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Thermoelectric Generation Using Water Lenses

RYOSUKE O. SUZUKI,[1,2] ATSUSHI NAKAGAWA,[1] HONGTAO SUI,[1] and TAKEYUKI FUJISAKA[1]

1.—Faculty of Engineering, Hokkaido University, Kita-13Jou, Nishi-8Choume, Kita-ku, Sapporo, Hokkaido 060-8628, Japan. 2.—e-mail: rsuzuki@eng.hokudai.ac.jp

A solar light concentrator composed of water and plastic transparent film has been designed. This flexible lens design can trace the solar movement through control of the tensile stress and amount of water, and concentrate the solar energy onto the thermoelectric (TE) module surface. An experimental water lens was constructed, and the concentrated intensity was monitored by a photodiode as a function of *x*–*z* position; For example, when 3.0 kg water was filled and tension of 69.0 N/m was applied to the transparent vinyl sheet, the concentration ratio was evaluated as the maximum of 28.0 at a depth of 657 mm from the water lens bottom surface. TE generation was tested to show the validity of the water lens. The surface condition of the receiver was found to be critical.

Key words: Thermoelectric power generation, solar light concentration, optical lens

INTRODUCTION

Thermoelectric (TE) generation based on the Seebeck effect can directly convert heat into electricity. A TE generation system has the advantage of not requiring a large-scale system and has been studied as a way to recover unused heat, such as waste heat from automobiles,[1] fuel cells,[2] and marine engines,[3] as well as solar heat.[4,5] Solar power generation using silicon photoelectric cells covers a wide range of wavelengths of solar radiation, but energy from longer waves in the infrared area is not converted completely, and the residual component of infrared rays is not satisfactorily used. Because the energy density from the sun is low for thermal utilization, light concentrators such as convex and Fresnel lenses are needed. A parabolic mirror is also effective to concentrate solar energy. However, these light concentration devices and the corresponding ray-tracking mechanisms are complex and unaffordable; precise mechanical control of these heavy concentrators requires mechanical power and they rely on expensive materials such as glass or gold mirrors.

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Because the conversion efficiency of TE generation systems is generally as low as a few percent, it is necessary to increase the hot-side temperature of TE modules by strong concentration of solar energy. The concentration ratio, C, is defined as the ratio of receiver surface area to lens surface area; For example, C is required to be 50 to obtain a temperature difference, ΔT, of 100 K so that *p*–*n* Bi_2Te_3 elements of 3.0 mm length can be used.[6] Increasing C is an effective approach to obtain larger ΔT and larger power, because the performance is proportional to the square of ΔT. When we consider the applicable maximum temperature for high-performance Bi_2Te_3 material at room temperature, C should not exceed 150 to prevent melting of welding at the joints.[6]

Figure 1 shows a proposed solar power generation system using a water lens array. The plastic bags filled with water act as lenses to concentrate solar light onto the TE module, whose cold surface is cooled by a thermal fluid such as natural water. By feeding water to the lenses, their thickness can be varied. We expect that such flexible lenses may enable focusing of solar light with adjustment for solar movement during the day and with the seasons. If the motion of the TE modules to receive the light can be limited to only a horizontal plane, it