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LLNL-TR-740346

Low Voltage Electron Beam Processing Final Report CRADA No. TC-645-93-A

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October 20, 2017

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LOW VOLTAGE ELECTRON BEAM PROCESSING

Final Report
CRADA No. TC-645-93-A
Date Technical Work Ended: November 30, 2001

Date: November 27, 2002 Revision: 1

A. Parties

This project was a relationship between Lawrence Livermore National Laboratory (LLNL) and American International Technologies, Inc.

The Regents of the University of California
Lawrence Livermore National Laboratory
7000 East Avenue
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Dr. Hao-Lin Chen
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American International Technologies, Inc
5740 Cerritos Ave
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Mr. George Wakalopulos
Tel: (310) 503-4583

B. Project Scope

This CRADA project was established to develop a small, inexpensive sealed-tube electron beam processing system having immediate applications in industrial, high speed manufacturing processes, and in the Department of Energy (DOE) waste treatment/cleanup operations. The technical work involved the development and demonstration of a compact, sealed, 50-75 kilovolt (kV) EB generator prototype, including controls and power supply.

The specific goals of this project were to develop a low cost vacuum tube capable of shooting an electron beam several inches into the air, and to demonstrate that wide area materials processing is feasible by stacking the tubes to produce continuous beams. During the project, we successfully demonstrated the producibility of a low cost electron beam system and several material processing operations of interest to US industry, DOE and, since September 11, 2001, the Homeland Security.

There were six basic program milestones:

1) Membrance demonstration *(completed)*
2) Tube demonstration *(completed)*
3) Six inch prototype module demonstration *(completed)*
4) Tube mass production feasibility demonstration *(completed)*
5) Government application demonstration and commercialization *(completed)*
6) Window fabrication process refinement *(completed)*

Milestones 1,2.3,4,5 and 6 are all successfully completed as planned. At the request of American International Technologies, Inc. (AIT), two amendments were established between LLNL and AIT to extend the scope of Milestone 5 to include refinement of fabrication process, and the commercialization of thin film windows and the electron beam gun, using funds-in from AIT.

Deliverables

LLNL

- Technical reports on the window fabrication process developed at LLNL were written and delivered to AIT.
- Two Records of Inventions were written and submitted to the LLNL Patent Office. The ROIs covered design features and the fabrication process for the thin film electron beam windows and current detectors developed under this CRADA.

AIT

- Developed electron gun and power supply for production and commercialization.

C. Technical Accomplishments

Milestones 1,2,3, 4,5 and 6 were successfully completed. An integrated low voltage electron beam gun is currently available in the marketplace for curing inks, adhesives and paints. A high power unit could also be used for US government (Homeland Security) to kill bacteria and harmful microorganisms. The specific accomplishments were:

- This CRADA Project was selected as a 1995 R&D 100 Award Winner.
- This CRADA Project was also selected for 1997 FLC Award for Excellence in Technology Transfer.
- The project was placed on display by the Department of Energy in the Rayburn U.S. House of Representatives Office Building in 1996.

- Two Records of Inventions have been written and submitted to the LLNL Patent Office.
- IL-9805, *Rigid Thin Windows for Vacuum Applications,* Glenn A. Meyer, Dino R. Ciarlo, Booth R. Myers, Hao-Lin Chen, George Wakalopulos. A U.S. Patent 6002202, *Rigid Thin Windows for Vacuum Application, was* awarded in December 14, 1999.
- IL-9909, *Electron Beam Current Monitor Using Oxidized or Nitrided Silicon,* Booth R. Myers, Glenn A. Meyer.
- A technical report on "Material Processing Using Miniature Low Voltage Electron Beam Guns" was published in the Proceedings of the 1997 Annual Meeting of American Nuclear Society, June 1997.
- Two technical reports on "Performance Measurements of Sealed Tube Windows" were published in the Proceeding of the RadTech North America 1996 Conference and RadTech Japan Conference in 1997.

D. Expected Economic Impact

For the last two decades, wide area electron beam (EB) processing for governmental and commercial applications has cost millions of dollars because of the x-ray shielding required, and the associated cost of vacuum equipment and power supplies. The low voltage electron beam (LVEB) technology developed by this CRADA now offers this technology at an order of magnitude lower cost.

