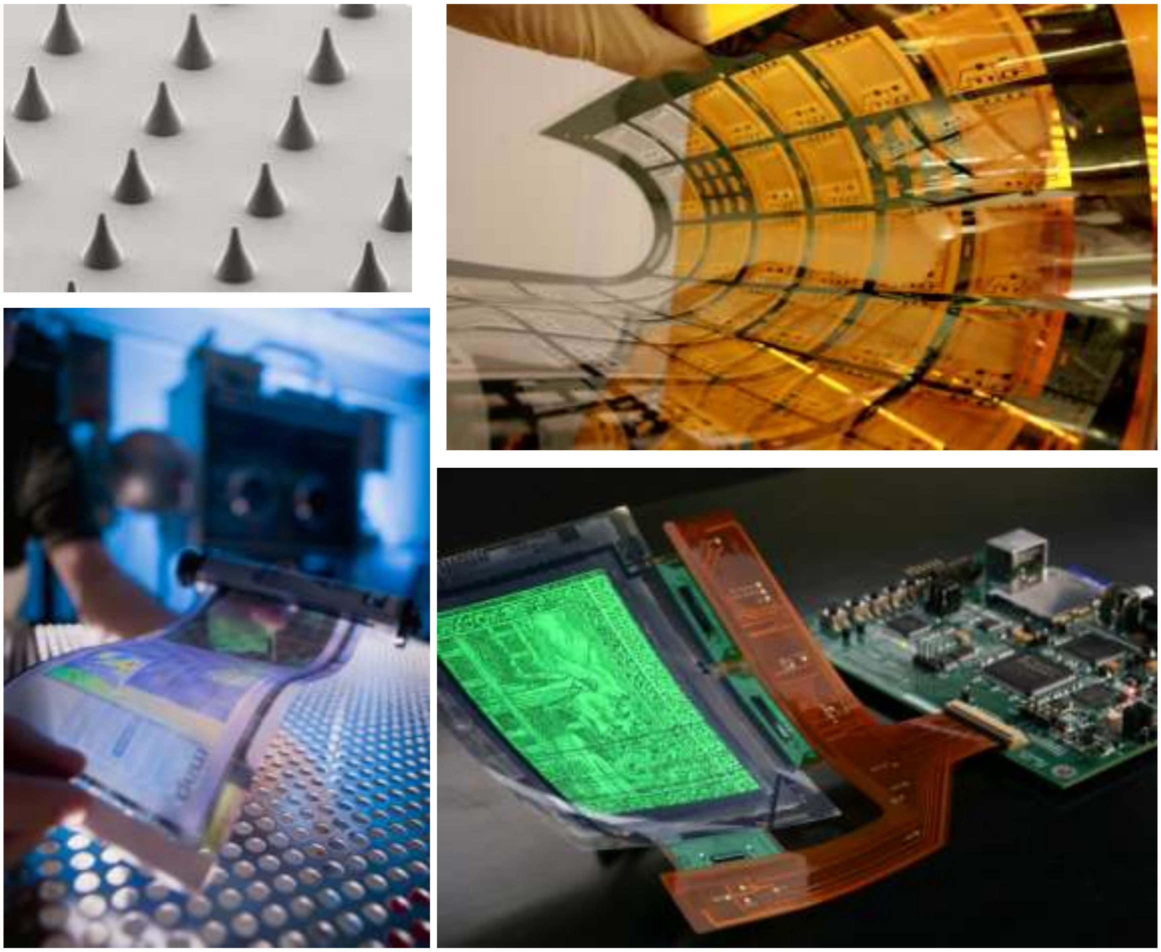
Advanced Materials Initiative



Arizona State University
Technology and Research Initiative Fund (TRIF)

Business Plan

Fiscal Years 2010–2011

August 2009

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0. Executive Summary

The U.S. has the opportunity to become a worldwide leader in the innovation, application and production of flexible electronics, incorporating a set of technologies that can readily address many challenges in the consumer, industrial, medical and defense markets. The past 50 years have shown unprecedented economic growth, manufacturing efficiency, and the advent of information services, all enabled by the microelectronics revolution. The U.S. leadership in developing microelectronics for both commercial and defense applications has been a significant driver of job and wealth creation that continues today. A similar opportunity is emerging — the use of flexible electronics applied across a multitude of applications. These products can be manufactured on thin glass, metal foil or plastic, but the common theme across each application is a very different approach to the creation of electronic devices. Specifically, electronic devices can now be built on a larger, human scale with simpler and lower cost processes, using materials that do not require toxic and expensive ultra high purity processing. While some applications are widely known (e.g., the use of organic light emitting materials (OLED) for displays) the true promise of this technology is only beginning to be realized.

Large area flexible electronics will grow into a multibillion-dollar industry over the next decade and will revolutionize our view of electronics and how we, as a society, interact with intelligent and responsive systems. The unique properties of flexible electronics, such as its compliant structures, ultra-thin profiles, low weight and potential low cost and high reliability could have enormous impact on consumer electronics, aviation and space electronics, life sciences, military applications and telecommunications. Large area flexible electronics will enable a broad range of devices and applications not possible today. For example, through flexible electronics, simple devices like medical bandages can be given the ability to sense both wound healing and the presence of infection, alert medical staff to changes in a patient's condition and deliver needed medication, all at low cost. Lightweight, foldable, rugged solar panels and electronics will change many space and aviation applications. Smart clothing with integrated electronics and displays will have many consumer and military applications. The three large area flexible electronics based products identified as near-term commercialization opportunities are: displays, photovoltaics, and sensors.

To achieve a leadership position in this promising emerging technology arena, ASU is investing future TRIF funding in the Advanced Materials Initiative. The Initiative combines capabilities that have been developed for flexible displays and flexible electronics with bio-sensor capabilities to provide display and sensor arrays with advanced functionality to meet the potential of the emerging flexible electronics industry. The Advanced Materials Initiative will be the nexus to attract top talent, leading and developing companies, and synergistic academic programs for advanced electronics and materials research in the newly emerging flexible electronics industry.

With the dynamic rate of change for this new industry, manufacturing will locate near the centers of knowledge creation in order to take first advantage of new developments. As proper automation takes place in the manufacturing toolset, the relative contribution of labor decreases, and manufacturing costs are reduced dramatically, then it becomes advantageous to site production at numerous locations where product is used and the materials and equipment knowledge is created. This factor is a key reason why ASU and the State of Arizona should be an active and committed participant in the flexible electronics industry, and why there is a compelling return in this investment in terms of high quality job creation as a result.

1. Core Vision/Project Description

1.1. Overview of Flexible Electronics Industry

The Advanced Materials Initiative seeks to expand ASU's research capacity in sensor development, nanotechnology, and the development and characterization of materials of interest to the flexible electronics areas. This initiative builds on ASU's existing strengths in nanoelectronics, sensor development, materials characterization, and emerging strengths in flexible electronics, nanoscale science and technology. Applications for these technologies include novel microelectronic (low-power, high-power, high-temperature, and/or high-frequency), microfluidic, and biotechnology devices integrated into microsystems for high-value-added applications in the information technologies, health care, threat detection, transportation, processing, and manufacturing industries.

The emerging flexible electronics industry is expected to be a lucrative market sector on scale with the microelectronics industry. The 2009 iNEM (International Electronics Manufacturing Initiative) Large Area, Flexible Electronics Roadmap Chapter provided an overview of the most critical technologies necessary for commercial launch and market diffusion of large area flexible electronics-based products. Some of the technical drivers of the industry cited by the Chapter include availability of higher performance semiconductor materials such as solution processable pentacene, inorganic pre-cursors, nanoscale silicon and other novel inorganic and organic dispersions, commercialization and near-commercialization of large area processing equipment compatible conductive and dielectric materials, development of large area, lower-cost manufacturing processes leveraging roll-to-roll equipment infrastructure and a growing demand for low-cost sensors, low-frequency wireless devices, innovative signage, and flexible displays.

Innovation and demonstrated improvements in materials and processes are enabling the development of signage, gaming, low-cost sensors, displays, and low-frequency wireless device products, as well as advances in organic, inorganic, and hybrid semiconductor technologies and advances in the design and layout of large area flexible electronics based products. The industry is experiencing paradigm shifts with integration of electronics in non-traditional objects and places, processing and manufacturing platforms that enable large-area flexible electronics and novel form factor electronics-based products, and low-cost electronics for single-use applications. However, there are some technology gaps to eliminate to address these shifts, such as:

1. Rate of commercialization of materials, manufacturing/processing equipment and in-line/off-line characterization tools technology is not occurring rapidly enough to meet the cost/performance/utility demands to enable near-term product launches.
2. Lack of a well-developed supply chain and deep infrastructure are slowing development of cost competitive products.
3. Lack of workflow architectures and systems that combine functional electronic content with non-traditional electronics placement are slowing large area flexible-electronics enabled product commercialization.
4. Lack of design and simulation tools are slowing the diffusion and acceptance of large area electronics into the market.

