct prismatic cell assembly. Advanced Device Prototyping Category: TRL-4 (current) to TRL-6 (at the end of the program)

 Cathode Manufacturing Tools for high energy density prismatic cells

WIN: $3.9M from DOE - Advanced Epi Tools for GaN LEDs

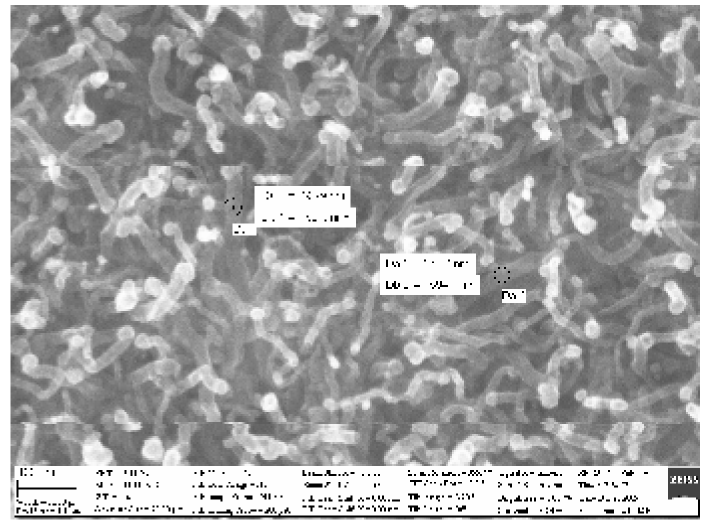
- Develop an advanced epitaxial growth system that will decrease operating costs, increase internal quantum efficiency, and improve binning yields.
  - decrease operating costs by decreasing cycle time, increasing throughput, and decreasing the cost of chemicals.
  - increase the internal quantum efficiency of LEDs by reducing the density of extended defects and point defects.
  - improve binning yields by improving the uniformity of wavelength and output power within the wafer, from wafer to wafer, and from run to run.

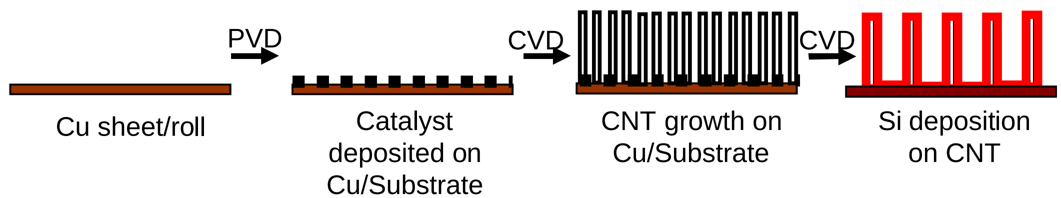


Proposed Epitaxial Growth System in
2 + 1 Configuration (2 MOCVD + 1 HVPE)

WIN: $3.6 M from CERDEC for Adv Energy Storage Solutions

- The key goals of this program are reduction in cost and improvement in performance.
  - For the negative electrode, improvements in specific and volumetric capacity will be achieved by a) substituting higher capacity Si or Sn for graphite and b) employing engineered structures increasing the active material fraction in the electrode.
  - For the positive electrode, higher specific energy will be achieved through substituting higher voltage material, LiMn1.5Ni0.5O4 (LMNO) or a variant spinel (LiMn2-xNixO4, x≤0.5), in place of the conventional materials.





SEM of CNT coated with amorphous-Si. Approximately 27 nm diameter Si (above)
Schematic of CNT – Si nanocomposite anode electrode (below)

WIN: $2 M form DOE ECW

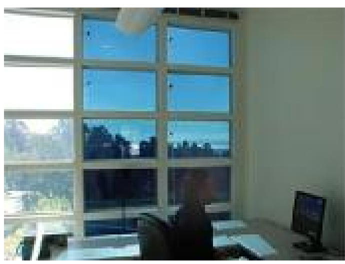
ECW Potential Impact

- ~ 6% of total US energy use due to windows
  - Total energy usage: ~ 100 Quads/yr (1 Quad = 1E15 BTUs)
- ECW Potential impact Projected Savings(@ market maturity)
  - 1.5 Quad/yr energy savings, i.e. 275 Million barrels/yr of petroleum
  - 87 Million Metric-tons of Carbon Dioxide/yr,

