General Electric Corporate Research & Development

Mercury-Free Lighting Could Provide Environmental and Economic Benefits

In 1994, William Woodburn, then vice president of worldwide marketing for General Electric (GE) Lighting, made the following statement regarding the lighting industry: "What was a relatively stable industry dating back to Thomas Edison's invention, with innovations coming at an evolutionary pace, has accelerated into a revolutionary outpouring of new technology and new products." During the early 1990s, many companies engaged in research and development to create technologies that would lead to further innovation in this field. One impetus behind these initiatives was the need to create lighting systems that are friendlier to the environment, a goal that led companies to focus on developing mercury-free lighting technologies. Many of these efforts centered on an earlier innovation-fluorescent lighting. GE focused on developing mercury-free fluorescent lighting because it recognized the technology's potential economic and environmental benefits. Because the technical risks were too high for internal funding, given the required rates of return when compared with less environmentally friendly products, GE submitted a project proposal in 1993 to seek co-funding from the Advanced Technology Program (ATP). Although the company did not achieve its goal of developing mercury-free fluorescent lighting for existing sockets, it did advance the state of the art of mercury-free fluorescent lighting. GE also used the technologies developed during this three-year project to improve conventional fluorescent lighting. Moreover, the company published papers and gave presentations on the subject and received three patents for technologies related to this ATP project.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 92-01-0132 were collected during October – December 2001.

Mercury-Filled Products Burden the Lighting Industry

For more than 62 years, fluorescent lighting has been used in offices and homes as a low-cost, energy-saving power source. Fluorescent bulbs last longer, are more energy efficient than incandescent bulbs, and have reduced the load on power plants. But there is a downside, fluorescent tubes contain mercury vapor, a substance that is toxic. In the early 1990s, it cost $275 million annually to dispose of fluorescent tubes in an environmentally sound manner, greatly burdening the industry and its end users. In fact, during this period, several states enacted legislation to ban or limit the disposal of any products containing mercury.

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Two essential elements are involved in fluorescent lighting: plasma and phosphors. In a fluorescent tube, electrical energy is used to excite electrons in conducting plasma, which emits ultraviolet photons that then strike a phosphorescent layer on the inner surface of the tube, emitting visible light. Mercury is used in plasma because it converts electrical energy into relatively low-energy ultraviolet photons with a high level of efficiency.

Phosphor and Plasma Technology To Replace Mercury-Filled Systems

In 1992, GE proposed to use ATP co-funding to develop a lighting source that was more environmentally safe and as cost efficient as the original fluorescent bulb. GE pursued research to develop a low-pressure xenon-positive column discharge, which would excite the phosphor to create white light.

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This discharge would replace the mercury gas discharge used in existing fluorescent lamps. GE's plan was to develop the two essential parts of the lamp: 1) the mercury-free discharge to produce the ultraviolet light and 2) the quantum-splitting phosphor that would convert the ultraviolet light into acceptable visible light. To replace the mercury, it was necessary to find a low-pressure plasma source that was comparable to the high efficiency level of mercury (roughly 65 percent) and was compatible with existing phosphors.

The difficulty was to create a mercury-free product that could be used immediately in current socket structures, since GE anticipated there would be low market penetration for a product that used new socket structures. Therefore, the company decided to concentrate its efforts on developing commercial phosphors and on lowering the amount of mercury in its current fluorescent lights, rather than creating a new mercury-free product. The technical risks for this project were too high to allow GE to use internal funds because other, less environmentally friendly products could produce a higher rate of return. The potential broad benefits to the economy and the environment from this project, however, could be significant.

Partnerships Contribute to Technical Success

GE's alliance with ATP gave the company access to rich resources throughout the life of the project and allowed GE to gain the support of valuable university subcontractors to perform some of the research. For example, the California Institute of Technology studied circuit topologies in an effort to develop a ballast prototype to contain the mercury-free light. (The ballast starts the lamp and then regulates the electric current that flows into it.) The University of Wisconsin helped in assessing plasmas as ultraviolet light sources. Access to the expertise at these universities proved invaluable to the research.

GE achieved spin-off benefits related to the development of quantum-splitting phosphors. The completed work on quantum-splitting phosphors led to an increased interest among universities.

Through ATP, GE met another ATP award recipient, Photonics Imaging, which manufactures plasma flat panel displays (PFPDs). A technology overlap existed between GE's primary path in this project and Photonics Imaging's primary path in developing PFPDs. GE's path involved low-pressure xenon-positive column discharge and an efficient phosphor used to create white light. Photonics Imaging's path was aimed at an intermittent atmospheric-pressure discharge in a gas mixture containing xenon, which excites phosphors to create red, green, and blue pixels. Through discussions regarding similar uses of phosphor technology, the companies shared knowledge that proved valuable to both efforts.