The applications and components listed in Table 1 are composed of organic, inorganic, or hybrid materials and fabricated via mass manufacturing compatible processes (ambient, vacuum, or hybrid). Several industry reports have projected that by 2015, the market could grow to greater than $100B with products such as flexible displays, sensors, energy modules, lighting systems, RF networks, and smart packaging. The global market for large area flexible electronics will grow from $0.65B in 2005 to $30B by 2015 with logic, displays, and lighting products contributing the greatest growth. Future projections show that organic electronics can potentially grow to be $250B by 2025, with products as diverse as logic/memory, OLED displays for electronic products, OLED billboards, signage, etc., non-emissive organic displays, OLED lighting, batteries and photovoltaics, and sensors. These large-area, flexible electronics-based products can be all-printed, or constructed using printed, flexible, laminated structures. Other potential products such as laminar, organic fuel cells and organic electrostatic and RF protection are also in the forecasts. Opportunities exist in aerospace and defense, automotive, medical, networking, and portable and consumer electronics for displays, memory, power, RF devices, sensors and anti-tampering circuitry.

Table 1. Total available market (TAM) for several large area electronics opportunities in 2020

Electronics System	TAM Opportunity	Technology
Displays/Signage	$30B	Emissive, reflective
Sensors	$6B	Chemical, biological, moisture, temperature
Low RF	$20B	Personal area network, RFID
Energy	$15B	Photovoltaic arrays, primary batteries
Lighting	$15B	OLED, electroluminescence
Logic & Memory	$30B	Crossbar
Authentication and Anti-tampering	$10B	Logic architecture

The combination of molecular lithography, polymer-based electronics and directed molecular assembly provides a broad range of commercial applications in the design of novel sensor systems for use in medicine and multiple industries, delivery systems for drugs and vaccines, and as control devices for clinical and biological reactions in diverse industrial settings. The National Science Foundation has predicted that the market for nanotechnology, or products containing nanotechnology, will reach $1 trillion in ten to 15 years.

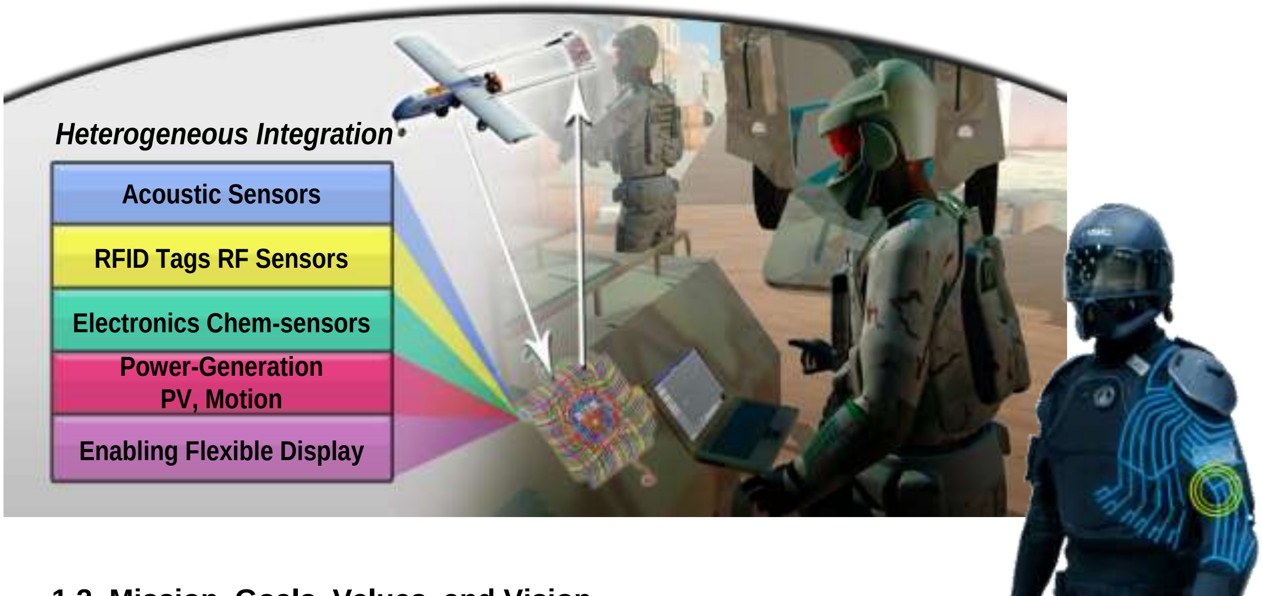
According to a 2008 study by the FlexTech Alliance (FTA), both the European Union (EU) and the U.S. governments have been investing in the flexible and printed electronics industry since 2001, including significant commitments for funding through the end of 2013. The combined total commitment of government funds to flexible and printed electronics is just over $1B over the period 2001–2013. Of this total, the EU commitment is $719M with a commitment of $327M by the U.S. government. In the U.S., directed funding for flexible and printed electronics is provided primarily through three agencies — the Defense Advanced Research Projects Agency (DARPA), the Army (generally through the Army Research Lab or ARL) and the National Institute of Standards and Technology (NIST) as part of the now-defunct Advanced Technology Program (ATP). These three agencies have invested or committed a total of approximately $200M in R&D funding over the 2001-2013 period. According to analysis done by the NIST Advance Technology Program, $1M in government funding triggers $1.6M industry costsharing, causing $8M total economic impact, creating/maintaining about 100 jobs based on an average high tech job average salary of $80K.

The Advanced Materials Initiative seeks to address some of these technology gaps and industry needs by combining expertise and capabilities developed at the Flexible Display Center (FDC), and the Applied NanoBioscence Center (ANBC). The FDC is a Center initiated in February 2004 under cooperative agreement W911NF-04-2-0005 by the U.S. Army to create an ASU-led Center that collaborates with government, industry, and other universities to develop solutions for technology development and manufacturing challenges in flexible displays and flexible electronics. Initially, the principal goal of the FDC was to provide the U.S war fighter with ubiquitous conformal and flexible displays that are lightweight, rugged, low power, and low cost to significantly enhance human-machine interfaces and in turn situational awareness and operating effectiveness. To accomplish this goal, the FDC has successfully implemented a Pilot Line manufacturing-consistent infrastructure and collaborated on materials and processing tools development to address supply chain issues and process development that addressed substrate system and handling issues.

ANBC is a Center that specializes in advanced materials and process development for flexible transparent conductors, integrated electronics and energy sources, organic electronics, and system-on-chip technology. ANBC actively seeks to foster productive interactions with the industrial and life sciences communities to enable commercialization of the research that is conducted at the Institute. In collaboration with universities and industry partners, ANBC is making significant breakthrough developments in converging nanoscience, biotechnology and cognitive science into technology platforms that can be mass produced. These platforms are designed for “anticipatory/predictive measures” critical to the emerging medical and service applications of this century. Employing the best scientific and engineering practices, ANBC hopes to develop novel molecular-based diagnostic tests that can be used by individuals and public health systems to facilitate personalized medicine. Personalized medicine is core strength of the institute. To create new ways to diagnose disease, monitor health, and build enabling polymer electronics, new technologies are merged from nanoscience, microelectromechanical systems (MEMS), polymer and ambient intelligence with genomics and molecular biology. This fusion allows for the creation of novel sensor systems with a broad range of commercial applications. These sensors have applications in drug and vaccine delivery systems and in clinical and biological reaction-control devices for diverse industrial settings.

The core competencies demonstrated by the FDC and ANBC demonstrate synergies that are anticipated to make dramatic impacts on the advanced electronics and materials needed to support the emerging flexible electronics industry. Specific areas identified for “synergistic technology development” between the Centers include:

- Printed batteries and sensor systems
- Polymer processing; Nanoscale feature forming in substrate polymers using Next Generation Lithography Techniques
- Development of new photoresist materials for high resolution patterning
- Hybrid solar-fuel cell systems
- Plastic electronics for medical devices (e.g. heaters and thermal probe for thermal management of bioreactors)
- Displays and detectors for medical applications (e.g. X-Ray detectors)
- Ambient Intelligence and Advanced Lighting for Patient Care



1.2. Mission, Goals, Values, and Vision

The substantial investments in the unique facility of the Advanced Materials Initiative and its infrastructure, human capital, Pilot Line toolsets, and all the associated learning in design, processing, testing and evaluation, and integration and innovation represents a tremendous innovation potential and national asset for new technology development. The Initiative will evolve to become a one-of-a-kind institution whose lifetime transcends that of technology development cycle times, and whose technology scope includes macroelectronics and flexible electronics technologies beyond information displays. This rapid new technology development initiative will bridge the capability gap between proof-of-concept laboratory work and manufacturable integrated products or components. Independent of specific technology target, the organization will continue to leverage its unique strengths in design, process, and new material development, fabrication and rapid prototyping, test, and integration. Technology targets include portable power including solar, on-body diagnostics and environmental sensors, RFID, antennae and other communications components. Potential application areas include portable energy, security, personal health monitoring, and communication. As Pilot Line processes mature and improve, a portion of the Pilot Line capacity may be applied in a MOSIS-like operation for partners and customers.

