Memorandum

To: Department of Commerce, National Institute of Standards and Technology

Subject: Response to Request for Information, Advanced AMNPO, RIN:063-XC001

Re: National Network for Manufacturing Innovation

Date: October 18, 2012

Introduction

On May 4, 2012, A Request for Information (RFI) was published in The Federal Register[1], to solicit ideas relative to the formation of the proposed new program, named the National Network for Manufacturing Innovation (NNMI). This program is to be the backbone of President Obama's program for the Advanced Manufacturing Partnership (AMP), mentioned in his State of the Union Speech on January 20, 2012. Nine days prior to the publication, on April 25, the first workshop to solicit input on the formation of the NNMI was held in Troy New York. Several members of the Finger Lakes region of New York[2] were in attendance, and were enthused by the idea of the Advanced Manufacturing Partnership, and brought their enthusiasm back to the region. In attendance was a good mix of local Government (e.g. Congressional Staff, MEP) Universities, (e.g. RIT, University of Rochester), and Industry Consortiums: (e.g NY BEST (Energy)). Since the workshop, guided by our local MEP representatives, we have met frequently and considered actions necessary to establish a center for advanced technology, much as the model of the Institutes for NNMI were considered. We have adopted an identification as a group, focused on **Flexible Film and Coating Technology**. Our first action is to submit our comments on the aforementioned RFI. This document contains our group answers to the questions posed in the RFI, in addition to a suggestion that the AMNPO consider adaptation of Flexible Film and Coating Technology as a candidate for an Institute.

Disclaimer

This is strictly to be regarded as response to the RFI. It is NOT a proposal to become an Institute. We understand that the AMNPO and/or the managing collaboration of NNMI will issue a request for proposal for the technologies they adopt, and will respond at that time if a technology is requested that is within our expertise.

[1] https://www.federalregister.gov/articles/2012/05/04/2012-10809/request-for-information-onproposed-new-program-national-network-for-manufacturing-innovation-nnmi

2. Nine county region surrounding Rochester NY: Monroe, Livingston, Ontario, Yates, Seneca, Wayne, Orleans, Genesee, and Wyoming counties

Dialogue 1: Technologies with Broad Impact

1. What criteria should be used to select technology focus areas?

Technology areas should have the following characteristics:

- Enabling
- Applicability across multiple industries
- Leverage, where possible underutilized US manufacturing
- Easily scalable

2. What technology focus areas that meet these criteria would you be willing to co-invest in?

- Flexible Film and Coating Technology
    - Particularly, the fabrication and integration of function in flexible films
        - Functional Printing
        - Additive Manufacturing
        - Unique coatings for thermal, electronic, chromic, optical application

A white paper concerning this technology is attached to this memo.

3. What measures would demonstrate that the Institute technology activities assist U.S. Manufacturing?

- Job creation
- Export share increases
- Surveys
- Applications of technologies
- Number of industry alliances
- Sales reports from products affected by technology
- Number of startup companies using the technology
- IP generation

4. What measures could assess the performance and impact of Institutes?

- Investments, other than government
- Positive peer review
- Published papers in manufacturing journals
- Literature citations
- Retention of member organizations

Dialogue 2: Institute Structure and Governance

5. What business models would be effective for the Institutes to manage business decisions.
    - 501C3 Non Profits
    - Fraunhofer Institute (Germany)
    - NYSTAR New York
    - Sematech
6. What Governance models would be effective for the Institutes to manage governance decisions?
    - Institute would have its own board of directors
    - Institute management via 501C3 (e.g. MEP Center)
    - Directors Council
    - Pre-agreed fee structure, perhaps based on means and contribution
    - Pre-ordained IP structure, other legal
7. What membership and participation structure would be effective for the Institutes, such as financial and intellectual property obligations, access and licensing?
    - Fee-for-service R&D
    - Simplified initiation of membership and renewal
    - Common IP models, or at least simplified access.
    - Mentor/advisory approach to start-ups.
    - Structured fees based on means,
8. How should a network of Institutes optimally operate?
    - Collaboratively with other Institutes (see 1.)
    - Responsive to industry changes or wishes therof
    - Collaboratively within membership (pre-competitively)
9. What measures should assess effectiveness of network structure and governance
    - Member company growth
    - Frequent surveys of stakeholders
    - Track number and duration of projects, trend.
    - Website performance statistics

Dialogue 3: Strategies for Sustainable Institute Operations

10. How should initial funding co-investments of the federal government and others be organized by types and proportions?
    - Capital
    - Staff
    - Leverage existing resources
    - Fund "low hanging fruit" projects for sustainable "success stories"
    - Transition for private funding over time
11. What arrangements for co-investment proportions and types could help an Institute become self-sustaining?
    - Means-based membership fees
    - Equity funding
    - "commission" on Institute revenues (licenses, royalties, etc.)
    - Decrease federal funding, increase non-federal funding over time
    - Outsider fees for prototype or contract R&D
    - Fees for process training for outsiders
12. What measures could assess progress of an Institute towards being self-sustainable?
    - Growth in membership
    - Growth of jobs and payroll
    - Growth in outside (non-federal) funding.
    - "Success" – meeting milestones, accomplishments according to plan.
    - IP portfolio growth
13. What actions could improve how Institute operations support for domestic manufacturing facilities while maintaining consistency with our international obligations?
    - Supply chain support
    - Protect IP rights, limit institute IP to US companies
    - Tax credits for domestic manufacturing – "Keep it in the US"
    - Invest in Manufacturing education – "workforce development in US"
    - Diligent cost effectiveness – be mindful of true landed costs.
14. How should Institutes engage other manufacturing related programs and networks?
    - NNMI leadership to stimulate collaboration among Institutes
    - Regular, planned interactions both in person and virtual
    - Encourage cross-participation by board members
    - Technical Staff exchange
15. How should Institutes interact with state and local economic development authorities