Applied's strategy

- Innovations for EC technology
  - Materials for better performance (key layers are EC, IC and CE)
  - Material stack innovations (cost reduction, better integration, color stability and shifting)
  - Process integration and device architecture (yield improvement and product diversification)
- HVM technologies for EC manufacturing
  - High throughput IC layer
  - HVM compatible Li deposition source
- Establish key partnerships

Architectural Windows

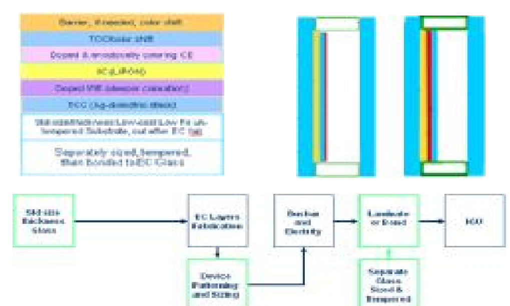


$13.8B, 2012

Transportation

$11.7B, 2012

EC Innovations



WIN: $0.8 M from CERDEC Phase I TFB

5x5mm (~ 50 µAh)	1 in² or 25x25mm (~ 1mAh)		Stacked (>10 mAh)
Backup Real time clocks Memory backup	**Tagging/ID** RFID, SmartCards, SecurID	**Wireless Sensors** Automotive, Energy Health, Industrial	**Devices** Consumer, Telecom, Medical

10's µAh ⟷ 10's mAh

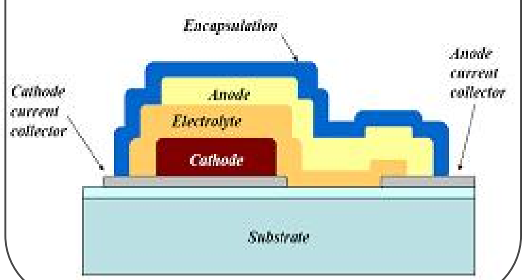
TFB Opportunity

- Robust, rechargeable, micro-sized, solid state battery for micro-powered applications
- Nearly a $10 Billion end-use battery market for Back-up and RFID applications

Applied's strategy

- Innovations for TFB technology
  - HVM compatible TFB technology
  - Mask-less Integration, high dep rate sources, elimination of inert ambient requirement
- Bifurcated equipment platforms and TFB types/applications
  - Si IC platform/substrate for very small TFBs (small--< 5mm x 5mm)
  - Inline large area coater for large TFBs (large -- ~ 1" x 1")
- Vertically integrated consortium formation

TFB Schematic Drawing



New Aristo Platform

APPLIED MATERIALS

Enabling Flex Electronics: Advanced Barriers

DISPLAY

↓

Electrophoretic Displays

OLED Displays

Barrier Performance ($g/m^2/day$)	Application
10^{-6}	
	OLEDs
10^{-5}	
	Solar Cells
10^{-4}	
	Thin-Film Batteries
10^{-3}	
	Electrophoretic Displays, Sensors
10^{-2}	
	RFID Electrochromic Displays
10^{-1}	
	Medical Packaging Food Packaging

New Barrier Tech. (10^{-6} – 10^{-3})

Single Layer (10^{-2} – 10^{-1})