The Initiative will evolve towards this new mission by integrating additional functionalities (e.g., power, sensing, wireless communications component) on flexible substrates and in integrated technology demonstrators in the next 6-10 year time period. ANBC's goals to: (1) apply advances in nanoscience, molecular biology and genomics to a new generation of enabling tools converging nano- and micro-scale technologies in order to better understand the molecular origin of diseases; (2) employ best scientific and engineering practices to help fundamentally change the approach to improving global public health by developing and facilitating the use of molecular diagnostic tests by individuals and public health systems; and (3) to contribute to the advance of personalized medicine by fostering the transformation of biological and physical principles into effective products with focused impact on oncology, orphan rare diseases and infectious diseases will be fundamental to increasing functionality of flexible electronic systems.

Full integration of an education and training dimension is positioning the Institute to provide industry with highly capable engineers and scientists skilled in emerging technology development. Educational and workforce development plans include expansion and development of a formal internship program, a devoted student research pilot line tool set, curriculum offerings specific to flexible electronics, an Arizona corporate advisory and sponsorship program, and Arizona university and high school student outreach efforts.

Over the next five years, the overarching goals will be to raise the Initiative's profile, evolve our successful business model to strategically address technology opportunities, develop a research engine to accelerate technology transition opportunities, and provide leadership in the flexible microelectronics industry to achieve sustainable funding for long-term success of this unique ASU, Arizona-based capability.

Our vision is to evolve and leverage the FDC's world-class flexible display capabilities, in concert with the ANBC and other ASU synergistic research and development, to achieve a global leadership position in the emerging flexible electronics and displays industry and establish ASU as a unique, high-value national asset for our government and industry partners.

Vision: Achieve global leadership in innovative research, development, engineering and technology demonstration of flexible displays and flexible electronics.

The Initiative's mission is to advance full-color, video-rate, flexible display technology and catalyze development of a vibrant flexible display and flexible electronics industry. To realize this mission, the Initiative will: (1) produce integrated flexible display technology demonstrators for stakeholders with ever-increasing performance and advanced functionality; (2) collaborate with government, academia, and industry to provide comprehensive flexible displays and electronics development capabilities that bridge the high-risk, resource-intensive gap between innovation and product development in an information-secure environment for process, tool, and materials co-development and evaluation; and (3) integrate the concept of sustainability into all activities.

Mission: Accelerate commercialization of flexible electronics and delivery of revolutionary, high-functionality information display technology.

2. Operational Strategies

2.1. Development and Production

2.1.1. Development Status

The MacroTechnology Works (MTW) Facility, where the FDC and ANBC are collocated, was designed as a new organizational mechanism that allows ASU to advance technology in three integrated modalities that are a departure from standard university practice: (1) large scale engagement of industry; (2) integration of design, technology, and engineering for product development; and (3) rapidly applied consumer-driven innovation. MTW bridges the gap between conceptual research and production-ready-product. MTW enables marketable science starting with collaboration and moving through the necessary steps — conceptualization and testing, prototype production, regulatory compliance, etc. — leading to a refined manufacturing-ready product. Utilizing University-provided, state-of-the art infrastructure, and leveraging ASU and Arizona core competencies, Centers working within the MTW infrastructure are championing a new paradigm for rapid product and intellectual property development. Expert recombinant developers will collaborate on development and manufacturing processes in these select areas: advance materials development, flexible displays and electronics, wireless technology, alternative energies for devices, and personalized medicine.

The MTW Facility has been established since February 2004 and is located in the ASU Research Park, in Tempe, Arizona. The building encompasses a world-class facility with 43,000 sq. ft. of Class 10/100/1000 Fabrication Clean Rooms and 12,000 sq. ft. of Class 10,000 and nonrated wet/dry labs with the following Pilot Line Fabrication Capabilities:

- 6-Inch (150 mm) Wafer-scale Pilot Line for Research and Development (3 micron feature size (L/S))
- GEN II (370 mm x 470 mm) Pilot Line for Low Volume Production (3 micron feature size (L/S))

Both Pilot Lines are linked to a Manufacturing Execution System (MES) for efficient lot management and statistical process control (SPC)

Electronic Design Automation (EDA) for IC Design, Modeling and Simulation: A professional suite of flexible, large-area microelectronics design tools has been implemented including: circuit simulation, design rule checking (DRC), layer verification (LVS), layout, AutoPlace and Route with *Standard Cell Library Development Capability,* state-of-the-art a-Si:H transistor models including VT Shift, and an extensive suite of digital and analog circuit testing equipment. Recently, a circuit simulator that can predict the complex post-degradation response of arbitrary a-Si:H TFT circuits has been developed. A computer model of the ΔV_{th} was incorporated in a SPICE circuit simulator. The Vth degradation model was added to the SPICE 3.0 TFT device model to obtain a composite model. Also, a standard cell library for a-Si:H TFTs on flexible stainless steel and plastic substrates has been developed. The standard cell library enables layout automation with a standard cell place and route tool, significantly reducing the time to layout a-Si:H digital circuits on the backplane and thus enhancing display functionality. Since only n-channel transistors are available, the gates were designed with a boot-strap pull-up network to ensure consistent output voltage swings. The cells were experimentally characterized for delay versus fanout. Automatic extraction of electrical interconnections from layout, enabling layout versus schematic (LVS) were also incorporated into the existing tool suite.

Pilot Line Fabrication Tools and Processes: Full 6-in wafer and GEN II Pilot line tool sets (Figure 2) are processing silicon, glass, PEN, stainless steel (SS) substrate materials. The one of a kind Azores stepper offers automated distortion compensation for flexible substrates (upper left). The EVG Photoresist large area mist coater was built to FDC specifications and demonstrates high uniformity and unprecedented material utilization efficiency that has resulted in a commercial success for EVG (bottom right). The EVG developer is shown as installed (lower left). The AKT 1600 3-chamber PECVD / 2-chamber Etch, *World's First* Hybrid GEN II Deposition/Etch tool is dedicated to flexible displays and was designed by AKT to FDC specifications (upper right). The tool has a new “active cooling” deposition chamber design for accurate temperature control that is crucial for temperature-sensitive plastic substrates. Also the EIT FPDGEN2EA, *World's First* GEN II High Density Plasma Polymer Asher / RIE designed by EIT to FDC specifications was installed to enable unprecedented polymer layer patterning.

Fig. 2 GEN II Pilot Line Tools

A full suite of analytical techniques and materials testing tools an process have been implemented to support research and quality control: Ellipsometry for film thickness and optical properties, White Light Interferometry for optical surface profile, Atomic Force Microscope (AFM) for film thickness and surface roughness, Step Height Profilometer, Film Stress, Four Point Probe, Fourier Transform Infrared Spectrophotometer (FTIR) for film characterization, Wafer Flatness for measurement of wafer bow and warp, critical dimension (CD) measurement, Field Emission Scanning Electron Microscopy (FESEM) for surface morphology and Focused Ion Beam (FIB). Electrical Testing has been developed that includes automated transistor and PCM testing and Automated TFT array test.