- **Engage an economic development agency as leader of Institute**
- **Include state and federal economic development agencies as board members**
- **Include state and local economic development funding sources**

16. What measures could assess Institutes contribution to long term national security and competitiveness?

- **Metrics on manufacturing jobs created and retained**
- **Metrics on products and processes developed within the Institute which have been commercialized**
- **Metrics on IP developed**
- **Continuous innovation to maintain security and global competitiveness in key technologies**

Dialogue 4: Education and Workforce Development

17. How should Institutes support advanced manufacturing workforce development at all educational levels?

- **Organize the institute such that both Universities and Community colleges are members, organize work such that R&D “flows” to Community colleges so that workforce development is keeping pace with technology development.**
- **Implement K-12 involvement in STEM, as well as “attractiveness” of a manufacturing career**
- **Develop, incorporate manufacturing curriculum throughout High School and Community colleges**
- **Bootstrap current industry workforce to improve skills to achieve advanced manufacturing positions**
- **Fund scholarships at all academic levels to promote manufacturing careers, with concomitant employment commitment by recipient and grantor**

18. How could Institutes and NNMI leverage and complement all other education and workforce development programs?

- **Offer or sponsor mentoring, apprenticeships, fellowships, internships, co-ops, or sponsored research with Institute and other industry partners**
- **Incorporate existing, funded programs or their structures into NNMI**
- **Encourage access and expert mentoring from Institute resources to educators**
- **Certification and accreditation programs for post-degree continuing education**

19. What measures could assess Institute performance and impact on education and workforce development?

- **Employment rates for graduates connected to the Institute.**
- **Graduation statistics for graduates entering the industry workforce, number of students pursuing a manufacturing career**
- **Measures of “students” involved in Institute-sanctioned training courses**
- **Industry survey for Institute effectiveness**
- **Number of domestic manufacturing jobs created**

20. How might Institutes integrate research and development activities and education to best prepare the current and future workforce?

- **Involve students at all levels in industry-driven, team-oriented R&D activities.**
- **Include R&D using state-of-the-art equipment (supplied by Institute) as requirement in certificate and degree programs**
- **Provide opportunities for internships in Institute member companies**
- **Ensure relevancy of R&D programs to promote student satisfaction, as well as contribution to Institute program.**

Thank you, reader, for viewing some of our thoughts on the formation of the institutes. We call your attention to our appendix, where we highlight the advanced manufacturing technology we feel is deserving of investment, i.e Flexible Film and Coating Technology. Our white paper on this technology reveals key sustainability industries, namely batteries, energy storage, ultra-capacitors, fuel cells, and solar cells, which can benefit from the continued development of Flexible Film technologies. Functional integration (e.g. functional electronic circuit printing) with such films will become an enabling technology for several technologies, identified by the Presidents Council of Advisors on Science and Technology's REPORT TO THE PRESIDENT ON CAPTURING DOMESTIC COMPETITIVE ADVANTAGE IN ADVANCED MANUFACTURING, from July 2012, including:

- Advancing Sensing, Measurement, and Process Control
- Advanced Materials Design, Synthesis, and Processing
- Visualization, Informatics, and Digital Manufacturing Technologies
- Sustainable Manufacturing
- Nanomanufacturing
- Flexible Electronics Manufacturing
- Biomanufacturing and Bioinformatics
- Additive Manufacturing
- Advanced Manufacturing and Testing Equipment
- Industrial Robotics
- Advanced Forming and Joining Technologies

Thanks again. For continued discussion, please contact:

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Appendix 1:

What comprises **Flexible Films & Coating Technologies**?

Flexible Films and Coating Technologies cover a very broad set of market applications – both as an end-use, product, as well as an enabling and value-adding, integrated component. It's important to note that, while this paper focuses on Flexible Films and Coating Technologies as an enabler to the development of alternative and clean energy solutions, Flexible Films has the potential to create many jobs in a variety of market segments, including: automotive, consumer electronics, medical and pharmaceutical, display technologies, window films, etc. Specifically, roll-to-roll produced thin film products have the potential to provide breakthrough technology in a number of market segments beyond clean technology. Multiple functionality combined in a single, low cost film creates a competitive advantage that can be leveraged into a number of devices. In the past several years there has been significant activity in the development of Flexible Films in the following technology areas:

1. Electronic films
- transparent conductors
- Patterned conductive layers
- EMI shielding
- General Flexible electronics

2. Optical films
- display films (polarizers, retarders, brightness enhancers)
- lighting film (filters, diffusers)
- Window films (passive solar, filters, tinting)
- Holographic display films
- Electrochromographic films (changes color when an electronic charge is applied).

3. Medical and diagnostic films
- Detection films (presence of certain biological agents)
- monitoring films (e.g. glucose level)

4. Security films
- Anti-counterfeiting
- Identify verification/protection

5. Packaging films <<
- functionalized substrates (moisture barriers, oxygen barriers, UV protection, smart functions, etc)
- Functional materials added to *commodity* substrates
  - Contamination indicators
  - Embedded electronics (RFID, LED)

6. Environmental films
- Anti-pollution filter media
- environmental detection films

7. Cross-Functional Films

Cross boundaries between applications to create new film applications, specifically when films are integrated with technologies such as functional printing, additive manufacturing, and biological engineering.

