

Stephen Patrick Shea, Ph.D.
404-276-6103
steveshea@fulcrumtechgroup.com
www.fulcrumtechgroup.com

Expert in Photovoltaic device and product development, process implementation and large-scale manufacturing with over forty years' experience

- ▶ Solar cell, ingot, wafer and module process and product development
- ▶ Technology performance and cost evaluation
- ▶ Expert Testimony
- ▶ Product safety and reliability
- ▶ Industrial hygiene, safety and environmental compliance
- ▶ Manufacturing and production, including equipment specification and acquisition
- ▶ Factory design and construction
- ▶ Process launch, expansion and generational technology transformation
- ▶ Technology transfer
- ▶ Engineering and Operations Management
- ▶ Research & Development

EDUCATION

Ph.D., Applied Science/Electrical Engineering and MEE, University of Delaware
BS, Engineering Science and BA, English Literature, Swarthmore College

EXPERIENCE

More than forty years overall experience in Photovoltaics (PV), including: R&D; manufacturing; manufacturing process development; factory construction, launch, expansion and upgrade; technology transfer; and technology, engineering and operations management.

Currently Owner of and Principal Consultant with Fulcrum Technology Group LLC.

Recent work includes: product engineering for a solar-thermal (PVT) module manufacturing start-up; a Gigawatt-scale solar cell manufacturing facility design, equipment purchase and factory start-up; and an analysis of the impact of shadowing and module mis-match in a very large solar single-axis tracker field.

Expert witness in several legal proceedings involving intellectual property issues in the field of photovoltaics and testimony before the International Trade Commission.

Previously VP of a photovoltaic manufacturing start-up engaged in the commercialization of a low-cost Interdigitated Back Contact (IBC) cell process.

Preceding eight years as VP with another high-tech photovoltaic manufacturing start-up, including the design and construction of the manufacturing facility and the creation and management of the manufacturing organization through two subsequent expansions and three subsequent transfers of new technology from laboratory to manufacturing.

Three earlier years as a PV consultant, including sole responsibility for design, installation, process definition and training for a crystalline PV manufacturing line start-up in Cairo, Egypt.

Twenty years with a start-up that became one of the largest vertically integrated photovoltaic companies (Solarex/BP Solar) covering all aspects of R&D, process deployment, manufacturing and equipment engineering and large-scale manufacturing process management and control.

R&D work with a wide variety of thin-film materials through doctoral and later work at the University of Delaware's Institute of Energy Conversion.

EMPLOYMENT HISTORY

February 2017 – Present – Principal Consultant Fulcrum Technology Group, LLC

- www.fulcrumtechgroup.com
- Recent Work Includes:
 - Expert witness in legal proceedings involving intellectual property issues in the field of photovoltaics.¹
 - Technical Advisor for Convalt Energy, a renewable power developer preparing to start-up PV manufacturing facilities in New York State (www.convalt.com)
 - Technical advisor for Tyll Solar, a PV/Thermal hybrid start-up in New York State (www.tyllsolar.com).
 - Technical advisor in the sale of physical and IP assets of Beamreach Solar after that company's bankruptcy (<https://www.prnewswire.com/news-releases/hilco-streambank-to-sell-beamreach-solar-intellectual-property-300457727.html>).
 - Testified before the International Trade Commission and before the U.S. Trade Representative in support of Suniva/Solar World petition seeking trade relief.²

June 2016 – January 2017 – Beamreach Solar, Milpitas California

Vice President, Cell Engineering and Operations

- Achieved record cell and module efficiencies and process yields using a proprietary, manufacturable, low-cost interdigitated back contact (IBC) cell structure.
- Reduced facilities and operations costs by 20%.

October 2007 – March 2016 – Suniva, Inc., Norcross Georgia (Metro Atlanta)

January 2011 – March 2016 – Vice President, Chief Engineering Officer

October 2007 – December 2010 Vice President, Manufacturing

- Employee #3 of this innovative Photovoltaic manufacturing start-up in suburban Atlanta, (Georgia Department of Economic Development Manufacturer of the Year Award for 2016).

¹ SunPower Corp. v. Bunea, American Arbitration Association Case No. 01-19-0003-9663. Expert witness on behalf of defendant, providing expert report and testimony.