Reflective and Emissive Display Integration and Characterization: The following capabilities have been developed:

- Display and flexible circuit design
- Display simulation and modeling
- Flexible circuit simulation and modeling
- Display and circuit layout
- Display tooling layout (masks, fixtures, hardware)
- Electro-optic design and modeling
- Display packaging and assembly
- High-density interconnect assembly
- TAB, COF, COG assembly
- Final display test
- Display characterization: Eldim EzLite, PR670, Minolta CA2000
- Display design verification and test structures

• Demonstrator design and hardware

Flexible and Organic Electronics Development Laboratory: The following capabilities have been developed:

- OLED Materials Optimization: small molecule, phosphorescent, fluorescent and macromolecules
- Encapsulation: liquid- and vacuum-based approaches
- OTFT Materials Characterization for bottom and top contact devices; small molecules, conjugated polymers, hybrid Inorganic/organic structures, molecular nano-tube based coatings and transparent inorganic-based TFT materials; organic: PMMA, PVP, photoresist, various resins; inorganic: SiO2, Al2O3, TiO2 gate insulators; and organic (PEDOT: PSS, PANI) and metal (gold, silver, aluminum) contacts
- Photomask Aligner (6-in., 25 substrate cassette)
- 8-in. Spin Coater (Controlled Atmosphere)
- Blade Coater
- Inkjet Printers: Dimatix Piezoelectric Inkjet, Litrex (4-cartridges), HP and Cannon heat (bubble) inkjet technology
- Reactive Ion Etcher (RIE): oxide or nitride
- Atomic Force Microscopy (AFM): tapping mode and contact mode for surface topography, Tunneling AFM (TUNA) and scanning tunneling microscopy (STM) for conductivity measurements; and Nanoman with nanoindentation, nanolithography and nanomanipulation (carbon nanotubes); and tapping mode in liquid (biomaterials)

Strategic Research Partners:

- **UT Dallas** and ASU have several large-area flexible sensing array projects defined to incorporate FDC a-Si or mixed-oxide transistor processes with custom organic diodes developed by UT Dallas. One application is for neutron imaging for detection of special nuclear materials. Novel diodes are proposed that incorporate nanoparticles in the organic diodes thereby converting the neutrons to detectable charged particles, potentially revolutionizing the sensitivity achieved for neutron detectors. Numerous other applications of large flexible sensing arrays include large cameras for persistent surveillance, wearable sensing arrays for IR detection, and detectors for structural integrity of physical infrastructure.
- The **FlexTech Alliance (FTA)** is the only organization headquartered in North America exclusively devoted to fostering the growth, profitability and success of the electronic display and flexible, printed electronics supply chain. The FTA offers expanded collaboration between and among industry, academia, and research organizations for advancing displays and flexible, printed electronics from R&D to commercialization. ASU is integral to their mission to advance the growth, profitability, and success throughout the flexible, printed electronics and displays manufacturing and distribution chain; to facilitate collaboration between and among industry, academia, and research organizations to share practical experience and develop solutions for advancing flexible, printed electronics and displays from R&D to commercialization; and to foster development of the supply chain required to support a world-class, manufacturing capability for flexible, printed electronics and displays. The FDC serves on the FTA Technical Advisory Board and is able to leverage FTA-funded research to address technology gaps for the FDC such as material and tool development.
- The **Center for Advanced Microelectronics (CAMM)** was established in 2005 when Binghamton University, a global leader in electronics packaging and small-scale systems

integration, was selected to spearhead development of next generation roll-to-roll (R2R) electronics manufacturing capabilities. The CAMM brings together partners from government, industry and academia to:

- map emerging flexible electronic technologies
- validate the design of flexible electronic manufacturing capabilities
- develop essential process technologies and manufacturing know-how
- demonstrate specific technologies and products through test-bed projects and low-volume device manufacturing.

One of the critical enabling technologies for large area flexible electronics is roll-to-roll (R2R) processing. Today R2R is practiced in many mature industries (paper, film, printing, etc.). Due to its attributes, R2R high-volume manufacturing has been proposed for electronics as a means to lower the cost of non-Si wafer based large area flexible electronics such as displays. Display technology will drive the need for materials and processes that can make 2-5 μm features, at high yields, on a 24-inch web at a rate of at least two feet per minute. The FDC serves on the CAMM technical advisory board and ASU's development plans strive to be R2R consistent. A significant factor in the success of R2R for large area flexible electronics lies in the selection of the flexible substrate material that developments at the FDC have enabled.

Related ASU Research Programs and Capabilities:

- Center for Solid State Electronics Research (CSSER): Nanostructures — Molecular Beam Epitaxy and Optoelectronics;
- Materials and Process Fundamentals; Low Power Electronics, Bio & Molecular Electronics; MEMS & Nano-fluidics;
- High-K Dielectrics & Nano-magnetics;
- WINTech: Wireless Integrated Nanotechnologies, incl. communications components, telemetry, antennas;
- BioDesign Institute at Arizona State University:
- Photonics: IR Displays
- MEMS: Capacitive Sensors and Accelerometers
- Center for Advanced Photovoltaics
- Center for Solid State Science (CSSS)

2.1.2. Production Process – Research Initiatives

Flexible Display Center (FDC) — Director: Nicholas Colaneri

Research: In the first five years of operation, the Center experienced many successes: comprehensive in-house design-to-build capability including qualified 6-inch wafer-scale and GEN II display-scale Pilot Lines with associated metrology capabilities; a proprietary low-temperature amorphous silicon (a-Si:H) thin film transistor (TFT) process producing world class TFT performance and high quality TFT arrays; manufacturable flexible substrate systems and handling protocols; and demonstration of flexible polyethylene naphthalate (PEN) and stainless steel (SS), 4-in QVGA electrophoretic (EP) and organic light emitting display (OLED) technology demonstrators. Several companies have commercialized tools and materials based on FDC specifications and development work.

Major Grants: In February 2004, the U.S. Army awarded ASU a $43.7M, five-year cooperative agreement to establish and lead a collaborative university-government-industry partnership called the Flexible Display Center (FDC) to develop flexible, rugged, light-weight, low-power, information displays for the future war fighter and other military and commercial applications. An option for renewal for an additional five years for another $50M was executed in November 2008. Industrial members have provided an additional $10M million in in-kind and cash contributions and are projected to provide another $10M over the next 5 years. Most of the science for the flexible display initiative has been conducted at the Center; however some related FTA funded projects have allowed the FDC to leverage another $10M in funding to support technology development. Annual funding averages from 2004 and projected through 2013 are shown in Table 2.

Table 2. Annual Grant Funding

Grant Source	Amount (Millions)
Government	$9.5M
Industry (Direct)	$ 2 M
Industry (Indirect)	$ 2 M
Annual Total	$13.5M
10-Year Total	$135M

Partnerships & Contracts: The FDC has a proven collaborative partnership model with over 25 engaged industry members as shown in Table 3 with 2 university members Lehigh University, Bethlehem, PA and University of Texas at Dallas, Richardson, TX. In addition to these formal partnerships the FDC has been involved with research organizations funded by the FlexTech Alliance that include National Starch, Henkel, ASM, Vitex, and Impria.

Table 3. FDC Industry Collaborators

Company	Location	Relationship	Annual $
Arizona Employers			
Abbie Gregg	Tempe, AZ	Supplied FDC tool system installation and configuration control	$50K
BAE Systems	Phoenix, AZ	Collaborating on integration of FDC displays and electronics	$50K
Boeing-McDonnell Douglas Helicopter Co.	Mesa, AZ	Collaborating on Integration of FDC displays and electronics	$50K
Etched In Time, Inc	Tempe, AZ	Collocated Headquarters at the MTW Facility — provides etch support and engineering design and fabrication for tool development	$50K
EV Group	Tempe, AZ	Collocated North American Headquarters with the MTW Facility. Developed specialized tools for the FDC and provided $2M in bond tooling.	$200K

General Dynamics C4S	Scottsdale, AZ	Collaborated on concept device demonstrated to the Army — Mission Briefer	$50K
Honeywell	Phoenix, AZ	Codeveloping interlayer dielectric materials for TFT processing and provided $4M in IP	$50K
Ito America	Tempe, AZ	Collocated Headquarters at the MTW Facility and provide TAB bonding capabilities	$50K
Surface Science Integration, Inc.	Tempe, AZ	Provided instrumentation for wafer identification and tracking	$50K
US Based Companies			
AKT America, Inc.	Santa Clara, CA	Collaborating on advanced transistor material and processing research	$50K
E Ink	Cambridge, MA	Building TFT backplane optimized for their electrophoretic material front plane — basic to all technology demonstrators to date	$50K
FlexTech Alliance	San Jose, CA	Serve as Technology Council Member to drive display related projects funded by the FTA and instrumental in leading Flexible Electronics Initiative in the US. Funded development of many FDC tools in particular the Azores Stepper for automated substrate distortion control.	$200K
Hewlett Packard	Palo Alto, CA	Collaboration on self-aligning photolithography process	$50K
Kent Displays	Kent, OH	Building TFT backplane optimized for their cholesteric LCD front plane material	$50K
L3 Communications	Atlanta, GA	Collaborating on integration of FDC displays and electronics	$50K
Lockheed Martin	Orlando, FL	Collaborating on integration of FDC displays and electronics	$50K
MOCON Corp.	Minneapolis, MN	Provides instrumentation for measurement of material water permeation rates	$50K
Particle Measuring Systems	Boulder, CO	Provides instrumentation for automated particle measurements in the Clean Room environments	$50K
Plextronics Inc.	Pittsburgh, PA	Collaborating on deposition processes and materials development for specialized processes. Additional Grant of $32K	$50K
Raytheon	Plano, TX	Ongoing collaboration on concept device — Wrist-borne display	$50K
Ulvac Technologies	Methuen,	Provided Litrex printers — capability	$50K

	MA	needed for flexible electronics research	
Universal Display Corp.	Ewing, NJ	FDC building TFT backplane optimized for their proprietary OLED materials.	$200K
Foreign			
DuPont Teijin Films	Middleborough, England, UK	Codevelopment of planarized plastic substrate material system enabling transparent flexible displays	$50K
LG Display	Seoul, Korea	Candidate for transfer of process IP for manufacturing application	$50K

Member retention and recruitment is expected to be dynamic as technology development evolves into displays with increased functionality and flexible electronic applications.

