

Photovoltaics Innovation and Commercialization (PVIC) in Ohio

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ABSTRACT

Photovoltaics Innovation and Commercialization (PVIC) was funded to strengthen the photovoltaics research and manufacturing base. Activities aim to eliminate market barriers faced by companies in the photovoltaics sector. Companies active in the photovoltaics industry, from those researching advanced materials development to those installing energy producing devices, advise and coordinate PVIC members. For maximum impact on increasing production efficiency and lowering costs, PVIC takes a vertically integrated approach from research in advanced materials to the fabrication of production-scale modules, to issues related to installation, and finally to aspects of customer acceptance. Collaborators in PVIC possess knowledge of how to overcome real-life problems arising in connecting a module to the electric grid and how to obtain customer support for building integrated PV designs. Companies along the entire value chain have been brought into PVIC.

Keywords: industry-academics, photovoltaics, materials, small business, manufacturing

1 INTENT OF PVIC

The Center for Photovoltaics Innovation and Commercialization (PVIC) supports activities centered on eliminating commercialization barriers currently facing companies in the photovoltaics (PV) sector. Ultimately, PVIC consists of a development center with an infrastructure attractive to companies already successfully marketing PV and to researchers of the future generations of PV devices. These activities bring together established companies and researchers seeking to be at the forefront of developments in the PV industry to seed the formation of new startup companies. To fulfill its mandate, PVIC concentrates on photovoltaics and on the generation of hydrogen fuel from PV-driven electrolysis of water. For maximum impact, PVIC takes a vertically integrated approach from research in advanced materials to the fabrication of production-scale modules, to issues related to installation, and finally to aspects of customer acceptance. Collaborators in PVIC possess knowledge of how to overcome production problems that arise in connecting a

PV module to the electric grid and how to obtain customer support for integrated PV designs.

Companies along the entire value chain contribute to PVIC, and each has identified its current market status relative to shipping products or providing services to customers. Each company identified the commercialization barriers existing between their current positions and where they need to be in order to satisfy customer demands. Equipment, instruments, and techniques were identified to eliminate commercialization barriers faced by each of the companies involved in the Center. Budget items are selected because they overcome barriers faced by more than one company. Because such infrastructure is required for companies poised for near-term markets and for market entry in the future this ensures maximum leverage for an extended period of time.

Five thematic areas, reflecting the strengths of the PVIC partners and the current needs of the industry, emerge in this effort. They are:

- (1) Acceleration of the commercialization of the next generation device technologies, in particular, those based on quantum dot structures incorporating both organic and inorganic components and those based on dye-sensitized metal oxides;
- (2) Improvement in the current generation of thin film PV for lower production costs, higher deposition rates, and higher performance due to improvements in cell fabrication and characterization;
- (3) Reduction of barriers involving fabrication of thin film (especially Groups II-VI CdTe and amorphous silicon) photovoltaic modules, including the use of ultralight weight substrate materials, improved high-volume deposition methods, advanced inline process monitoring, and improved understanding of material properties, as well as the packaging and environmental testing of these devices;
- (4) Development in balance-of-systems (BOS) that tie these modules to actual power delivered in the home, business, or generating station;
- (5) Promotion of the use of PV, including the training and organization of installation contractors, promotion of uniform PV-related building codes across the State, coordination of activities with major utility companies, and outreach efforts informing the public about the benefits of PV.

Photovoltaics is the focus of PVIC in part because Ohio has a long history of producing successful companies along the entire value chain of PV technology (PV module fabrication, glass and polymer manufacturing, building integration), a field of high economic growth and high employment generation. PVIC is intended to solidify leadership in the manufacture of current PV technology and build infrastructure ensuring leadership in the PV technologies of the future.

2 PV IN OHIO

The state of Ohio has a proven history of generating companies capable of producing and selling photovoltaics modules and their components. Building on this track record, PVIC will repeat this success by providing services and expertise to companies possessing PV module fabrication technology promising to lead to a lowering of production costs and to lower cost PV modules than currently available.

Imaging stage products. Ohio's major universities are world leaders in the development and characterization of PV materials and the conceptualization of new PV devices. Over the years, the needed expertise and equipment for these activities have been established through industrial, federal and state competitive funding programs.

Incubating stage products. Concurrently, Ohio universities have developed the infrastructure for incorporating PV materials in thin film form into small-area functional PV devices; hence they possess the resources to take PV from the imaging stage on to next level of development. These resources have been obtained for the "second generation" thin film PV such as amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium-gallium diselenide (CIGS). These resources can be used to bring the "third generation" technologies from the imaging to the incubating stage; these include inorganic quantum dots, wires, and tubes, organic thin films, and hybrids. PVIC incorporates the infrastructure to overcome barriers to incubation of the third generation technologies that will sustain the PV industry.

