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LLNL-TR-746383

# Low Cost Field Emission Flat Panel Displays Final Report CRADA No. TC-0774-94

A. Bernhardt, R. Duboc

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## Disclaimer



This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

# LOW COST FIELD EMISSION FLAT PANEL DISPLAYS

**Project Accomplishments Summary**
**CRADA No. TC-0774-94**

Date: March 2, 1999 Revision: 4

## A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Candescent Technologies (formerly Silicon Video Corporation). Since the conclusion of the TTI funding, the company has changed its name to Candescent Techologies.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-795
Livermore, CA 94550

Candescent Technologies
(Formerly Silicon Video Corp.)
6320 San Ignacio Ave
San Jose, CA 95119

## B. Background

In the FY 1993 budget, Congress gave ARPA $60 million to fund industry National Laboratory research and development collaborations. The line item appropriation was entitled National Center for Advanced Information Components Manufacturing (NCAICM).

In setting up the ARPA development program, several key areas of LLNL instrumentation and expertise were pivotal, especially the availability of a flexible high energy ion accelerator and the large area precision electroplating capabilities recently demonstrated by the Microelectronics group. However, in order to exploit the fullest performance potential of the nanofilament technology, it was necessary to include the participation of a much broader range of Laboratory facilities in what may become one of the most visible technology transfer efforts at the Laboratory.

Approximately $2 million was granted for the Candescent-LLNL collaboration under NCAICM, $1.6 million of which was spent at LLNL.

LLNL and Candescent were funded by ARPA under NCAICM to develop field emission flat panel display technology. The ARPA funding provided to support this project was provided through the DOE in a separate Work-For-Others Agreement (AWP L-4103) with LLNL which was not included in this CRADA. However, as an

addition, $1 million of DOE Defense Programs Technology Transfer Initiative funding was granted to provide for an expansion of the ARPA/WFO effort.

The ion accelerator at LLNL enabled the fabrication of field emitter cathodes with unique physical attributes not previously available. These properties enabled Candescent to fabricate field emission displays in a low cost, manufacturable manner with cathode performance (efficiency and emission quality) unprecedented in the industry

C. Description

Candescent and LLNL delivered to ARPA, at the end of the 15 month program, a 3" diagonal black and white display with 80 lines per inch resolution, greater than 20 foot-lamberts brightness, and at least 16 levels of gray. Additionally, there was a like 3" diagonal color display DOE deliverable. In comparison to liquid crystal displays, the field emission display was brighter, sharper, and consumed 1/3 to 1/2 the power per unit area.

The objective of the project was to confirm the efficacy of a new technology (ion tracking) for making efficient, cost effective cathodes for flat panel displays. LLNL was to provide the ion tracking system and expertise and Candescent was to provide the requirements, complete the fabrication of the cathodes, and incorporate them in flat panel displays. The program was quite successful. Candescent is now on the verge of commercializing 5.3 inch diagonal full color flat panel displays using this technology.

D. Expected Economic Impact

Tangible and Intangible:

(a) This project provided scientists from LLNL and Candescent the opportunity to work together and learn from one another while solving technological problems critical to our nation.

(b) This project pursued a truly revolutionary FEC technology with the cost and performance potential to enable Candescent and its licensees to dominate the $17 billion computer and TV display field, most DOD display applications, and a wide range of other, non-display applications (i.e., medical diagnostics, fluorescent tubes and high power ion sources).

E. Benefits to DOE

One of the missions of the DOE is to foster industrial competitiveness of U.S. Industry. The market for flat panel displays is estimated to be $20 billion by the end of the century. Strong U.S. participation in this market would represent the recovery from near extinction of the U.S. consumer electronics industry. The DOE Defense Programs Technology Transfer Office made funding flat panel display technology a priority and tracked its portfolio of such projects at the National Laboratories separately from microelectronics and other more general program areas.

This project took advantage of and enhanced LLNL core competencies in materials processing, vacuum microelectronics and high density electronic packaging.

Display products were required for Defense Programs core nuclear weapons and non-proliferation missions including visualization of computer simulation of nuclear device operation, nuclear effects, weapon delivery, and geographic and atmospheric dispersion of fission products. Flat panel displays of the type being developed under this CRADA/JWS had enormous advantages over the existing CRT and active matrix liquid crystal display products including better visual quality and much lower power dissipation. Furthermore, displays of the type developed under this will be much less expensive than the flat panel active matrix liquid crystal displays available at the time or in the foreseeable future.

## F. Industry Area

The displays enabled by this technology will benefit every market requiring a color, bright, power efficient display from general television and computer and laptop markets, to hand held communication markets and the automotive market.