Commercialization: Several tool and materials supply chain FDC members have developed and commercialized enabling products for flexible displays, including: (1) DuPont Teijin Films' Planarized PEN™; (2) EVG's large-area thin film spray coater; and (3) HEM's planar thermally stable (PTS) family of planarization/electrical isolation/passivation material. As shown in Table 4, FDC has generated IP for non-volatile amorphous silicon memory, flexible substrate systems, low-temperature transistor processing directly onto flexible substrates and temporary bonding procedures to allow standard semiconductor processing of flexible substrates. Discussions are in progress with 6 companies for transition of this IP to commercial use.

Table 4. FDC IP Disclosures

Intellectual Property	Total Since Program Inception
Disclosures	40
Patent Applications	20
Patents Awarded	20
License Discussions	6 Companies

Staffing: The staff consists of 33 full-time and 13 part-time professional (38.5 FTE). The majority of these positions are engineers obtained from the local semiconductor industry; however faculty and students/advanced degree candidates are employed every year as shown in Table 5.

Table 5. Students Funded and Entering Work force

	2009	2010	2011	2012	2013
Undergraduates involved in Research	17	20	22	24	26
Post-doctorial and Graduate Students	12	10	12	14	16

Entering the Work force	20	20	20	20	20

Future Plans: The plans for the next 5 years are based in part on a comprehensive FDC Program Review conducted in April 2008 by display technology Subject Matter Experts (SME) and senior Army program leadership. Opportunities going forward were identified in order for the FDC to migrate to a sustainable business model through evolution of the partnership model, focused outreach for collaborations with other organizations, increasing basic research activities with partners, and increasing awareness of FDC's role and successes within industry and military venues. This leadership input was considered along with ARL program deliverables and with ASU strategic organizational goals, to generate the FDC highest level goals in Management and Technical categories as summarized below:

Management Goals:

1. Raise the Profile: Create a compelling identity and unique educational experience to attract funding through government programs, industry participation, and academic partnering
2. Accelerate Industry Growth: Connect ASU with the business community and increase industry outreach to address specific technology gaps and drive commercialization.
3. Strategically Grow Longer-range Research: Position the FDC to solve future technical challenges in flexible electronics.
4. Promote and Encourage Innovation and Technology Transition: Accelerate intellectual property generation and subsequent technology transition to industry and government programs.
5. Position the FDC to Provide Enduring High Value to the Government and Industry Partners: Expand the funding base to achieve long-term, sustainable funding through aggressive business development activities. In doing so realize a leadership role in flexible display and complementary flexible microelectronics technology development.

Technical Goals:

1. Develop Enabling Manufacturing Processes: Develop and demonstrate processes, materials and protocols to MRL 5 in a pilot line environment with a production capability (1000 units/year) to fabricate full color, video rate, high-resolution reflective and emissive (OLED) flexible displays featuring intrinsic ruggedness and reduced power, weight, and volume.
2. Deliver Display Technology Demonstrators: Collaborate with Army stakeholders and industry technology integrator partners to produce demonstrators for military systems and for industry member program for evaluation, human factors studies, business development and marketing.
3. Expand Technology Scope and Impact: Integrate flexible electronics and other complementary technologies with flexible displays to achieve advanced technology demonstrator functionality for Army systems and for evolving applications in areas such as first responder situational awareness and space exploration.

Center for Applied NanoBioscience (ANBC) — Director: Frederic Zenhausern, Ph.D.

Research: Research at ANBC is focused in four broad areas: integrated nano/micro-systems design, modeling, and prototyping; development of fabrication and characterization techniques optimized for nanoscale applications; molecular techniques for manipulating single biomolecules and cells; and integrated systems for application-oriented products and information solutions. Areas in which the ANBC's teams had demonstrated considerable proficiency include: biochips for genomics/proteomics; microfluidics and microanalytical technology; nanoconstrictions; atomic and molecular technology; nanosystems design and fabrication; microscale fluid dynamics modeling; and hybrid nanoelectronics processing and "lab-fab" prototyping. The ANB team has great skills in bioassay development and polymer-based processing that leverage its product development capabilities (e.g. Quality Systems, ISO and FDA compliance).

Research focus has been on growing translational research in medicine and energy systems. During the last 5 years, ANBC's scientific discoveries has attracted large funding from federal agencies and corporations while participating in large international consortia (e.g. E.C. 7th Framework). Several technology platforms have been scaled up and commercialization is ongoing. DNA solutions have been jointly developed with FBI, large crime labs in the EC and U.S., and a world leader in DNA forensics. They are currently validating ANBC's platform as an international standard for deployment in casework investigations. The center has also developed specialized molecular medical responses for acute medical management for radiation injury in cancer treatment or radiologic and nuclear events. The ANBC blood based gene expression assay and instrumentation have been submitted to FDA, through a pre-IDE step of the 510K filing procedure. This initial development has been sponsored through an NIH Center for Medical Countermeasures against Radiation (CMCR) with major participation from Columbia University, Tgen, and Georgetown University. Further PMA certification by FDA is pending through a multi-institutions contract from DHHS/BARDA. Novel bioassay chemistries are also optimized in collaboration with several diagnostics corporations and federal agencies (e.g. CDC) for molecular diagnostics of cardiovascular diseases, colon cancer, and melanoma.

Major Grants: Currently, the center has a $3.8 million grant from the Department of Justice to develop a system for the FBI that integrates the current multiple steps of forensic DNA analysis for faster results, an $800,000 grant from the Naval Research Laboratory to develop a lab-on-chip for bioagents, and a $580,000 grant from the Department of Justice to design a microchip for detecting terrorist activity.

Partnerships & Contracts: The Center has nearly a dozen active partnerships and/ or joint consortium with a wide range of organizations including: IBM, STMicroelectronics, Philips Research, Honeywell, PADT, Corning, Boeing, Stanford University, Columbia University, Princeton University, AZ Translational Genomics Consortium, Mayo clinic, and Scottsdale Healthcare. The Center infrastructure comprises clinical resources with Scottsdale Clinical Research Institute, TGen Clinical Services and other AZ clinical partners. ANBC and Tgen co-founded Nanobiomics, which merged with the Molecular Profiling Institute, which was then acquired by Caris Diagnostics in late 2007. ANBC is also involved in developing energy systems using biofuels and fuel cells (FC). DoE research projects on advanced materials and more recently an SFAz program for the development of a biofuel reformer/FC system, with the Boeing Company and Honeywell, will demonstrate in-flight applications of such "green" high-density power sources in 2011.

ANBC developed a Center for Interdisciplinary Research in Nanotechnology (CIRN), in partnership with Motorola Labs, to develop nanosensors for first responder product applications, and a MIDRA Consortium with Motorola Italy and the University of Florence to develop sensors and wireless communication networks. ANB is also developing strategic alliance with major international consortia in Europe and Asia. In this context, ANBC is affiliated with the polyAPPLY Associated Network. ANBC's fuel cell program is also sponsored by the Korean Institute of Technology (KITECH).

ANBC has major research contracts (several hundred thousand dollars) sponsored by industries such as Sony Labs in Japan, Scientific Software, General Dynamics, and Pfizer (pending). The Center has also received more than $2M cash equivalent in equipment donations from Motorola, General Dynamics, and GE/Amersham.

Commercialization: ASU and the Translational Genomics Research Institute (TGen) have started a spin-off company, Nanobiomics, whose goal is to develop and commercialize a novel diagnostic platform for human disease. Nanobiomics was recognized as the Arizona BioIndustry Association's 2005 Start Up Company of the Year. Among the products in development are "lab-on-a-chip" devices which will have applications for disease diagnosis, crime-lab forensics, and sensors for biological or chemical agents. Nanobiomics is also in the process to be merged with the Molecular Profiling Institute to provide a more integrated company (i.e. Service Division & Product Development Division) with larger market capitalization value. ANBC researchers have more than 40 issued patents, four cases filed, and more than ten disclosures in the pipeline.

Facilities and Equipment: ANBC partners have donated more than $1 million in equipment comprising major pieces of equipment for semiconductor processing (e.g. JenOptik Hot Embosser), analytical instrumentation (e.g. Bruker NMR 400 MHz) and bio-analytical characterization (e.g. ABI 310 Capillary System).

Staffing: In addition to the Center Director, ANBC is comprised of 25 members, including 15 research members and two academic professionals. ANBC is also hosting several visiting faculty members from Taiwan and Korea.