ENERGY & ENVIRONMENTAL

↓

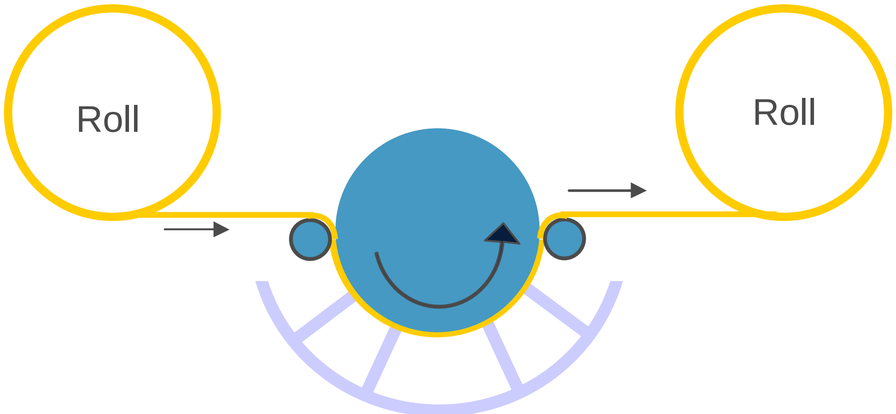
Flex PV

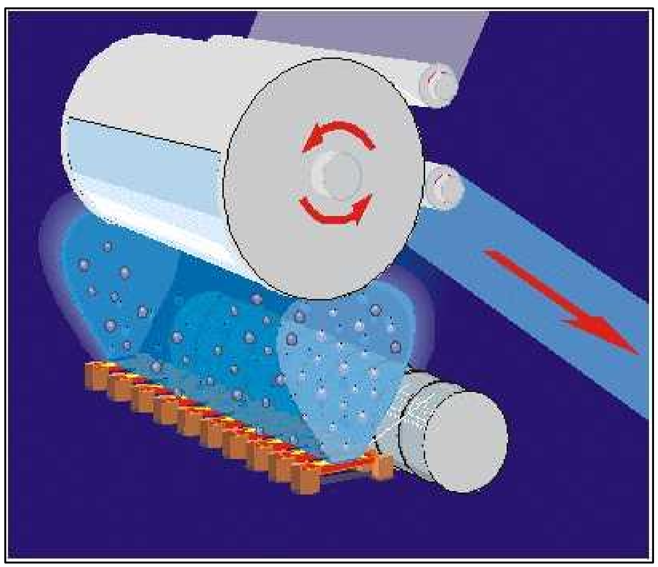
OLED Lighting

Flexible TFB's

Barrier Required to Protect Active Layers from Oxygen & Moisture

Roll-to-Roll Processing Fundamentals





- High productivity processing
  - Substrates several km long
  - Substrate thickness < 180 µm
  - Typical width 0.4 – 1.4 m
- Batch based inline coating process
  - PVD, CVD & thermal evaporation processes used
  - Coating drum for substrate temperature control
  - Patterning & etching tool for defining device structures
- Inline process monitoring & control necessary to maximise productivity
  - High speed for throughput
  - Accuracy for yield & reliability

Research Categories and Organizations

- Major Consortia: SRC/GRC & SRC/FCRP
- Global R&D centers (Applied Materials Nanomanufacturing Center at IIT-Bombay, AMAT Center of Excellence on PV at Zhejiang and Nankai Universities)
- Collaboration with major research institutes (e.g., LBNL, MIT-LL, and NREL in USA, Fraunhoffer and ZSW in Germany, CEA in France and CSIR and NCL in India)
- Mini-consortia memberships (e.g. UCB, Stanford, MIT, and SUNY-SB)
- Tool donations and service support (e.g., UCB, Stanford, IIT-B)
- Innovation funds (e.g., Shanghai, Xi'an, India and Israel)
- Individual faculty research grants and faculty sabbaticals at Applied.
- Applied Materials fellowship grants for graduate students
- Industrial post-doctoral fellowship program
- Summer undergraduate internships
- Membership in large NSF and DOE funded multi-university research centers
  - NSF/EUV-ERC (CO & CA)……Extreme Ultraviolet Technology
  - NSF/Nano-CEMMS NSEC (Univ Illinois)….Nanomanufacturing
  - NREL/CRSP (CO)…Center for Revolutionary Solar Photoconversion
  - NSF/ERC (RPI)…….Smart Lighting
  - NSF/EFRC (USC)….Solar Cell and LED Technologies

Applied Materials Collaborates with Over 100 Global Universities, Consortia and Research Institutes with an Annual Investment o

APPLIED MATERIALS