## G. Project Status

DOE/TTI funding for the program ceased in 1996. The company funds continuing effort at LLNL under a CRADA which is amended approximately yearly to extend its scope and funding.

## H. LLNL Point of Contact for Project Information

Anthony Bernhardt
Lawrence Livermore National Laboratory
7000 East Avenue
P.O. Box 808, L-271
Livermore, CA 94550
Phone: (925) 423-7801
Fax: (925) 422-7309

## I. Company Size and Point(s) of Contact

Since the conclusion of the TTI funding, the company has changed its name from Silicon Video Corporation to Candescent Technologies.

Robert Duboc
Executive Vice President
Candescent Technologies
6320 San Ignacio Ave
San Jose, CA 95119
Phone: (408) 229-6150
Fax: (408) 229-0850

Candescent has committed funding of $365 million, and the company employs 350 people.

## J. Project Examples

Candescent is producing 5" diagonal full color field emission video displays which are a great "show and tell" item. The use of photos and hardware by DOE will have to be arranged with the company.

## K. Background Intellectual Property

LLNL

IL-8140 Anthony F. Bernhardt and Robert J. Contolini, "Electrochemical Planarization", U.S. Patent No. 5,256,565

IL-8536 Steven T. Mayer, Robert J. Contolini, and Anthony F. Bernhardt, "Method and Apparatus for Spatially Uniform Electropolishing and Electrolytic Etching", U.S. Patent No. 5,096,550

IL-9384 Ronald Musket, "Process to Modify Work Functions Using Ion Implantation"

IL-9460 Anthony F. Bernhardt, "Electromechanical Formation of Field Emitters"

Candescent Technologies

U.S. Patent No. 5424605 - "Self Supporting Flat Video Display"; Paul A. Lovoi

U.S. Patent No. 5541473 - "Grid Addressed Field Emission Cathode"; Robert M. Duboc, Jr., Paul A. Lovoi

U.S. Patent No. 5589731 - "Internal Support Structure for Flat Panel Device"; Robert M. Duboc, Jr., Theodore S. Fahlen, Paul A. Lovoi

U.S. Patent No. 5462467 - "Structure and Fabrication of Filamentary Field Emission Devices, Including Self-Aligned Gate"; J. M. Macaulay, P. C. Searson, R. M. Duboc, Jr., C. J. Spindt

U.S. Patent No. 5559389 - "Electron-Emitting Devices Having Variously Constituted Electron Emissive Elements, Including Cones or Pedestals"; C. Spindt and J. Macaulay

U.S. Patent No. 5686790 - "Flat Panel Device with Ceramic Backplate"; Christopher J. Curtin, Anthony P. Schmid, Paul A. Lovoi

Additionally Candescent had 26 invention disclosures listed as background intellectual property..

## L. Release of Information

**I certify that all information contained in this report is accurate and releasable to the best of my knowledge.**

Karena McKinley 3/20/00

Karena McKinley, Director Date
Industrial Partnerships
and Commercialization

## RELEASE OF INFORMATION

I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.

R M Duboc 8/31/99

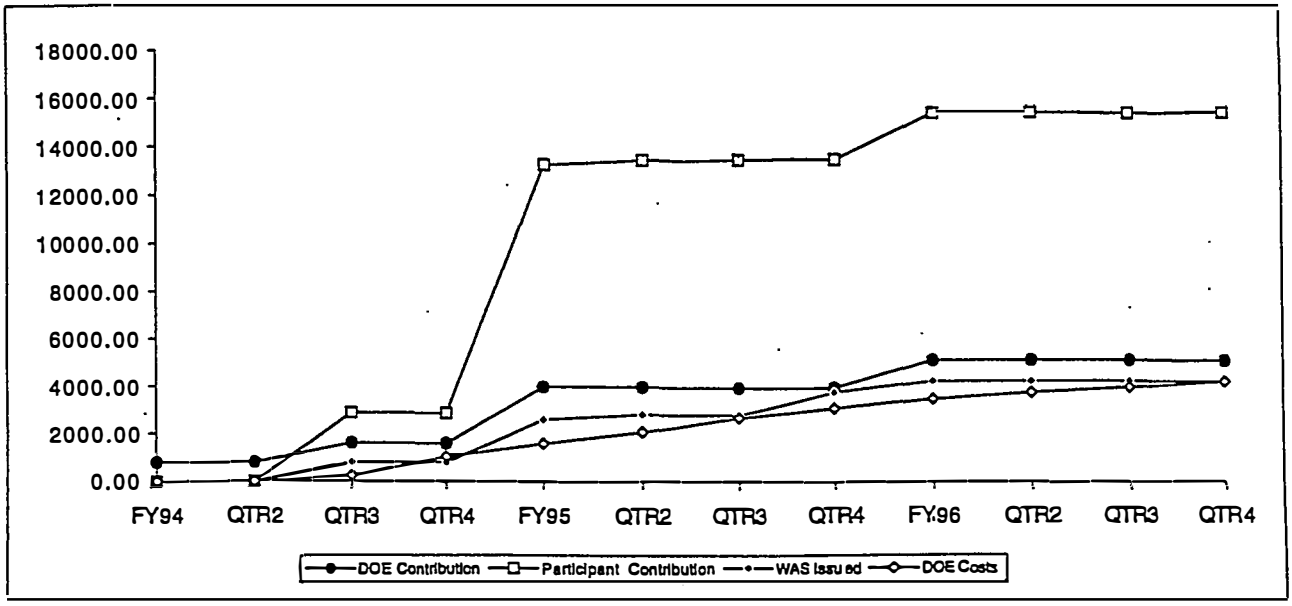
Robert Duboc Date
Candescent Technologies