Future Plans: Near-term (1–3 years) to include: improved micro/nano fabrication processes, improved materials biocompatibility, improved assays, and improved integration and functionalities. Long-term targets (beyond three years) to include: improved processable materials, flexible transparent conductors, integrated electronics and energy sources, organic electronics, and system-on-chip technology. A key goal for the Center is to transfer one of its technology platforms for a population study in molecular diagnostics, thus opening up further opportunities for the commercialization of diagnostic products. The Center will continue to seek partners for research activities that leverage the Flexible Display Initiative and the Center's own research projects. Grant proposals have already been submitted to the Keck Foundation, National Science Foundation, National Institute for Health (NIH) and DARPA.

ANBC will seek to commercialize its research on fuel cell technology and personalized medicine. Although the researchers expect that a practical room temperature fuel cell prototype is still a couple of years away, several consumer product manufacturers have expressed interest in the Center's technology. ANBC is also initiating some new concepts for philanthropic activities enabled by the convergence of the Center's technology portfolio and partners network (e.g. E-Book for A Child). These activities will also provide a path to impact society and engage individuals into new trends in public health.

The Center will also develop its educational impact by offering new interdisciplinary courses, seminars and workshops. In particular, there are initial efforts to possibly create an international web-based program on flexible polymer electronics in collaboration with the FP6 from the European Community.

2.1.3. Cost of Development

See Section 2.1.2 Grants and Pro Forma Financials (Section 4)

2.1.4. Labor Requirements

See Section 2.1.2 Staffing and Future Plans

2.2. Marketing and Promotion

2.2.1. Strategy

Market Opportunity: In 2007–2008 the FTA organized a National Working Group on Flexible Electronics and convened workshops on printed and conformal electronics to further identify current status, critical needs and opportunities. From these discussions and previous studies, clear directions emerged for further research needed to accelerate the pace of development. These R&D topics cover both novel materials and improvements in the manufacturing infrastructure necessary to create the products and new markets as follows:

- **Improved Materials Performance** — There have been significant advances in organic and inorganic oxides and nanomaterials. Still needed are improvements in breakdown voltage, mobility, and leakage current for these materials that will enable faster transistors, better solar cells and sensors, and more efficient lighting, for example.
- **Material Stability and Improvement** — Many of the more promising materials show degradation, due to the environment they are used in or under prolonged use. Still needed is an understanding of the fundamental degradation mechanisms to determine how to improve these materials and to develop barriers, sealers and encapsulants that make them suitable for long-lived applications. Materials used in a medical environment may only need to have a short lifetime, but those used in building materials or remote-sensing applications could require usage measured in decades.
- **Patterning Technology —** Improvements in throughput, resolution, and registration capability are essential for increasing the capability of printed electronics.
- **Design Tools** — An essential ingredient to the rapid customization of electronics today is the ability to simulate new circuits and verify that they will meet the requirements even before production is started. Still needed are similar tools for the printed electronics industry that can enable designers to predict performance, and design components and circuitry with these new materials.
- **Integration** — Hybrid devices that combine the benefits of conventional silicon circuitry with large area flexible electronics will enable many new systems and capabilities. An understanding of how to best optimize this system approach, how to interface between printed and conventional electronic components and how this evolves as printed materials improve are still needed.

As extracted from a technology gap analysis conducted by the 2009 iNEMI Large Area, Flexible Electronics Roadmap Chapter, medical sensors need high accuracy and repeatability, and there is a need for an external power source to run the sensor and store the historical data. The most often mentioned gaps and showstoppers for commercialization and wide adoption of large area flexible sensors are as follows:

1. Nano-material based sensing providing high accuracy
2. Intelligent sensing materials for simple sensor calibration
3. Printed RAM memory for storing event history
4. Mobile standardized read-out technology and infrastructure
5. Disposable environmentally preferred battery for active sensing

Governments around the world are investing in flexible electronics to accelerate the pace of knowledge creation and spur the creation of partnerships within private industry and academia. The European Union has been foremost in this regard, funding over $700M in R&D projects in their 5th, 6th, and 7th Framework Research Program, plus national projects. For example, in 2005 the German government announced a 5-year program funded with an investment of up to $140M. Government funding in Asia is not as transparent as that in Europe, but Taiwan’s Science and Technology Advisory Group (STAG) announced one initiative that will spend over $120M in the next 8 years to establish at least 15 companies specializing in flexible electronics in order to raise Taiwan’s market share to 20% by 2015, when they anticipate the global market for such products will be over $15B.

Three specific organizations that demonstrate capabilities and research that overlaps the core capabilities that the Advanced Materials Initiative most closely emulates are:

1. **Palo Alto Research Center (PAR):** PARC was incorporated as a wholly owned subsidiary of Xerox in 2002, and conducts research into biomedical technologies, "clean technology," user interface design, sensemaking, ubiquitous computing, large area electronics, and embedded and intelligent systems. The PARC infrastructure is similar to the FDC and includes an 8-in Pilot Line Research toolset; however it is not a “user” facility that is open to other research interests.
2. **The Industrial Technology Research Institute (ITRI):** ITRI is based in Hsinchu, Taiwan with a facility strategically situated at the heart of the Silicon Valley, To enhance ITRI's R&D capacities and promote its visibility on the world stage, ITRI, International has engineered collaborations with prestigious universities, such as, MIT, Stanford, UCLA, and the Georgia Institute of Technology. ITRI, International has also undertaken a wide range of joint projects in electronics, bio-medicine, micro-electromechanical Systems (MEMS), packaging, and nanotechnology. In line with industrial needs in Taiwan, ITRI, International has helped ITRI enter into alliances with companies, such as the Rockwell Science Center, Dow Chemical, Symyx Technologies, Inc., Draper Labs, and the National Research Council of Canada (NRC), to jointly develop LCD compensators, electronics materials, combinatorial chemistry, chemical sensors, and semi-solid forming technologies, to enhance Taiwan's industrial competitiveness in world markets. ITRT is government-sponsored to promote Taiwan’s industries with a more specific technology and basic research focus vs. the research-to-manufacturing model of the FDC.
3. **Interuniversity Microelectronics Centre (IMEC):** IMEC is a world-leading independent research center in nanoelectronics and nanotechnology located in Leuven, Belgium. Its research focuses on the next generations of chips and systems, and on the enabling technologies for ambient intelligence. IMEC’s research bridges the gap between fundamental research at universities and technology development in industry. Its unique balance of processing and system know-how, intellectual property portfolio, state-of-the-art infrastructure and its strong network of companies, universities, and research institutes indicate its worldwide position. IMEC has a global network of more than 550 partners

including IC manufacturers, universities, and semiconductor equipment and material suppliers, representing over 50 nationalities. Global partner members include Intel, Texas Instruments, Philips, Infineon, Samsung, Matsushita, and ST Microelectronics. IMEC does both affiliated research — where partners end up with shared IP — and customized programs where cost and IP rights are defined ad hoc. The "shared" research is typically pre-competitive generic work, meaning that current research is focused on processes and materials for CMOS at 32 nm and below. In addition to a pilot-line for 300-mm CMOS that covers the entire process flow, IMEC is also working on heterogeneous integration to incorporate 3D technologies, RF-MEMS, thermal-management optical interconnect and more within CMOS fabrication. IMEC also has a strong focus on biomedical electronics, including a neuroelectronics lab working on such devices as neuron on chip, implantable devices with close interaction between the living cell and the silicon surface — devices that start capturing and interacting with the neuron — such as neuro-probes that sense electrical activity and stimulate as injected neurotransmitters from a MEMS device.

Where the Advanced Materials Initiative differentiates itself is by the following attributes:

Unique U.S. Institution. The Advanced Materials Initiative is the only academic program of its kind within the U.S. This fact makes it appealing to U.S. industry and U.S. government that have sensitive research needs or are restricted by geography or export control.
Direct relationship with the U.S. Army. Key federal agencies can be early adopters and deploy technology that can serve essential needs for energy, homeland security, infrastructure protection and improved healthcare. It is apparent that applications and areas of responsibility touch nearly every major agency within the federal government. This fact dictates why broad cross-agency and industry cooperation and coordination of programs is essential in order to achieve the maximum benefit at minimum investment, yet in the shortest time to market that is possible.
Unique government-academic-industrial membership model. Project initiation with the Advanced Materials Initiative is streamlined by application of the membership model. The model provides collaborations that maximize industrial synergies and allows opportunities to evaluate and develop materials and tools in an IP-secure environment.
"User facility" design. Organizations such as PARC are devoted to research projects as identified and funded by their corporate sponsor. The Advanced Materials Initiative has flexible clean room space that can be used to allow an organization to set up a research line or a model by which visiting scientists and students can be inserted into Advanced Materials Initiative research and development projects**.**
One stop services. All-inclusive capabilities and services that can take a research idea from design, modeling, and simulation to fabrication and pre-manufacturing and through prototyping for human factors studies. Most research organizations will focus on a specific research problem as opposed the Advanced Materials Initiative research-to-manufacturing approach.
Immersive educational experience for engineering students and near industrial experience for faculty an approach that best prepares future engineers for future engineering challenges. Real world projects also involve design and business students through the Innovation Space Program.