Demonstration stage products. Ohio's major universities are world leaders in the fabrication and characterization of small-area PV devices. For the second generation PV devices, the capability is established for scaling up small-area functional PV device processes into large areas. PVIC acts to overcome barriers to demonstration projects by completing the state-of-the-art facility for large-area deposition of PV structures. This facility has the capability of using a variety of different substrates as required by the industry collaborators of PVIC. In addition, PVIC will install large-area characterization tools also required by the industry collaborators. With state-of-the-art deposition and characterization instruments and the expertise to supervise

them, PVIC becomes unique world-wide and is expected to attract new companies to Ohio. Although a majority of the large-area deposition equipment is devoted to second generation thin film modules, some equipment is devoted to third generation demonstration projects, as is all the characterization instrumentation.

(a) **Demonstration of substrates and coatings.** Ohio has long been a leader in the production of glass and polymer articles. Currently, glass, stainless steel, and polymers are used as substrates for the fabrication of PV devices and modules. Companies with plants in Ohio seek to coat glass and polymer substrates with high performance electrically conducting materials, thereby establishing product lines preferred by PV fabricators. These companies possess the necessary resources to fund such a project, but lack the equipment and expertise to fabricate PV devices and modules and thus are not in a position to optimize their coated substrates for the PV market. PVIC provides services and expertise leading to the fabrication of completed PV devices and modules along with comprehensive device characterization. In this way PVIC speeds up the production of coated substrates optimized for the PV fabricators. In summary, PVIC overcomes market entry barriers faced by substrate producers by providing PV semiconductor deposition and completed PV devices and modules for the coated substrate producers.

Ohio has also been a leader in the production of value-added coatings on glass. Currently, coated glass substrates are modified to enhance the performance of PV devices and modules. Optimized coatings for maximum performance are required by all the thin film PV technologies from a-Si to organic semiconductors. Overcoming these problems, by providing these companies with testing facilities ranging from optical properties to durability of the coatings, directly enhances the power output and durability of PV modules.

(b) **Demonstration of modules.** Ohio companies exist with semiconductor deposition technology capable of fabricating photovoltaic modules at a lower cost (for example, using less expensive atmospheric pressure systems), and have sufficient resources to build manufacturing deposition equipment. In order to complete work on preparing the technology for market entry questions of weathering, long term light exposure, laser scribing and field testing need to be addressed so as to provide a convincing set of data to potential customers. PVIC acts to overcome market entry barriers related to PV module durability by building infrastructure providing these services. Weathering, light soak, field testing and other forms of durability testing (as well as scribing technology) are required for all PV technologies.

Market entry. PVIC assists Ohio PV companies to progress rapidly from the demonstrating phase toward the market entry phase -- made possible through world-class expertise and facilities. Problem areas of great interest to PVIC members include bringing to market (i) low-cost high performance PV based on glass substrates for utility scale generation of electricity and (ii) a flexible building-

integrated PV roofing product designed for the residential market with higher performance, easier installation, and pleasing aesthetics. Throughout the demonstrating and market entry process, module developers interact closely with system designers, engineers, and installers within PVIC so products brought to market yield lower balance of systems, installation costs, and satisfy customers demands. PVIC staff with broad technical expertise along the full value chain will catalyze this dialog.

Growth and sustainability. PV is a paradigm-changing technology requiring not only overcoming the barriers to the marketplace, but also tracking levels of customer acceptance. With the rapid increase in residential and commercial PV use, consumer acceptance is also likely to change rapidly and this is a key variable in any marketing strategy. Thus, market research will be helpful to identify consumer trends in PV as well as the marketing strategies required by PV value chain companies. The conclusions of this research are expected to impact the nature of the product and may require returning to unanticipated demonstrating to meet the customer's evolving needs. In addition, consumer education is required to counter misconceptions about PV identified in surveys and to emphasize the societal benefits of renewable energy.