Sensor Films for touch screens

tissue regeneration films

Flexible Films and Coating Technologies in Renewable Energy Applications

The development of flexible films and coated materials to facilitate the manufacture of highly-efficient products for enabling integrated sources of alternative energy is on the rise. Flexible Films have enabled significant advancements in the development of the following technologies, each of which will be described in this paper:

- ULTRACAPACITORS FOR ENERGY STORAGE
- LITHIUM ION BATTERIES
- PHOTOVOLTAIC CELLS
  - Flexible
  - Organic
  - Inorganic
- FUEL CELL MEMBRANES AND ELECTRODES

For each of the technologies described, we will investigate the market advantages of utilizing Flexible Films in the manufacturing of these applications and inherent production challenges, as well as next steps toward enabling commercial application of these market-leading advances.

Flexible Films and Ultracapacitor Development

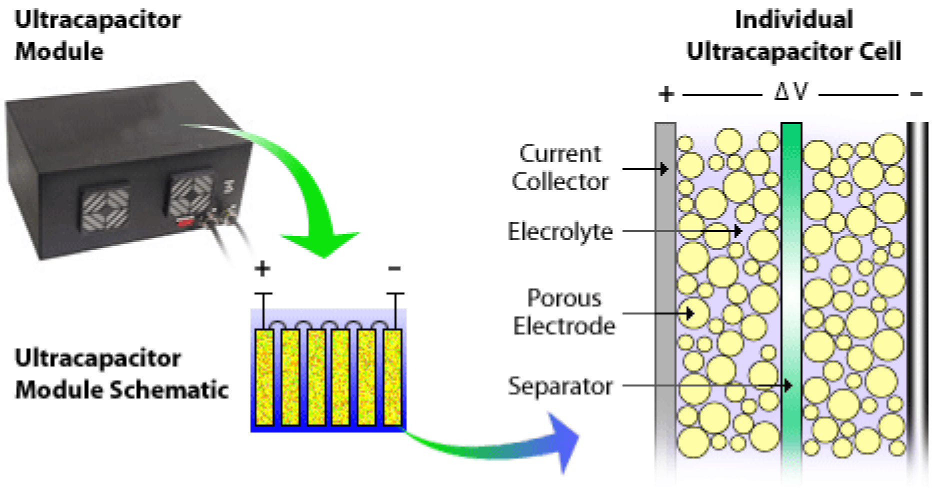
Ultra Capacitors are part of a foursome of energy storage and generating technologies that also include Batteries, Fuel Cells, and Electrolysers. Each of these technologies has, at their core, thin film coatings of various materials. The key to these technologies becoming widespread and commercially viable at high volume will be the reduction of costs through both material improvements and manufacturing yields.

Many applications can benefit from ultracapacitors, whether they require short power pulses or low-power support of critical memory systems. Ultracapacitors can be primary energy devices for power assist during acceleration and hill climbing, as well as for recovery of braking energy in transportation applications. An ultracapacitor used in conjunction with a storage battery combines the power and performance of the former with the greater energy storage capability of the latter. It can extend the life of a battery, save on replacement and maintenance costs, and enable a battery to be downsized. At the same time, it can increase available energy by providing high peak power whenever necessary.

Technology Description

The ultracapacitor, also known as a double-layer capacitor, polarizes an electrolytic solution to store energy electrostatically. Though it is an electrochemical device, no chemical reactions are involved in its energy storage mechanism. This mechanism is highly reversible, and allows the ultracapacitor to be charged and discharged hundreds of thousands of times.

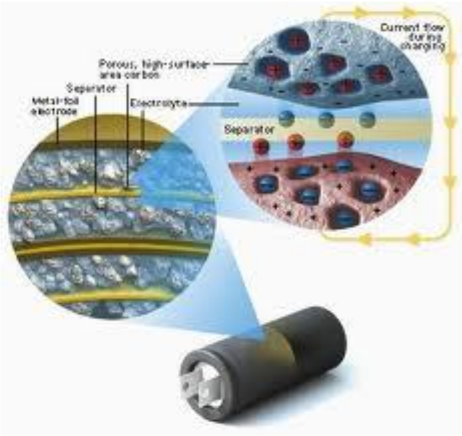
Like an ordinary capacitor, an ultracapacitor has two plates that are separated. The plates are made from metal coated with a porous substance such as powdery, activated charcoal, which effectively gives them a bigger area for storing much more charge. In an ordinary capacitor, the plates are separated by a relatively thick dielectric made from something like mica (a ceramic), a thin plastic film, or even simply air. When the capacitor is charged, positive charges form on one plate and negative charges on the other, creating an electric field between them. The field polarizes the dielectric, so its molecules line up in the opposite direction to the field and reduce its strength. That means the plates can store more charge at a given voltage. That's illustrated in the diagram you see here.

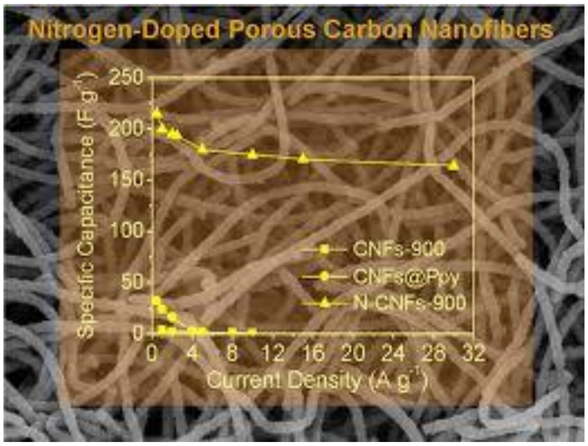


In an ultracapacitor there is no dielectric as such. Instead, both plates are soaked in an electrolyte and separated by a very thin insulator (which might be made of carbon, paper, or plastic). When the plates are charged up, an opposite charge forms on either side of the separator, creating what's called an electric double-layer, maybe just one molecule thick (compared to a dielectric that might range in thickness from a few microns to a millimeter or more in a conventional capacitor). This is why ultracapacitors are often referred to as double-layer capacitors, also called electric double-layer capacitors or EDLCs).