The Solaria Corporation v. Canadian Solar Inc. and Canadian Solar (USA) Inc., No. 4:20-cv-02169-JST (N.D. Cal.), "Certain Shingled Solar Modules, Components Thereof, and Methods for Manufacturing the Same". Expert witness on behalf of Canadian Solar, providing expert report and testimony.

Hanwha Solutions Corporation and Hanwha Q Cells USA, Inc. v. REC Solar PTE. LTD., Case Nos. IPR2021-00988, IPR2021-00989. Expert witness on behalf of REC. Provided reports, deposition and testimony.

"Certain Silicon Photovoltaic Cells and Modules with Nanostructures, and Products Containing The Same", 337-TA-1271, United States International Trade Commission. Provided research and expert advice.

² Crystalline Silicon Photovoltaic Cells (Whether or Not Fully Assembled into Other Products), TA-201-75, United States International Trade Commission. Testified before the ITC.

- As Chief Engineering Officer, responsible for planned manufacturing expansions. Designed factory renovation, expansion to triple the existing capacity and transition to new-generation process technology. Sourced the equipment for that expansion, which was completed in 2017.
- Completed start-up project through financial analysis; site selection; equipment specification and quotation; complete building and infrastructure design; agreement with local government and financial institutions; pre-screening of local employment candidates.
- Responsible for guiding next generation technology selection for scale-up.
- Responsible for product reliability for existing and next generation products.
- As VP of Manufacturing, specified equipment for scale-up of laboratory processes to industrial scale.
- Specified plant infrastructure including advanced Manufacturing Execution System (MES) for automated process tracking and control.
- Managed plant construction (retrofit of existing warehouse shell).
- Identified and hired the entire operations and engineering team and managed the growth of the operations organization from inception to a group of nearly 200 employees over 18 months.
- Achieved first production on-schedule 12 months after hire and 14 weeks after start of factory construction.
- Managed continuous expansion which tripled production levels in 2009.
- Managed introduction of two additional generations of technology evolution from laboratory scale into manufacturing in 2009 and 2010 with no increase in capital cost and with reduced process complexity and variable cost.

March 2004 – October 2007 – PV Manufacturing Consultant

Clients include PV manufacturing and materials manufacturing companies such as:

- Renewable Energy Corporation (REC – Norway)
- Engelhard Corporation (U.S.)
- Green Mountain Engineering (U.S.)
- Madison Research (U.S.) – Project location Cairo, Egypt

Consulting work involved all aspects of the PV manufacturing value-stream including:

- Process costing and market evaluation
- Technology development and transfer
- Process tuning and staff training

Example: The Madison Research project involved installation of a solar cell production facility in Egypt with individual responsibility for: Process definition; Work Instructions; Operator, Engineering and Supervisory training; equipment start-up; process start-up and factory acceptance testing. Factory start-up and acceptance phase involved six months on-site in Cairo.

November 2005 – March 2006 – Visiting Senior Solar Energy Technologist – Xerox PARC

This was a temporary, full-time position as part of a PARC (Xerox Palo Alto Research Center) team working to define, to value and to commercialize breakout photovoltaic technology. The chosen technology was covered by a number of patents and successfully licensed to a large PV manufacturing company. Continued to work with PARC as a consultant as recently as 2012.

July 1999 – December 2003 – Director of Technology – BPSolar (Global)

BPSolar was the result of a merger between Solarex (owned by Amoco) and a heritage BPSolar company owned by BP. This took place after BP acquired Amoco. Responsible for all advanced technology and new product development and deployment for the Crystalline Division of the new company, including factories in Frederick, Maryland; Sydney, Australia; Bangalore, India; and Madrid, Spain.

June 1985 – July 1999 - Manager, Research and Development - Solarex (Global)

Held a progressive series of management positions in Manufacturing Engineering and Research and Development within Solarex, including:

Advanced process development and process implementation at the two Solarex factories (Frederick, MD and Sydney, Australia)

- Achieved ISO certification at both factories.
- Supervised re-write of all process specifications and work instructions to facilitate the ISO application.

Responsible for all Crystalline Products Division process (manufacturing) engineering

- Improved process control: 25% improvement in product revenue.

Responsible for the specification and control of all Frederick MD production processes, as well as specification, installation and release to production of new process equipment

- Implemented strict process control throughout a new, 50,000 square foot manufacturing facility, along with installation of process automation equipment leading to a 15% product cost reduction.