3 PVIC ALLIANCE STRUCTURE

PVIC's success in achieving its targeted problem solving assets, intellectual property commercialization and PV production goals will be significantly impacted by organizational and operational structures. The PVIC organizational structure revolves around an alliance between universities, companies and the Battelle Memorial Institute ("PVIC Alliance"). The PVIC Alliance enables a more effective and efficient operational structure crucial to the integration of solar energy research, technology development and intellectual property commercialization. The PVIC Alliance success factors include a synergistic technology pooling from multiple universities for the purpose of licensing "technology packages" of greater value and create new business development growth in photovoltaic materials, components and solar energy products. The PVIC Alliance organizational and operational structures eliminate or minimize many of the biggest challenges companies face in dealing with multiple institutions by including the following elements:

- A formal alliance agreement establishing protocols for collaborative technology platform research focused on market driven customer needs.
- Companies negotiate with one entity (PVIC IP management) for multi-institution IP created on laboratory equipment and instrumentation of the PVIC Center.
- Companies will be able to collaborate with multiple institutions simultaneously through the PVIC Alliance and fund multi-laboratory research

and development projects, knowing that the resulting IP will be pooled into a technology package for a specific commercialization target, and business development objective.

- Companies will be able to structure projects within PVIC spanning the "solar energy value chain". These projects will involve collaborative projects involving material suppliers, component producers and solar energy device manufacturers with each company having the option to license technology packages for a specific field complementary to their position in the value chain and commensurate with their level of participation in the Center.
- The executive director of the center will have an Industrial Advisory Board assisting in the development of the R&D agenda, a business plan and a licensing strategy based on pooled intellectual property.

Reporting to the co-directors will be a "IP Strategy and Commercialization Manager" ("IP Manager") responsible for developing an IP strategy aligned with the PVIC Center business plan and provides for an integration and pooling of IP.

An objective of the PVIC Alliance agreement is to have a position below the co-directors to coordinate IP issues, which provides a single person with whom companies interact for IP packages involving multiple institutions.

4 INTERACTIONS WITH PVIC

The primary objective of PVIC is to assist companies in overcoming barriers inhibiting their progress along the Commercialization Framework. Some of the barriers are quite straightforward and only require the collection of a set of data. The data collection may involve an analytical characterization, a material deposition or some other technique within the expertise of PVIC personnel. In other cases the barriers may be more complex and require further analysis. A company may require an involved study in order to better understand the barrier to commercialization inhibiting growth and the introduction of products to the market. In order to meet this objective PVIC can interact with companies in one of three ways:

- 1) the company can apply to PVIC for services for which IP is not generated and there is not an exchange of IP between the company and PVIC;
- 2) the company requires further knowledge and the possibility exists for IP generation; or
- 3) the company is attract to the IP held by PVIC and arranges a license agreement to use the IP in the company's commercialization strategy.

Companies interacting with PVIC would initially do so through the appropriate director (either in Toledo, Dr. Robert Collins, or Columbus, Dr. Robert J. Davis) who would determine whether the company is interested in PVIC services or requires a PVIC research contract or

requires a licensing agreement. For PVIC services the company would pay user fees for collection of the information required. For companies requiring more in-depth analysis where IP may be generated on the part of PVIC members a research contract between the company and PVIC would be implemented. In research contracts and licensing agreements issues related to the handling of IP and the scope of the work would be clarified. Conceivably, other possibilities exist for interactions between PVIC and companies. The appropriate co-Director in consultation with the Executive Board of Industrial Advisors will handle each case to ensure the best interests of PVIC members, the company, and the State of Ohio are served.

The PVIC "IP Strategy and Commercialization Manager" ("IP Manager") reports to the co-Directors and is responsible for leading an IP Innovation Council (IPIC) composed of technology transfer/commercialization managers from the PVIC institutions. The IP Manager is responsible for pooling and bundling IP from all institutions for the purpose of accelerating the licensing of "technology systems" that can be commercialized by PVIC member companies, new prospect companies or can be the basis for launching start-up companies. The PVIC IP Innovation Council will meet quarterly to ensure the intellectual management process is focused on creating an intellectual

property pipeline aligned with market drivers and customer's needs.

5 COMMERCIALIZATION

The PVIC commercialization strategy supports this mission by focusing on two generations of PV technologies and a portfolio of advanced products that will enable existing companies to grow, and also holds the prospect of creating new start-ups and commercialization alliances that will benefit the job growth targets of PVIC. The foundation of the commercialization strategy is based on a strong proprietary contract research program aligned with market drivers, a PVIC catalyzed "constellation of alliances" throughout the PV product value chain, and the ability of a multi-organizational alliance to create an intellectual property pipeline that meets the needs of industry.

The Center will create and support a portfolio of products as the industrial collaboration projects move closer to commercialization. A nearer-term "portfolio of PV products" includes the following PVIC collaborations and alliances with industry shown in the figure below.

