Thermophotovoltaics – a New Concept Evolving in Energy Conversion: Summary of a Panel Session Presentation

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***Abstract* — Thermophotovoltaic (TPV) systems are designed to produce direct-current electrical energy via high-temperature semiconductors receiving radiant energy from the combustion of fuel. Unique system elements and design are required to maximize the transfer of energy from the flame to a radiator to the receiving cells and cooling apparatus. The new concept of a Micron-gap TPV system (MTPV) is also discussed. This panel session presentation is a basic introduction to these concepts, which have more potential for non-grid-connected distributed generation (DG) applications than typical grid-connected DG.**

***Index Terms*—thermophotovoltaics, TPV, MTPV, high-temperature semiconductors, DG, distributed generation**

I. Introduction

THIS panel session presentation summary provides an overview of efforts made to create systems which can generate dc electricity using the radiant energy given off from the clean combustion of a fuel, in contrast to high-temperature fuel cells and thermoelectric systems.

II BASIC TPV SYSTEM ELEMENTS

A burner capable of producing a steady flame as the result of efficient combustion is the first basic component. The second element is a specially-designed radiator that both smoothes out the inherent fluctuations in a flame, and re-radiates the incident photons in a narrow range of wavelengths ideally matched to the receiving photovoltaic cells (the third component). These cells are arranged around the radiator to ensure that maximum radiant energy can be collected. The fourth component is a cooling system to draw heat away from the cells, which may operate in the range of 1,000 to 2,000 degrees C. Figure 1 is an illustration of the basic components in one type of TPV system..

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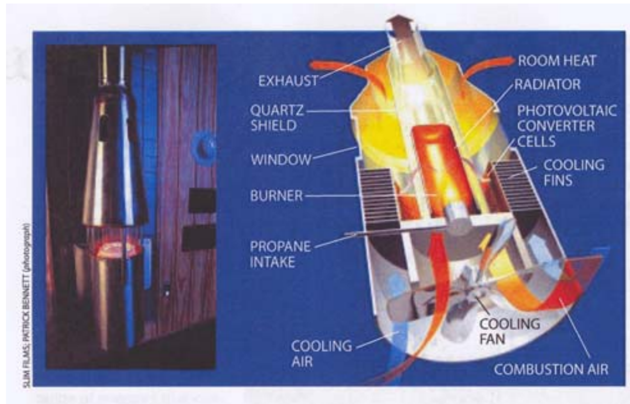
FIGURE 1
BASIC TPV SYSTEM COMPONENTS *



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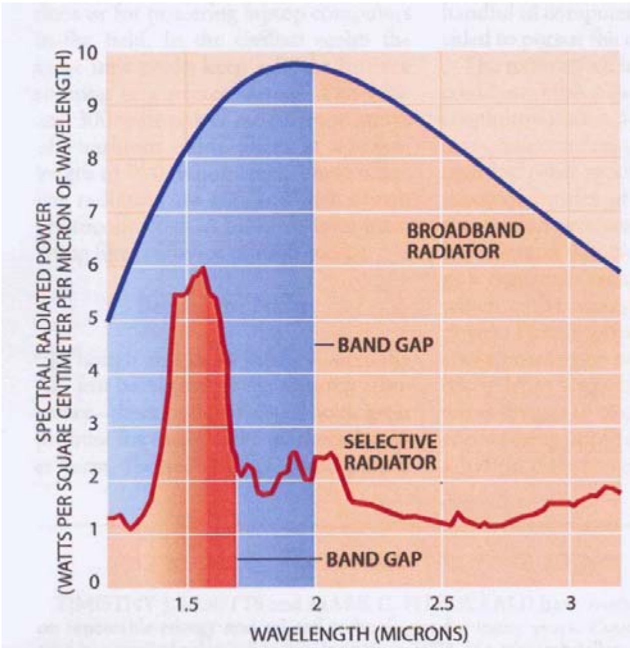
The tradeoffs involved in radiator design include cost versus performance versus temperature. For example, a relatively inexpensive material like silicon carbide can be used as a radiator, with emission in a broad range of wavelengths, at the lower end of operating temperatures (1,000 C). If this material is employed, it dictates that receiving PV cells employ a material such as gallium antimonide or indium gallium arsenide to capture radiant energy efficiently. In contrast, using a rare-earth material like ytterbium oxide in the radiator (emitting in a relatively narrow bandwidth) allows use of simple silicon in the PV cells. The drawback is that the radiator must operate around 2,000 C to provide sufficient power intensity.[1] Figure 2 on the next page shows some of the semiconductor material choices possible for a range of band-gap energy levels.

III THE MICRON-GAP TPV APPROACH

The TPV devices discussed so far employ separation on the order of centimeters between radiators and PV cells. Research personnel working to improve efficiency and power levels realized that locating the radiator and receiver [cell] very close to each other, at a distance less than the range of wavelengths employed, could enhance energy transfer[2]. Figure 3 shows the concept physically and graphically.

FIGURE 2
BROADBAND AND SELECTIVE RADIATORS *



* Illustration credit: Scientific American, September 1998

FIGURE 3
THEORETICAL BASIS FOR MTPV CONCEPT*

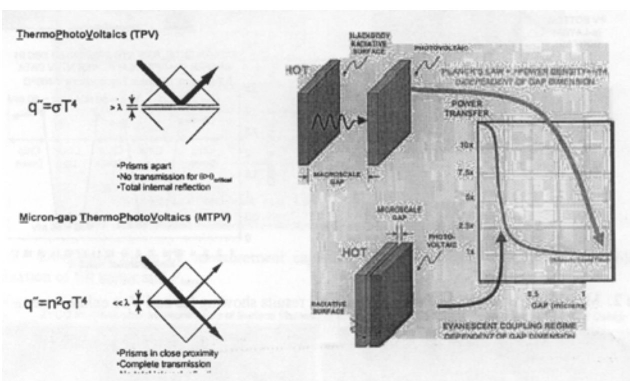


*Illustration credit: Reference 2, Figure 1

The presentation will discuss the materials employed in the MTPV approach, problems remaining and potential solutions.

IV References

[1] *Thermophotovoltaics*, by Timothy J. Coutts and Mark C. Fitzgerald, Scientific American, September, 1998, pp 90-95.

[2] *Micron-gap ThermoPhotoVoltaics (MTPV)*, Research Report LM-04K064, R. DiMatteo et al., Charles Stark Draper Laboratory, Inc., Cambridge, Ma; Lockheed Martin, Schenectady, NY, and Bechtel Bettis, Inc., West Mifflin, PA

V Biography

JOHN J. BZURA (M-1980, SM – 1989) was born in Albany, Georgia on September 14, 1944. He received the B.S., M.E.E. and Ph.D. degrees from Cornell University, Ithaca, NT, in 1966, 1967 and 1971 respectively, all in electrical engineering. In 1974, an M.B.A. degree was granted by Syracuse University, Syracuse, NY.

Dr. Bzura was employed by Arthur D. Little, Inc. from 1974 to 1983, where he performed technical and economic analyses of energy systems. He joined the New England Power Service Company (now National Grid USA Service Company) in 1983, and spent 10 years as Principal Engineer in the Demand Planning R&D Group. The last 13 years have been with the R&D / Technology Transfer group within Engineering. Projects and topics of interest include solar and wind energy systems, distributed generation (DG) technologies, DG interconnection issues, distributed energy storage, electric vehicles and broadband power-line communications.

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