The success of this CRADA project has made a significant positive impact on the U.S. economy due to its multi-industrial diversity. Key technologies that benefit include the semiconductor equipment industry, thin-film manufacture, environmentally conscious printing, painting and coating, waste and hazardous biological chemical treatment plants and other environmental industries, as well as the U.S. Homeland Security Office.

The near term economic impact to U.S. industry and market is estimated to be about $150M, which includes the curing of coatings (~$45M) and inks (-$30M), sterilization (~$10M) and surface treatment (~$75M) for adhesive applications. It should be noted at present there is virtually no UV formulations approved by the FDA for food contact. Since EB formulations do not require the toxic photo-initiators currently used in the UV chemistry, the food packaging market (which is in the $B range) is ideal for implementation of low-cost EB equipment.

D.1 Specific Benefits

Benefits to DOE

Currently, high-energy, wide area EB treatment of waste streams is an established, albeit expensive technology in the industrial sector. This CRADA could potentially benefit DOE by providing Low Voltage Electron Beam processing as a cost effective technology for treatment of

DOE's large inventory of mixed waste streams, and as an alternative for treating DOE's non-radioactive waste streams.

Benefits to Industry

Key industrial areas that will benefit from the success of this CRADA technology include the semiconductor equipment industry, thin-film manufacture, environmentally conscious printing, painting and coating, sterilization, food packaging, waste and hazardous chemical treatment and other environmental and governmental organizations.

E. Partner Contribution

AIT developed a new concept for the design and integration of a compact high-voltage power supply and sealed tube electron beam gun for industrial application. The thin-film window technology was first developed at LLNL. However, the successful introduction of this window into a useful commercial product required the integration of this window material with advanced sealing techniques and gun design. These were technologies in which AIT is, and was, a leader in the industry. The EB simulation code developed at LLNL has also further enhanced the performance of this low voltage electron beam system.

LLNL personnel trained the AIT personnel in the window manufacture technology and cost reduction methods, but retained end user access to the technologies and methods for further or future LLNL use and/or research.

AIT personnel were primarily responsible for the overall system integration and commercialization of the finished product.

F. Documents/Reference List

Technical Reports

- "Material Processing Using Miniature Low Voltage Electron Beam Guns" was published at the 1997 Annual Meeting of American Nuclear Society, June 1997.

- "Performance Measurements of Sealed Tube Windows" was published in the Proceeding of the RadTech North America 1996 Conference and RadTech Japan Conference in 1997.

Copyright Activity

None

Subject Inventions

IL-9805
U.S. Patent No. 6,002,202
Date Issued: 12/14/99
Title: *"Rigid Thin Windows for Vacuum Applications"*
Inventors: Glenn A. Meyer, Dino R. Ciarlo, Booth R. Myers, Hao-Lin Chen, George Wakalopulos

IL-9909, patent application was not pursued

Background Intellectual Property

IL-9348: Patent Application abandoned

U.S. Patent No. 5,490,912 (LLNL Docket IL-9363) - *Apparatus for Laser Assisted Thin-Film Deposition*; issued 2/13/96; Inventors: Bruce E. Warner, William McLean II

AIT is not interested in licensing the above intellectual property.

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Industrial Partnerships and Commercialization

Acknowledgement

rticipant's signature of the final report indicates the following:

The Participant has reviewed the final report and concurs with the statements made therein.
The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed and included in Section E or are included on a list attached to this report.
The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
The Participant certifies that proprietary information has been returned or destroyed by LLNL.

REV. CEO AIT 1/21/03

eorge Wakalopulos, Title (if available)] Date
merican International Technologies, Inc.

Hao-Lin Chen 4/30/03

ao-Lin Chen, Principal Investigator Date
awrence Livermore National Laboratory

5/7/03

arena D. McKinley, IPAC Director Date
awrence Livermore National Laboratory

Attachment I – Final Abstract

George Wakalopulos 310 989 9938 p.1

LOW VOLTAGE ELECTRON BEAM PROCESSING

Final Abstract (Attachment I)
CRADA No. TC-645-93-A
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E. Project Dates

May 24, 1994 through November 30, 2001