June 1983 – June 1985 – Staff Scientist - Solarex Corporation, Rockville, Maryland

Responsible for the initiation, development and transfer to manufacturing of new technology

- Developed and implemented a new manufacturing process, saving \$1MM a year
- Completed a new, \$1MM process laboratory with facilities for pilot production and advanced analysis.

January 1981 - June 1983 - Research Associate, Inst. of Energy Conversion, Univ. of DE

Responsible for all materials analysis of promising materials for thin-film photovoltaics

- Identified the cause of common manufacturing defects in certain thin film solar cells
- Established a full-service materials analysis lab

References:

Dr. Ajeet Rohatgi
Founding Director of University Center of Excellence for Photovoltaics Research and Education,
Georgia Institute of Technology, Atlanta, GA

ajeet.rohatgi@ece.gatech.edu

770-977-3313 (Office)

404-894-7692 (Mobile)

Dr. Scott Elrod

Associate Director at the Stanford Office of Technology Licensing

Formerly: Vice President at the Xerox Palo Alto Research Center

scott.elrod@stanford.edu

650-725-9409

John Baumstark – CEO and Immediate supervisor at Suniva, Inc.

jwbaumstark@comcast.net

404-307-7452 (Mobile)

PUBLICATIONS:

Rapolu, Kalyan & Singh, Pritpal & Shea, Stephen & Meier, Daniel. (2010). “Numerical two dimensional modeling of silicon solar cells with experiment validation”, 10th International Conference on Numerical Simulation of Optoelectronic Devices (NUSOD), 75-76. 10.1109/NUSOD.2010.5595660.

Rapolu, Kalyan & Singh, Pritpal & Shea, Stephen. (2010). “Two dimensional numerical modeling of a silicon solar cell with selective emitter configuration”, Conference Record of the 35th IEEE Photovoltaic Specialists Conference. 002227-002232. 10.1109/PVSC.2010.5616564.

Rapolu, Kalyan & Singh, Pritpal & Shea, Stephen. (2009). “Two dimensional numerical modeling of a silicon solar cell with deep contacts in the emitter”, Conference Record of the 34th IEEE Photovoltaic Specialists Conference. 001048-001053. 10.1109/PVSC.2009.5411201.

Shea, S. P., “Current Trends in Silicon Solar Cell Manufacturing”, 13th Workshop on Crystalline Silicon Solar Cell Materials and Processes, 2003, Vail, Colorado, USA – Invited.

Winderbaum, S., A. J. Leo, S. P. Shea, T. D. Koval, and B. Kumar, “Characterization of Industrial-Scale Remote PECVD SiN Depositions”, 3rd World Conference on Photovoltaic Energy Conversion, 2003, Osaka, Japan.

Kumar, B., T. D. Koval, S. Narayanan, and S. P. Shea, “Commercialization of a Silicon Nitride Co-fire through (SINCOT) Process for Manufacturing High Efficiency Mono-crystalline Silicon Solar Cells”, Twenty-ninth IEEE Photovoltaic Specialists Conference, 2002, New Orleans, Louisiana, USA.

Williams, T., K. McVicker, A. Shaikh, T. D. Koval, S. P. Shea, B. Kinsey and D. Hetzer, “Hot Melt Ink Technology for Crystalline Silicon Solar Cells”, Twenty-ninth IEEE Photovoltaic Specialists Conference, 2002, New Orleans, Louisiana, USA.

Bragagnolo, J. A., J. Akita, H. Sato, Y. Chikaki, T. Hashimoto, M. Ito, I. Sugiyama, S. P. Shea “Processing of Crystalline Silicon Solar Cells in High Throughput Production Tools”, Twenty-ninth IEEE Photovoltaic Specialists Conference, 2002, New Orleans, Louisiana, USA.

Shea, S. P. and J. H. Wohlgemuth, “Improvements to Polycrystalline Silicon PV Module Manufacturing Technology”, Twenty-ninth IEEE Photovoltaic Specialists Conference, 2002, New Orleans, Louisiana, USA.

Shea, S. P., “Cost Effective High-Efficiency PV Processing”, Energy 2002 - A National Workshop on Energy Efficiency and Renewable Energy, Palm Springs, California, USA – Invited.

Cuevas, A., D. Macdonald, M. Kerr, C. Samundsett, A. Sloan, A. Leo, M. Mrcarica, S. Winderbaum, and S. P. Shea, “Evidence of Impurity Gettering by Industrial Phosphorous Diffusion”, Twenty-eighth IEEE Photovoltaic Specialists Conference, 2000, Anchorage, Alaska, USA.