Once the ultracapacitor is charged and energy stored, a load can use this energy. The amount of energy stored is very large compared to a standard capacitor because of the enormous surface area created by the porous carbon electrodes and the small charge separation (10 angstroms) created by the dielectric separator. However, it stores a much smaller amount of energy than does a battery. Since the rates of charge and discharge are determined solely by its physical properties, the ultracapacitor can release energy much faster (with more power) than a battery that relies on slow chemical reactions.

The first ultracapacitors were made in the late 1950s using activated charcoal as the plates. Since then, advances in material science have led to the development of much more effective plates made from such things as carbon nanotubes (tiny carbon rods built using nanotechnology), graphene, aerogel, and barium titanate as seen below.





Manufacturing Requirements

The requirements for making Ultracapacitors, Batteries, Fuel Cells, and electrolysers all are focused on thin coatings of specialty materials. The precision and placement of these materials is paramount to the performance and life of these devices as well as being a substantial element of the product cost. As new materials are developed the manufacturing processes for continued precision and quality will need to be developed. Additional performance will be able to occur as increased density of the basic materials can be increased.

Flexible Films and Battery Development

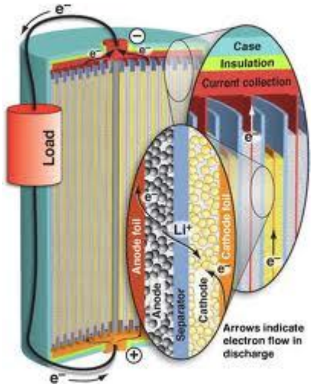
The battery industry is expanding rapidly in both the grid and transportation sectors. The drive for increased energy efficiency on the road and the ability to store off peak electricity makes batteries one of several key technologies that are being exploited in many industries. The current technology leaders are applications using Li-Ion technology. There are many new chemistries being developed around Li and all of them require thin coatings applied to both sides of various separator materials. To realize cost potential very high volume roll to roll processing capability will be required. The inherent capabilities of the Rochester Thin Film Manufacturing Technology Center have just such expertise. Additionally, the ability to both analyze the new materials as well as develop them will be a critical parameter for the commercialization of the complete evolution of Li Chemistry battery technologies and beyond.

The processes used for manufacturing Lithium batteries are very similar to those used in the current production of Nickel Cadmium cells and Nickel Metal Hydride cells with some key differences associated with the higher reactivity of the chemicals used in the Li cells - http://www.mpoweruk.com/battery_manufacturing.htm

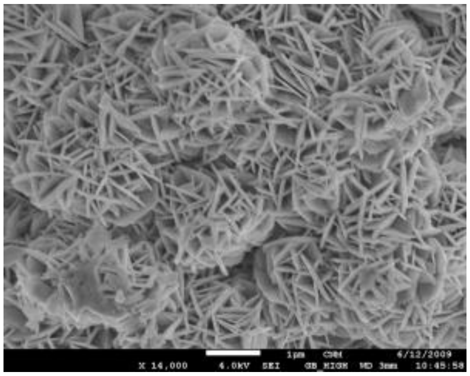
Technology Description (from how it works)

Li-Ion Batteries are generally much lighter than other types of rechargeable batteries of the same size. The electrodes of a lithium-ion battery are made of lightweight **lithium** and **carbon**. Lithium is also a highly reactive element, meaning that a lot of energy can be stored in its atomic bonds. This translates into a very high **energy density** for lithium-ion batteries. Here is a way to get a perspective on the energy density. A typical lithium-ion battery can store 150 watt-hours of electricity in 1 kilogram of battery. A **NiMH (nickel-metal hydride) battery** pack can store perhaps 100 watt-hours per kilogram, although 60 to 70 watt-hours might be more typical. A **lead-acid battery** (like the cranking battery in your car) can store only 25 watt-hours per kilogram. Using lead-acid technology, it takes 6 kilograms to store the same amount of energy that a 1 kilogram lithium-ion battery can handle. That's a huge difference.

The anodes and cathodes in Lithium cells are of similar form and are made by similar processes on similar or identical equipment. The active electrode materials are coated on both sides of metallic foils which act as the current collectors conducting the current in and out of the cell. The anode material is a form of Carbon and the cathode is a Lithium metal oxide. Both of these materials are delivered to the factory in the form of black powder and to the untrained eye they are almost indistinguishable from each other. Since contamination between the anode and cathode materials will ruin the battery, great care must be taken to prevent these materials from coming into contact with each other. For this reason the anodes and cathodes are usually processed in different rooms.



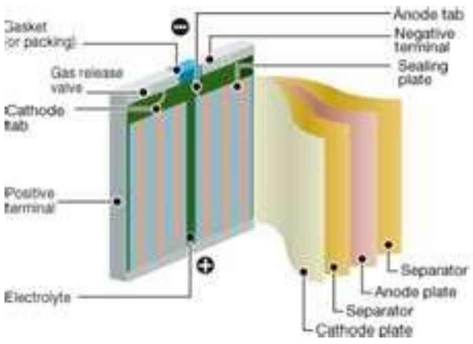
Li-Ion Battery Architecture



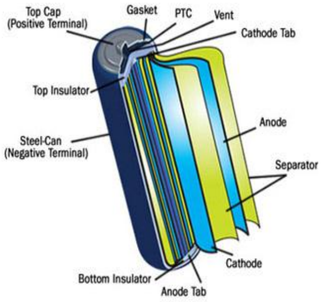
Li-Ion Anode structure

Particle size must be kept to a minimum in order to achieve the maximum effective surface area of the electrodes needed for high current cells. Particle shape is also important. Smooth spherical shapes with rounded edges are desirable since sharp edges or flaky surfaces are susceptible to higher electrical stress and decomposition of the anode passivating SEI layer, which can lead to very large heat generation and possible thermal runaway when the cells are in use.