## Lawrence Livermore National Laboratory

| | | | |
|---|---|---|---|
| Title: | Low Cost Field Emission Flat Panel Displays | Reporting Period: | 07/01/95 - 09/30/96 |
| Participant: | Silicon Video Corporation | Date CRADA Executed: | 3/21/94 |
| DOE TTI No.: | 94-LLNL-005-XX-1 | DOE Approval Date: | 3/15/94 |
| CRADA No.: | TC-0774-94 | Scheduled Ending Date: | 9/30/95 |
| TACT: | M&PM | Project Completion: | |
| Account Numbers | 4775-18 to 21, | B & R Code (S): | DP03D1, 35DP03 |
| Accounts Closed: | | | |

Approved Funding Profile ($K)

| | FY94 | FY95 | FY96 | FY97 | FYOUT | Total |
|---|---|---|---|---|---|---|
| DOE Contribution | 800 | 2425 | 1000 | 0 | 0 | 4225 |
| Add Fac & Dep | 0 | 174 | 188 | 156 | 0 | 518 |
| Participant In-Kind | 2882 | 9982 | 1000 | 1200 | 0 | 15064 |
| Participant Funds-In | 0 | 0 | 0 | 0 | 0 | 0 |
| WAS DP0301 | 800 | 2745 | 491 | 0 | 0 | 4036 |
| WAS 35DP03 | 0 | 225 | -5 | 0 | 0 | 221 |
| Total Costs | 1052 | 2069 | 1135 | 0 | 0 | 4256 |




| DP0301 | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | FYTD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FY94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 235 | 214 | 277 | 327 | 1052 |
| FY95 | 295 | 91 | 162 | 160 | 163 | 163 | 131 | 138 | 132 | 135 | 121 | 159 | 1849 |
| FY96 | 170 | 135 | 87 | 83 | 108 | 71 | 106 | 57 | 52 | 57 | 44 | 165 | 1135 |

4035

| 35DP03 | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | FYTD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FY94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FY95 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 23 | 190 | -3 | 0 | -23 | 221 |

221

STAFF w/phone:

| | | | |
|---|---|---|---|
| Lab PI: | Tony Bernhart (510) 423-7801 | Participant: | Robert M. Duboc, Jr. (408) 864-2603 |
| Resource Manager: | Vicki Evans (510) 423-0158 | | |
| DOE OAK: | Jerry Scheinberg (510) 637-1653 | DOE HQ: | R. Peavy (202) 586-7907 |

CRADA No.: TC-0774-94 **Lawrence Livermore National Laboratory**

Milestones and Deliverables:

List the complete set of milestones for all phases of the CRADA. Continue on a separate page if necessary.
Report any changes from the original CRADA or previous quarterly report on the CRADA Change Form.

Completion Date:
Scheduled Actual

See attached report

Verification of participants' in-kind contribution was made in accordance with LLNL policy. Explain basis of verification:

Please initial: YES X NO

I believe the participant's in-kind contribution is consistent with that agreed upon in the CRADA because the participant has met the milestones that were described in the contract.

List any subject inventions by either party (include IL# for LLNL inventions), additional background intellectual property, patents applied for, software copyrights, publications, awards, licenses granted or reportable economic impacts

Verification that all equipment and proprietary information has been returned to the initial owner or permanently transferred

Please initial: YES X NO

Accomplishments

Describe Technical/Non-Technical lessons learned and other observations.
Summarize causes/justification of deviations from original scope of work.

See attached report

Reviewed by CRADA project Program Manager: _____ Date: _____

Reviewed by Karena McKinley, Director, LLNL/IP&C: Karena McKinley Date: 3/20/00

Direct questions regarding this Report to IP&C Resource Manager, Carol Asher, at (925) 422-7618