Shea, S. P., “Manufacturing Issues for Processing Thin Crystalline Silicon Solar Cells”, Ninth Workshop on Crystalline Silicon Solar Cell Materials and Processes, 1999, Breckenridge, Colorado, USA.

Wohlgemuth, J. H., T. Koval, J. Creager, T. Tomlinson, J. Ellis, F. Artiglieri, S. Narayanan, J. Posbic, S. P. Shea, M. Roy, J. Cliber, M. Conway, D. Vanecek, B. Chen, and R. Fernanadez, “Progress in Solarex Crystalline Silicon PV Mat Program,” Twenty-fifth IEEE Photovoltaic Specialists Conference, 1996, p. 1181.

Shea, S. P. and J. H. Wohlgemuth, “Modeling of the application of high efficiency concepts to inherently low-cost solar cells,” Eighth European Photovoltaic Solar Energy Conference.

Wohlgemuth, J. H., T. Tomlinson, J. Cliber, S. P. Shea, and M. Narayanan, "Casting Larger Silicon Ingots", Fifth Workshop on the Role of Impurities and Defects in Silicon Device Processing, 1995, Copper Mt., Colorado, USA.

McLarty, P. K., D. E. Ioannou and S. P. Shea, "Recombination in solar grade polycrystalline silicon," J. Appl. Phys. 61 (7), 1 April 1987, p. 2672.

Wohlgemuth, J. H., S. P. Shea, R. K. Brenneman and A. M. Ricaud, "Elimination of Edge Roll-Off in Cast Semicrystalline Silicon," Nineteenth IEEE Photovoltaic Specialists Conference, 1987, p. 1524.

Shea, S. P. and T. D. Koval, "The effects of a dilute-source emitter diffusion on semi-crystalline silicon solar cells," Third International Science and Engineering Conference, Tokyo, Japan, November 1987.

Thornton, J. A., D. G. Cornog, R. B. Hall, S. P. Shea, and J. D. Meakin, "An investigation of reactive sputtering for depositing CuInSe₂ films for photovoltaic applications," 17th IEEE Photovoltaic Specialists Conference, May 1984, p. 781.

Shea, S. P., R. W. Birkmire and J. D. Meakin, "Origin of defects in CdS films associated with degradation of Cu₂S/CdS solar cells," 17th IEEE Photovoltaic Specialists Conference, May 1984, p. 1270.

Thornton, J. A., D. G. Cornog, R. B. Hall, S. P. Shea and J. D. Meakin, "Preparation of CuInSe₂ films by reactive co-sputtering," Electrochemical Society, Proceedings of Symposium on Materials and New Processing Techniques for Photovoltaics, 83-11, 1983, p. 419.

Shea, S. P., "Energy and atomic number dependence of electron depth-dose and lateral-dose functions," Electron Beam Interactions with Solids, SEM Inc., Chicago, 1982, p. 145.

Warter, P. J., S. P. Shea and L. D. Partain, "Space-charge-limited current in Cu_xS/CdS P-N heterojunctions," bulletin of the American Physical Society, 24, 1979, p. 273.

Shea, S. P., and L. D. Partain, "Effects of heat treatments on the minority carrier diffusion lengths and junction collection factor in copper sulfide/cadmium sulfide solar cells," World Electrotechnical Congress, Moscow, USSR, June 1978.

Shea, S. P., L. D. Partain, and P. J. Warter, "Resolution limits of the EBIC technique in the determination of diffusion lengths in semi-conductors," SEM/1978/V.1, p. 435.

Shea, S. P., and L. D. Partain, "Heat treatment effects on the minority carrier diffusion lengths, surface recombination velocity and junction collection efficiency of copper sulfide/cadmium sulfide solar cells," 13th IEEE Photovoltaic Specialists Conference, June 1978, p. 393.

Partain, L. D., and S. P. Shea, "SEM measurement of diffusion lengths, recombination velocity and junction collection factor in heterojunction solar cells," IEEE International Electron Devices Meeting, December 1978, p. 239.

Shea, S. P., "SEM evaluation of heat treatment effects on minority carrier diffusion lengths and junction collection factor in Cu_xS/ CdS solar cells," Technical Report IEC/PV/TR/77/4, Institute of Energy Conversion, University of Delaware, December 1977.