The Advanced Materials Initiative academic-government-industry business model and research-to-manufacturing operational model coupled with the unique and synergistic flexible backplane array and biosensor research capabilities and infrastructure positions the Advanced Materials Initiative to be a national leader in the flexible electronics industry. As demonstrated by the companies that have collocated with the FDC and spin-out companies relative to the ANBC, the Advanced Materials Initiative has potential to become a business nexus that will differentiate

Arizona and provide a competitive advantage for Arizona and Advanced Materials Initiative collaborators.

2.2.2. Method of Promotion

One of the fundamental goals of the Advanced Materials Initiative is to create a compelling identity and unique educational experience to attract funding through government programs, industry participation, and academic partnering (other university, as well as with other ASU faculty). Ultimately, promotion of the Advanced Materials Initiative will also promote Arizona businesses and position Arizona as a leader in the flexible electronics industry that will, in turn, build on the Arizona economy, provide more and higher-paid knowledge-based jobs in a “clean” industry and help attract new business investments to the state.

To accomplish this goal, the Advanced Materials Initiative has developed a robust Marketing Plan that engages ASU Public Relations and Government Public Affairs Offices for media cultivation, press releases and multi-media promotional materials including videos, brochures, exhibits, an “engaging” website, a periodic newsletter, a downloadable photo/video gallery and industry standard design specifications.

2.2.3. Advertising and Promotion Plans

A Public Relations Company with substantial industry and popular media network strengths is engaged to help identify Press Release (PR) material, develop a media plan and focus on timely release and an unfolding message. In addition, the following steps are in progress:

- Identify and participate in tech-related, broader-market venues based on metrics of prominence, attendance, and synergistic topics and audience.
- Work with ARL to identify and engage government programs, support ARL in Army conferences, meetings and exercises in which Advanced Materials Initiative technology are demonstrated and to develop a better understanding of Industry-Government contracts and leverage links to funded military programs.
- Expand the annual FDC Outreach Event to engage Government Program Managers (PMs) and other decision makers, ASU engineering and design faculty/students, universities with related programs, industry, and technology transfer and business development participants.
- Design and fabricate novel and imaginative mockups and functional, “art-of-the-possible” technology demonstrators for exhibit at selected venues for industry and student recruitment.
- Promote the unique business model and genuine intensive collaboration successes by documenting and publicizing the model through presentation at appropriate conferences and articles in key technical and trade journals.
- Formalize student internship program, engage ASU student recruiters and encourage industry sponsorship of internships.
- Continue work with the Arizona Economic Development Council to provide a high-tech venue for events and tours that showcase the Advanced Materials Initiative.

2.3. Project Management

2.3.1. Organizational Setup

The leadership team of the Advanced Materials Initiative reports to Dr. Sethuraman Panchanathan, the ASU Deputy Vice President for Research and Economic Affairs. Dr. Panchanathan and ASU's Office for the Vice President for Research and Economic Affairs (OVPREA) are responsible for ASU's overall strategic investment plan, including the internal approval of individual budgets and initiatives, and performance tracking of the initiatives.

Management Planning and Processes

The **Strategic Plan** provides the long-term (five-year rolling horizon), comprehensive and integrated view that guides annual project selection. This plan is designed by a Strategic Planning Team and contains the long-term vision of the Advanced Materials Initiative mission, goals, quantifiable objectives, and strategies and tactics for meeting those objectives. The annual review of the plan includes analysis of organizational strengths, weaknesses, opportunities, and threats (SWOT analysis) and review of strategy. Goals and objectives include management and member engagement objectives, as well as, technical objectives. The Strategic Plan graphically identifies technology interrelationships and critical paths for target integrated technology demonstrator production, technology development and technology transition opportunities.

Annual Project Selection is driven by the goals of the Strategic Plan. This is an open collaborative process initiated by Technical Advisory Board (TAB) Working Groups (WG). Technical leadership engages stakeholders and assists them in forming optimal teams and plans that are capable of delivering requirements. Each proposal has a well-defined scope, objectives, approach, resources requirements, cost, and schedule. Proposals are reviewed by Advanced Materials Initiative leadership who rank proposals using evaluation criteria, including: alignment with Strategic Plan priorities and milestones; capabilities and experience of the proposal team; quality of technical approach; and risk vs. benefit. Once a proposal is chosen, a complete project plan is prepared. The selected projects form the components of the Annual Program Plan. The APP including the annual budget is prepared by the Director, Program Management, and approved by the Initiative Director. The APP is submitted to the Governing Board for evaluation and recommendations, and to the funding stakeholders for approval.

Organizational Structure

The organizational structure within the Advanced Materials Initiative is described below:

Initiative Director: Nicholas Colaneri, Ph.D.

Dr. Colaneri has responsibilities to enhance the visibility of the Centers and related enterprises, to expand the basic research portfolio, to enhance industry engagement and intellectual property transition, and to achieve a sustainable enterprise model (without full funding from the U.S. Army) in year 10 and beyond. Nick has been involved in organic technologies since the discovery of polymer electroluminescence during his work as a Post Doctoral Research Assistant in Cambridge in 1989. He received his Ph.D. in Physics in 1987 from the University of California at Santa Barbara under the supervision of the 2000 Nobel Laureate in Chemistry, Professor Alan Heeger. Following post-doctoral research in the laboratories of Cavendish Professor Sir Richard Friend, FRS at Cambridge University, England, he became a founding employee of UNIAX Corporation in 1990. Over the following ten years, UNIAX became a global leader in the development of light emitting polymer technology. During that period Nick served in a variety of technical and business roles, eventually being named Vice President of Business Development in 1998. He was a member of the executive team that arranged and completed the sale of UNIAX to the DuPont Corporation in 2000, and subsequently became Director of Strategic Planning for the new DuPont Displays SBU until 2003.

Director, Program Management: Kristin Gillis, M.B.A.

Ms. Gillis has been employed at the FDC since its inception in 2004 with responsibility for developing management plans, policies, and procedures; developing the Annual Program Plan comprised of annual projects, schedules, and budgets; development and oversight of the project management process; and all financial and administrative management. As Principal Scientist and Supervisor of several NASA laboratories, she gained an extensive background, with over 18 years of experience in the aerospace industry, developing and managing program requirements, standards, and controls; strategic and annual planning in a multi- and complex engineering project environment; guiding process improvement initiatives; writing large-facility management proposals; and managing hazardous test facilities.

Director, Technology and Business Development: Shawn O'Rourke, M.B.A

Mr. O'Rourke was instrumental in the conceptualization, award, and development of the FDC. He has responsibilities for new processes, materials, and tools development, operation of the 6-in wafer scale and GEN II backplane fabrication pilot lines, cost modeling, IP portfolio management, and technology transition. He is the Chairman of the FDC Manufacturing and Integration Technical Advisory Board (TAB) and participates on the FlexTech Alliance Technical Council (TC). His research expertise gained at Argonne National and Pacific Northwest Laboratories and as a Principal Staff Engineer with Motorola Flat Panel Display and Life Sciences Divisions has spanned microelectronics packaging, bioMEMS, thick film materials, and display manufacturing. Prior to 2004, he was a Process Engineering Manager at ASU's Center for Applied NanoBioscience from 2001 to 2004.

Director, Research Initiatives: Doug Loy, Ph.D.

Dr. Loy is responsible developing synergies across the University to establish a basic research engine to address technology gaps identified to further development of flexible electronics and advance materials applications. His successes include developing material technologies, handling processes, and toolsets for pilot-line applications including permanent and temporary adhesives and associated bond/debond tools, and manufacturing processes and flexible substrate planarization materials and handling procedures. Prior to his current role, Dr. Loy was Director of Technology Assessment and cofounder of E3 Innovation where he performed competitive intelligence and technology assessments for clients. Before forming E3, he worked at Three-Five Systems where he charted an R&D program on Organic Light Emitting Displays. Dr. Loy has 9 years in engineering, R&D program management & process improvement. He brings an extensive technical background in basic and applied research of new electronic materials and display technologies.

Director, Display Systems: Jann Paul Kaminski, Ph.D.

