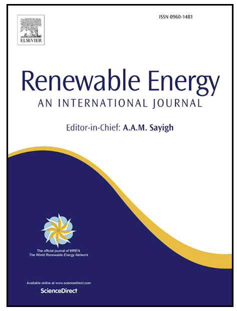
Accepted Manuscript



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PII: S0960-1481(18)30068-5

DOI: 10.1016/j.renene.2018.01.062

Reference: RENE 9667

To appear in: *Renewable Energy*

Received Date: 7 September 2017

Revised Date: 2 January 2018

Accepted Date: 18 January 2018

Please cite this article as: Momeni F, Ni J, Nature-inspired smart solar concentrators by 4D printing, *Renewable Energy* (2018), doi: 10.1016/j.renene.2018.01.062.

Nature-Inspired Smart Solar Concentrators by 4D Printing

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Abstract

Currently, solar concentrators, whether in solar PV or solar thermal applications are designed and utilized as a fixed shape such as elliptic, parabolic, V-shape, hyperbolic, and multi-stage forms. Here, we are inspired by diurnal and nocturnal flowers and their differences and propose a smart solar concentrator that can increase the overall optical efficiency more than 25% compared with its non-smart counterparts. We introduce the concept of smart solar concentrators inspired by nature and enabled by 4D printing and illustrate its necessity and advantages. We found that most of the diurnal flowers have parabolic and most of the nocturnal flowers have hyperbolic petals. Our proposed multi-functional concentrator has a parabolic shape for a portion of the day that parabola dominates all the other shapes in terms of the optical efficiency, then it can reversibly change its shape to hyperbola for another portion of the day that the hyperbola beats all the other geometries. By using this design, the optical efficiency trend will move from peak-and-valley form toward constant-at-peak format, resulting in overall efficiency improvement. The proposed biomimetic structure is an example of smart origami. It is simple, low-mass, and demonstrates the desired shape-shifting without reliance on cumbersome and expensive electromechanical systems.

Keywords

Smart solar concentrator; Biomimetic; Optical efficiency; Smart origami; Low-mass; 4D printing.

1. Introduction

The 3D printing provides unique features regarding geometry and functionality in the renewable energy field (Ruiz-Morales [1]). Recently, 4D printing technology (Tibbits [2] and [3]; Gladman et al. [4]; Momeni et al. [5]) came into the picture and attracted growing interests from various disciplines. One of the key goals of 3D printing is movement from form to functionality (Lewis [6]). 4D printing goes further and provides multi-functionality. To make the current article self-contained regarding the 4D printing concept, we provide a comprehensive figure based on a recent review study (Momeni et al. [5]). This figure (Figure 1) illustrates the 4D printing process and its differences from 3D printing. 4D printing conserves the attributes of 3D printing and adds the fourth dimension to provide shape, property, or functionality evolution over "time". 4D printing can be considered as the new level of additive manufacturing that deals with stimuli-responsive materials. Market analyses (marketsandmarkets [7]) demonstrate an economic growth rate of 42.98% from 2019 to 2025 for 4D printing utilization in various fields. Adaptive metamaterials [8 - 10], burn healing and self-healing [11, 12], organ regeneration [13], conjugated-polymer-based actuators [14], 4D textile [15], and so on are only some of the recent multidisciplinary explorations in 4D printing. Here, we propose the 4D printing in solar energy and demonstrate its necessity and advantages.

Both the solar PV and solar thermal modules can have three main elements, a receiver (mandatory), a concentrator (optional) and a tracking mechanism (optional). The primary reason for using concentrators is to converge the sunlight and obtain the same efficiency by using less solar cell materials in solar PV applications (Parida et al. [16]) and increase the receiver temperature in solar thermal applications (Tian