The metal electrode foils are delivered on large reels, typically about 500 mm wide, with copper for the anode and aluminum for the cathode, and these reels are mounted directly on the coating machines where the foil is unreeled as it is fed into the machine through precision rollers. Batteries can be configured in either cylindrical or prismatic cells.



Prismatic type cell



Cylindrical Cell

Cell Assembly

In the best factories cell assembly is usually carried out on highly automated equipment; however there are still many smaller manufacturers who use manual assembly methods.
The first stage in the assembly process is to build the electrode sub-assembly in which the separator is sandwiched between the anode and the cathode. Two basic electrode structures are used depending on the type of cell casing to be used, a stacked structure for use in prismatic cells and a spiral wound structure for use in cylindrical cells.

Formation

Once the cell assembly is complete the cell must be put through at least one precisely controlled charge / discharge cycle to activate the working materials, transforming them into their useable form. Instead of the normal constant current - constant voltage charging curve, the charging process begins with a low voltage which builds up gradually. This is called the Formation Process. For most Lithium chemistries this involves creating the SEI (solid electrolyte interface) on the anode. This is a passivating layer which is essential for moderating the charging process under normal use.

During formation, data on the cell performance such as capacity and impedance, are gathered and recorded for quality analysis and traceability. The spread of the performance measurements also gives an indication of whether the process is under control. (Beware of manufacturers who use this process for sorting their cells into different performance groups for sale with alternative specifications).

Although not the prime purpose of formation, the process allows a significant percentage of early life cell failures due to manufacturing defects, the so called "infant mortalities", to occur in the manufacturer's plant rather than at the customers' premises.

Manufacturing Requirements

Tight tolerances and strict process controls are essential throughout the manufacturing process which involves high speed roll to roll coatings and assembly. Contamination, physical damage and burrs on the electrodes are particularly dangerous since they can cause penetration of the separator giving rise to internal short circuits in the cell and there are no protection methods which can prevent or control this. Manufacturing expertise in Flexible Films will help drive down costs and minimize material usage as well as insure repeatability from part to part at high volume.

Flexible Films and Solar Technology Development

Among Renewable sources of energy to satisfy the demands of our society, the abundance of sunlight offers enormous potential both as a source of thermal and a source of electrical power. Photovoltaic (PV) cells afford the direct conversion of incident sunlight into electricity via the photoelectric process. Largely a semiconductor process, the absorption of a photon by a semiconductor material creates a charge carrier, which becomes mobile, moving from atom to atom, past a semiconductor junction, where it exits as an electron, capable of providing electric current, due to a potential formed across the semiconductor junction. See Figure 1.

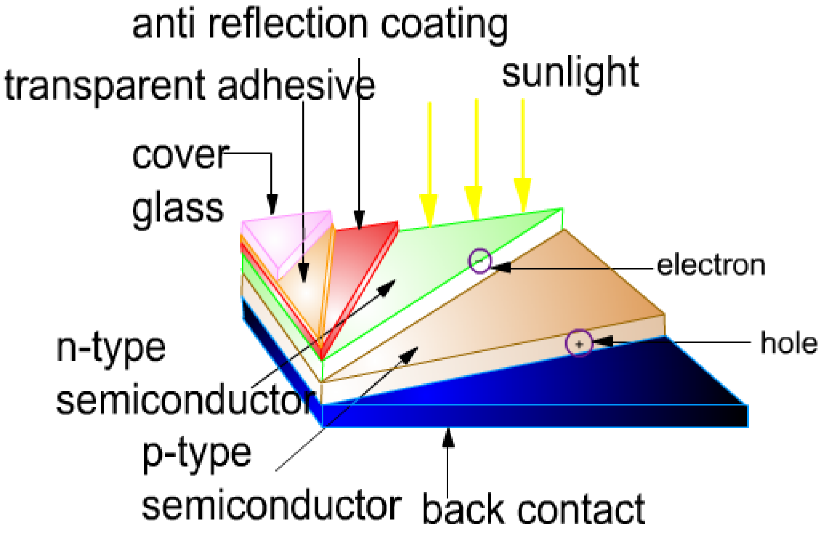


Figure 1 (Source: http://library.thinkquest.org/03oct/02144/glossary/solar_cells.html)

Early efforts to harness the Sun's power for electricity included silicon PV cells, consisting of crystalline silicon, formed into semiconductors. Even early devices exhibited relatively high efficiency, in the area of 20% of the incident light converted into useful power. Different silicon materials (mono- and poly-crystalline) and different junction arrangements yielded higher efficiencies (approaching 50%), but at the sacrifice of higher cost. As experiments progressed the manufacturing technology grew with progress, enabling relatively large "rods" of silicone, typically monocrystalline, to be produced, sawn into wafers, and sandwiched between two pieces of glass to form a solar cell. External electronics afforded control and direction of current, as well as electromechanical positioning of the PV cell, in order to efficiently capture maximum sunlight as time passed. The cell and its current carrying and positioning components comprised as solar cell system. While approaching reasonable efficiency, the cost of production has remained high, with systems affording the lowest cost at around $10/watt. In 2012, China has undertaken questionable economic policies (dumping) to bring crystalline silicon panels down to $1/watt, $2 to the customer, that have resulted in driving installed costs down, albeit artificially[1].