Dr. Kaminski is responsible for technology demonstrator projects and managing design and assembly efforts for full device integration, including backplane design, electronic drivers, interconnects, system and timing controllers, panel, module and demonstrator builds, final test and exhibitions. Jann received his doctorate from the University of California at Santa Barbara in 1989 in Physics. He continued at UCSB as a staff lecturer and researcher until joining UNIAX Corporation in 1996, a global leader in organic polymer electronics. While at UNIAX/DuPont Displays, Dr. Kaminski had responsibility for polymer OLED display designs, architecture, test, assembly, pixel and system electronics. In addition, he led the OLED design, test and electronics technology transfer to domestic and off-shore licensees for commercial production of OLED displays. With start-up companies and as an industry consultant, he has used his background to develop hardware/ software solutions, electronics and demonstrators for a variety of emerging display technologies, sensors and flexible electronics, including LCD, chLCD, PDLC, smOLED, PLED, EPD, LED.

Center Director, Applied NanoBioscience: Frederic Zenhausern, Ph.D., M.B.A.

Frederic Zenhausern received his Ph.D. in applied physics from the University of Geneva, Switzerland, in 1993. He is a professor at ASU and director of the Applied Nanobioscience Center. He is also an executive committee member of the Arizona Biodesign Institute. His expertise in nanobioscience, biomaterials, nanofabrication and NEMS is used to develop multi-disciplinary research projects. He leads over 40 research faculty and graduate researchers and is the research liaison for bio electronic research.

2.3.2. Advisory Board and Other Oversight

Executive Advisory Board

The Executive Advisory Board (EAB) is comprised of prominent government, academic and industry representatives and stakeholders, as well as Arizona business leaders to advise on high-level issues including economic trends, government directions and impacts, industry trends, strategic direction, funding acquisition, and potential collaborations and alliances that will ensure that Arizona competes on national and international levels. In addition the EAB works to engender support for the Institute on a broad basis. The EAB is formed on an ad hoc basis with membership determined upon recommendations of the Center Governing Board, U.S. government representatives, ASU representatives, and meets at least annually as part of the strategic planning process. The current board consists of:

1. David C. Morton, Flexible Display and Electronics Manager, Army Research Laboratory, Sensors and Electron Devices Directorate
2. Keith Rollins, Global Displays Market Manager, DuPont Teijin Films (UK) Ltd.
3. Abbie Gregg, Owner, Abbie Gregg Inc.
4. Steve Dwyer, VP and General Manager, EV Group, North American Headquarters
5. Mike Idacavage, Principal Research Fellow, Cytec Industries, Inc.

Governing Board

The Center Governing Board primary roles include reviewing and making recommendations to the Strategic Plan and the Annual Program Plan, as well as advising on new member recruitment, policy issues, and procedures. The non-voting Governing Board Chair is an ASU distinguished faculty member or senior administrator selected based on scientific accomplishments, experienced industrial executive leadership, and effectiveness as a science and policy adviser. Governing Board membership is exclusive and limited to two U.S. Army representatives, the FDC Center Director, one representative from each of the Principal Members, and one elected representative of the group of Associate Members and Technology

User Members. The Board meets quarterly and is governed by formal bylaws approved by the board.

Technical Advisory Board

The primary roles of the Technical Advisory Board (TAB) are development of technical display performance specifications and technology roadmap, initiation of annual project proposals and advising the technology development teams on an ad hoc basis. The TAB is organized into technology sub-system working groups (WG) depending on membership and technology needs.

The TABs determine overall technology requirements, as well as the specific technology gaps and needs for integration of specific selected technologies into working flexible technology demonstrators. These teams function in an integrated product and process development framework where product design and associated manufacturing processes and toolsets are considered concurrently. Each TAB WG is made up of representatives of the U.S. Army, appropriate industrial and academic members, and non-member content experts as appropriate.

2.4. Sustainability

The Advanced Materials Initiative faces several hurdles to long-term sustainability, mostly centering on external funding development, institutional/industry partnering, and faculty and engineering retention. Some of these issues are:

- The University must also make an ongoing commitment to retaining highly productive, faculty and service professionals who will become increasingly attractive targets for hire by other universities as their individual research programs gain in prominence.
- Active monitoring of seed grants is necessary to ensure that these grants lead to significant external funding while continuing to invest in other new and promising areas.
- The management and researchers must continue to seek new ways to effectively engage both other state educational institutions such as U of A and NAU as well as local industry in effective and highly productive research partnerships.

2.4.1. Anticipated Funding Sources for Ongoing Support

One of the goals of the Advanced Materials Initiative is to develop an effective and successful proposal generation engine that leverages ASU's PRIDE and ORSPA organizations, to indentify funding opportunities and partner for winning proposals. Also, industry relationships are being developed to leverage powerful industry proposal development engines and adopt best practices. The Initiative is working to develop fundamental research funding opportunities and is working with the Army to identify and define underlying basic research questions to be addressed through large-scale focused efforts such as DoD MURIs or NSF ERCs. Management is also aggressively engaging research partners by providing research/evaluation infrastructure and capability and organizing large-scale university "4M" alliances (multi-university, multi-disciplinary, multi-year, multi-million dollar) to solve critical long-range technical problems.

2.4.2. Timeline for Transitioning away from TRIF Support

Most aspects of the Advanced Materials Initiative will become self-sustaining with external funding from the federal government, private foundations, industry support, licensing, and other revenues within five years. ASU will review each segment of the Initiative annually. If any portion or portions of the Institute appear to be at serious risk for not reaching this goal, then the University will either take corrective action or amend the development plan for the Institute to reinvest TRIF resources in projects or human resources that exhibit the ability to provide a suitable return on investment.

3. Goals and Metrics

3.1. Specific Goals

The management and technical goals discussed in Section 2.1.1 for both FDC and ANBC are fundamental to the goals for this TRIF initiative. The annual metrics summarized in Table 6 and in the following narrative, are consistent with these goals. Metrics will be determined collectively for FDC and ANBC.

Table 6. Performance Measurements

Advanced Electronic Materials PERFORMANCE MEASURES/IMPACT	FY10 Proj	FY11 Proj
Return on Investment ($ amounts in millions)		.
Federal and non-federal awards	31.20	27.60
Royalty income	0.02	0.05
Foundation funding	0.04	0.04
Return Total	31.26	27.69
Work Force Contributions		
Post-doctoral appointments	20	23
Post-doctoral researchers leaving to enter the workforce	10	14
Graduate students employed	7	4
Graduate students earning degrees and entering the workforce	3	4
Undergraduate students involved	4	6
Partnerships/Collaborations		
The number of research grants/contracts involving funding from non-government entities	8	6
The number of research grants/contracts involving subcontracts to non-ASU researchers	3	5

3.1.1. Return on Investment (ROI)

Return on investment measures include federal and non-federal awards, royalty income and foundation funding. The sum of these components (Return Total) is divided by the related TRIF expendatures for the fiscal year to arrive at the ROI ratio included in the financial pro forma figures (Table 7) below.

3.1.2. Technology Transfer

Technology Transfer will be assessed by the following metrics:

- New invention disclosures
- New patent applications filed

- New patents issued
- Total companies licesnisng ASU technology
- Licenses or options signed as indication of technology adoption by industry

3.1.3. Industry Outreach

Industry Outreach will be assessed by the following metrics:

- Number of industrial meetings, tours and outreach efforts
- New programs or funding

3.1.4. Work force Contributions

Workforce contributions will be assessed by the following metrics:

- Post-doctoral appointments
- Post-doctoral researchers leaving to enter the workforce
- Graduate students employed
- Graduate students degrees and entering the workforce
- Undergraduate students involved in the program

3.1.5. Educational Outreach

Educational outreach will be assessed by the following metrics:

- Number of university and high school outreach efforts
- Number of curriculum offerings
- Number of student interns
- Student corporate sponsors

3.1.6. Government agency/community outreach

Government and community outreach will be assessed by the following metrics:

- Number of meetings, tours, and outreach efforts
- New programs or funding

3.1.7. Partnerships/collaborations

Partnerships and collaborations will be assessed by the following metrics:

- Total non government partners and collaborators
- New programs or funding

4. Pro Forma Financials

Table 7 summarizes the projected investments and expendatures of TRIF funding for FY 2010-2011.

Table 7. AMI ROI for TRIF funding

Advanced Electronic Materials	FY10 Rev Budget	FY11 Rev Budget
REVENUE		
Carry Forward		
New TRIF Revenue	400,000	400,000
TOTAL REVENUE	**$400,000**	**$400,000**
OPERATING BUDGET		
Personal Services	163,200	163,200
Employee Related Expenses	38,400	38,400
Operating Expenses	118,400	118,400
Total Operating Budget	$320,000	$320,000
CAPITAL BUDGET		
Building Renovation	80,000	80,000
Debt Service		
Total Capital Budget	80,000	80,000
TOTAL EXPENDITURES	**$400,000**	**$400,000**
Return On Investment	**78.1:1**	**69.1:1**