GE Encounters Technical Difficulties, but Realizes Spin-Off Opportunities

GE was able to achieve operating conditions under which a direct-current xenon discharge reached approximately two-thirds of the efficiency and output of a conventional fluorescent lamp. Unfortunately, the research team was not able to achieve its goal of a candidate discharge (low-pressure xenon-positive column) that was highly efficient at a high-discharge power density.

However, GE achieved spin-off benefits related to the development of quantum-splitting phosphors as well as technologies that can be used in any type of fluorescent lighting. The completed work on quantum-splitting phosphors led to an increased interest among universities and within GE to further develop such phosphors. GE is currently pursuing additional research and development efforts in this area.

The following technologies developed through this ATP project can be used in any type of fluorescent lighting:

- Lifelong, low-pressure cathodes, which led to higher lamp efficiency, lower ballast costs, and better performance from lamps that are frequently switched. These cathodes are used in a range of applications, from basic lighting to electron microscopes and plasma cathode electron guns.

- Electronic ballasts, which have advantages over conventional electromagnetic ballasts, including smaller size, lower weight, higher efficiency, and faster starting and dimming capability. This cheaper, more efficient method of applying power electronics to improve traditional fluorescent lighting eliminates flickering and reduces the acoustic noise associated with fluorescent bulbs.

- Electromagnetic shielding of ballast, lamp, and phosphors, which led to higher efficiencies by protecting the power system from spikes in energy and from the heat of the lamp.

Conclusion

Through the research performed during this project, GE made advances in the design and production of quantum-splitting phosphors. Although GE was not able to develop a mercury-free fluorescent light that is as efficient as mercury filled lights, the technologies developed have been used to improve conventional fluorescent lighting. For example, oxide quantum-splitting phosphors are being used generically in conventional fluorescent lights and in the development of miniature lamps.

PROJECT HIGHLIGHTS
General Electric Corporate Research & Development

Project Title: Mercury-Free Lighting Could Provide Environmental and Economic Benefits (Mercury-Free Fluorescent Lighting)

Project: To demonstrate the feasibility of developing an environmentally safe, cost-competitive fluorescent lamp source that is as efficient as the currently used mercury-filled fluorescent lamps.

Duration: 5/10/1993-5/9/1996
ATP Number: 92-01-0132

Funding (in thousands):**

ATP Final Cost	$1,336	40%
Participant Final Cost	2,044	60%
Total	$3,380	

Accomplishments: Through the ATP funded project, GE made improvements in the design and production of quantum-splitting phosphors. Although the company did not develop efficient mercury-free fluorescent light, the technologies developed have been used to improve conventional fluorescent lighting. GE also accomplished the following:

- Achieved a breakthrough in getting quantum-splitting phosphors to work in everyday chemicals (oxide-based) that are regularly used in manufacturing
- Published several technical papers and gave presentations regarding the mercury-free fluorescent lamp program and research that was conducted during the project
- Received the following patents for technologies related to the ATP project:
  - "Quantum splitting oxide phosphor and method of making"
    (No. 5,571,451: filed January 3, 1995, granted November 5, 1996)
  - "Determination process for determining if quantum splitting phosphors are obtained and novel compositions"
    (No. 5,788,883: filed February 28, 1997, granted August 4, 1998)
  - "Mercury-free ultraviolet discharge source"
    (No. 5,866,984: filed November 6, 1997, granted February 2, 1999)

Commercialization Status: GE was not able to commercialize the technologies that were developed under this project. The company is continuing to work to develop a commercial phosphor, however, and is concentrating its efforts on lowering the amount of mercury in existing fluorescent lights.

Outlook: While a clear path does not seem to exist for replacing mercury-filled fluorescent lighting with a mercury-free product, the research and development conducted during this project has led to further development in fluorescent technology. GE continues to improve its ability to measure phosphor-quantum efficiencies and to assess new candidate phosphor material, working toward its goal of developing a quantum-splitting phosphor that can be manufactured.

Composite Performance Score: *

Company:
General Electric Corporate Research & Development
One Research Circle
Niskayuna, NY 12309

Contact: Dr. Timothy Sommerer
Phone: (518) 387-6440

Subcontractors:
California Institute of Technology
University of Wisconsin

** As of December 9, 1997, large single applicant firms are required to pay 60% of all ATP project costs. Prior to this date, single applicant firms, regardless of size, were required to pay indirect costs.

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