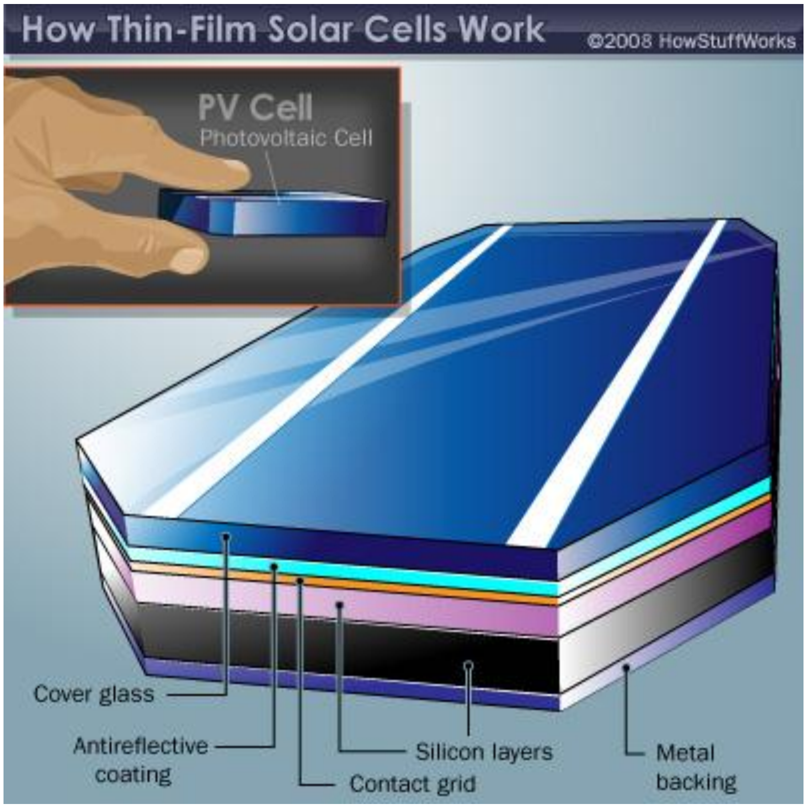


Figure 2 Thin Film Solar Cell(http://science.howstuffworks.com/environmental/green-science/thin-film-solar-cell.htm)

A majority of the World has adopted and is developing solar energy systems using the silicon technology. In the US, attention has turned to Thin Film photovoltaics, where the semiconductor consists of newly discovered materials such as Cadmium Telluride (CdTe) and Cadmium Indium Gallium Diselenide (CIGS), and the the semiconductor junction is formed in layers, as shown if Figure 2..

One of the bright promises of thin film solar cells includes cost. By 2008, solar cells made of CdTe had dropped costs to $1.14/ watt, and by 2011, CIGS cells were manufactured in California at a cost of $0.99, resulting in systems installations in Germany at $3/watt. Most recently**,** the high-tech engineering firm Manz (Reutlingen, Germany) has achieved a technological breakthrough: its integrated production line for CIGS thin-film solar panels, the Manz CIGSfab, can be used to manufacture solar panels that in the future will supply power costing between four euro cents (Spain) and eight euro cents (Germany) per kilowatt hour (Level-ized Cost of Energy, LCOE), depending on the location, the company reports[2]**.**

The greatest promise of the future is the cost of organic materials, such as Fullerene-Polymer-Polyethylene terephthalate(PET) are dissolved in solution, such as chlorobenzene (CB) and sprayed onto a film substrate, to form a thin, low cost, flexible solar cell, as depicted in Figure 3.

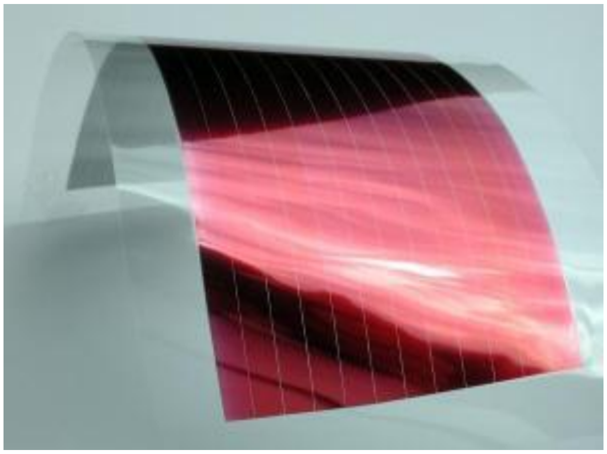


Figure 3 – Thin film solar cell (Source: ScienceDaily 2/10/08)

The operation of the organic photocell is diagramed in Figure 4, below.

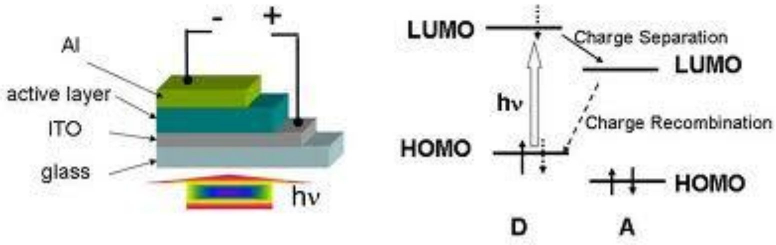


Figure 4. Organic photocell operation (.http://staff.science.nus.edu.sg/~chmxqh/research.html)

The drawback has been low efficiency. By mid-2010, organic PV cell efficiencies remained in the 5% area, as evidenced by Figure 5, which shows relative efficiencies of all of the configurations of cells to mid 2011. ON September 10, 2012, a German company reported a new world record for organic photocell efficiency of 10.7% , indicating 15% was reachable within 5 years.

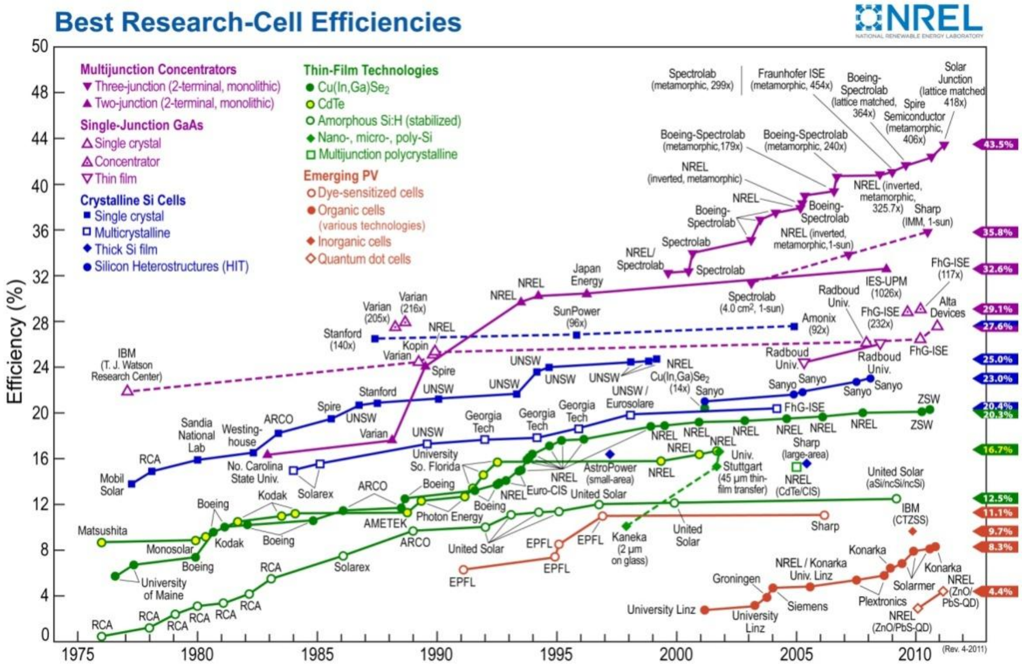


Figure 5. Various Photovoltaic Cell efficiencies.(Source Wikipedia, reprint from NREL)

Flexible films will play a major role in the further development of solar cells, particularly in the organic arena, where the semiconductor material is sprayed onto a film substrate. A polycarbonate film may be employed as the entry layer, instead of more costly glass. Beside cell material construction, Films may be deployable as a means to concentrate sunlight onto arrays of photocells, optically. Film- based Fresnel lenses are easily and inexpensively formed, and are capable of increasing efficiencies greatly, In a configuration as shown in Figure 6, below.

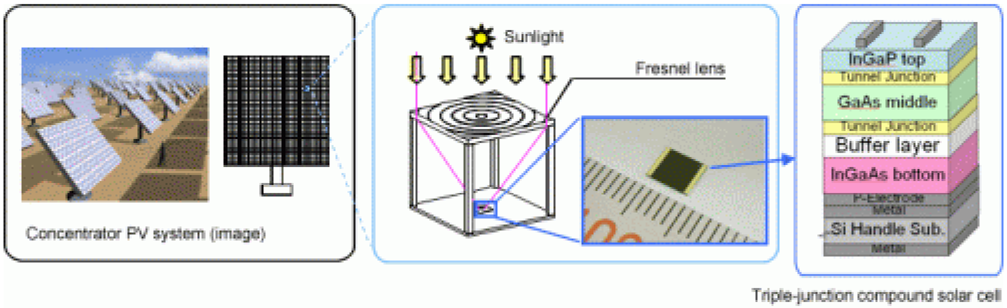


Figure 6 Concentrator Solar Cell arrangement. (http://sharp-world.com/corporate/news/120531.html)

In May of 2012, a multi-junction solar cell with a Fresnel lens set a record-breaking efficiency of 43.5%.

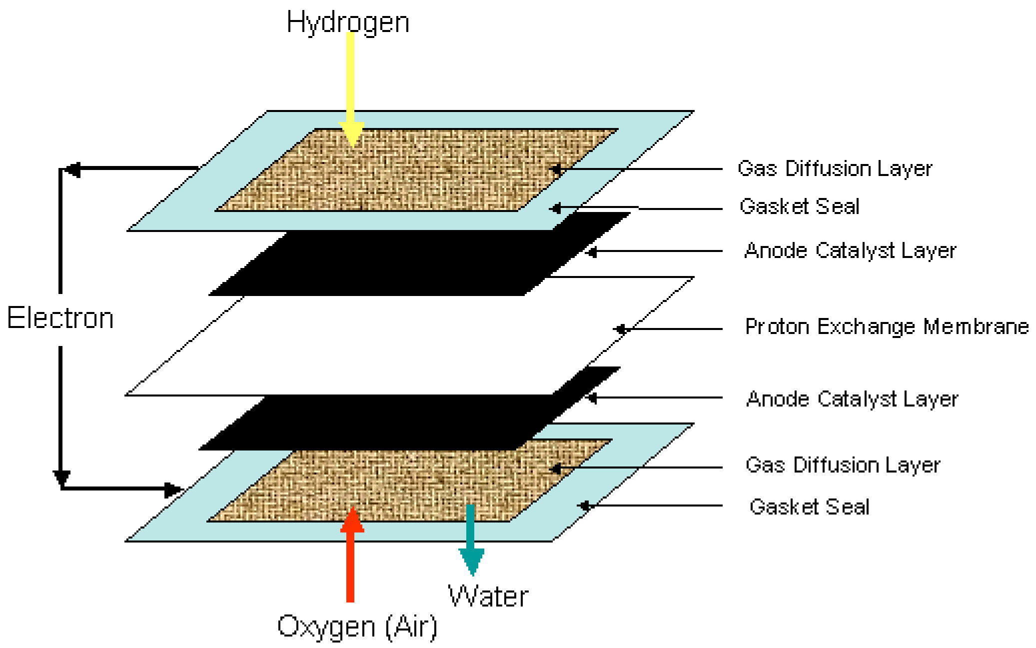
Lastly, research may provide the keys to unlocking more potential of solar cells. Advances in functional printing, printed circuitry (already used to fabricate organic PV's) and low-temperature sintering techniques may facilitate a return to complex, silicon, high-efficiency photovoltaic cells. Flexible Film and

Coating technology may play a key role in the research and fabrication of next-generation PV materials and cell production methods, achieving efficiencies greater than 50 % In a low-cost, flexible, solar cell.

The future is bright!

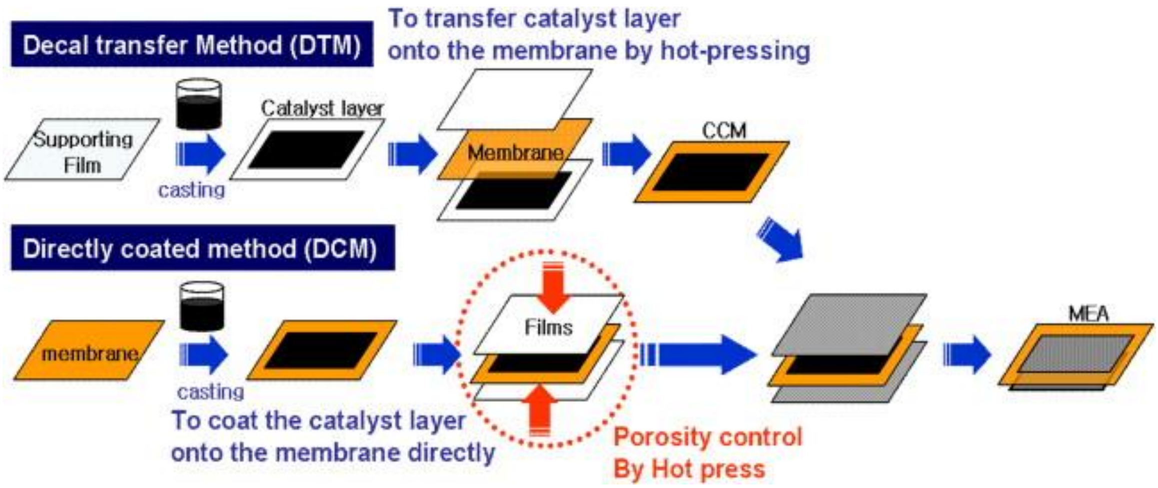
Flexible Films and Fuel Cell Development

The most important part of the PEM fuel cell is the membrane electrode assembly (MEA). Due to this and to the catalyst costs, many researchers have been studying the membrane and electrode assembly manufacturing processes that can reduce the content of Pt in the electrocatalyst layer while maintaining the performance. The MEA is the heart of the PEMFC and catalyst plays an important role into the fuel cell operation. The MEA consists of a proton exchange membrane, catalyst layers and gas diffusion layers (GDL).



■ Construction of MEA (Membrane Electrode Assembly)

There are different methods to make a MEA. The most employed methods are thin-film methods. In this method it is necessary to prepare an ink with the catalyst. This ink can be directly coated to the membrane. When the coat is made, it is necessary to dry the membrane under vacuum at temperature. Alternatively, the catalyst layer can be applied using a transfer printing method in which the catalyst material is coated to a PTFE blank. A subsequent catalyst layer is then decaled on to the membrane. Another method is to spread a thin film of catalyst slurry either onto the gas diffusion layer or the membrane. The assembly between gas diffusion layer and membrane is made by hot pressing or rolled.



Dear Reader: Thank you very much for reading our white paper on Flexible Film and Coating Technology. We strongly feel that this technology is worth consideration for investment in advanced manufacturing technologies. The basic technology of flexible films is over one hundred years old, yet the notion of re-purposing it and integrating substantial functions, among them electronic, mechanical, optical, biological applications, yields a contemporary freshness, worthy of advanced manufacturing technology recognition.

In the July 2012 Report to the President by his Council of Advisors on Science and Technology, concerning Capturing Domestic Competitive Advantage in Advanced Manufacturing, they suggest investment in several technologies:

- Advancing Sensing, Measurement, and Process Control
- Advanced Materials Design, Synthesis, and Processing
- Visualization, Informatics, and Digital Manufacturing Technologies
- Sustainable Manufacturing
- Nanomanufacturing
- Flexible Electronics Manufacturing
- Biomanufacturing and Bioinformatics
- Additive Manufacturing
- Advanced Manufacturing and Testing Equipment
- Industrial Robotics
- Advanced Forming and Joining Technologies

We suggest that Flexible Films and Coating Technologies (FFCT)be added to this list, which we believe are destined to be bases for future National Network for Manufacturing Innovation (NNMI) institutes. We re-state our belief that FFCT is both crossover and enabling technology for many of these potential NNMI – candidate technologies.