Green Energy Production by Bioluminescent Algae

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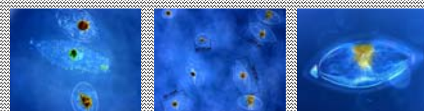
Introduction

Energy is undoubtedly the largest single challenge facing humanity today. While many proponents of solar energy point to its massive scale, large hurdles remain before widespread implementation can take place. One of the biggest and most immediate problems is the twelve hour solar cycle. This presents a need for energy storage techniques, such that excess sunlight can be collected during the day for use at night. While many techniques aim to store electricity converted from photons by a solar cell (e.g. batteries), we suggest an alternative approach that utilizes the process of bioluminescence. This is a natural method for the storage and delivery of energy developed by millions of years of evolutionary biology. Our system will use bioluminescent algae to collect sunlight during the day and then re-emit photons during the dark hours of the night to continually power a solar cell. Aside from sunlight, algae consume carbon dioxide (CO_2) during respiration in order to produce the proteins necessary for luminescence. This, in principle, makes possible a carbon-negative source of energy. The goal of this project will be to measure the power output and CO_2 consumption of our bioluminescent algal colony, which will provide proof-of-concept for a scalable combination of solar and bioluminescent systems.

Pyrocystis fusiformis



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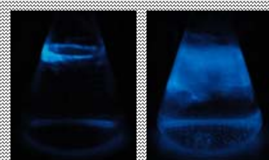
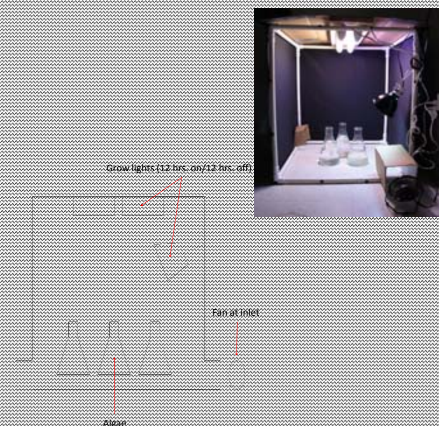


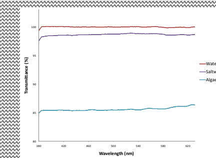
Dark field optical microscope images elucidate the microstructure of the single-celled algae, including a cell wall and nucleus. *Pyrocystis fusiformis* are amongst the largest dinoflagellates and range from 300 to 1000 µm in diameter. Photographs taken during agitation clearly show the blue-green bioluminescence.

Environment Setup



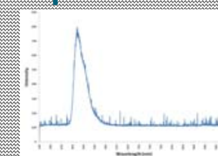
Shown here is the algae growth environment. Optimized growth conditions include a strict 12 hr. on/off light cycle and careful temperature control.

Transmittance



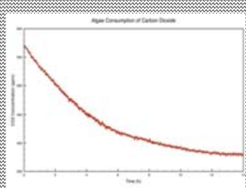
The algae show broadband absorbance across the visible range.

Bioluminescence Spectrum



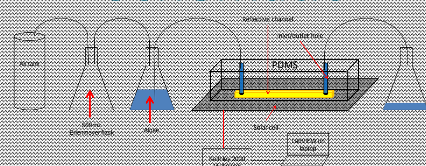
The bioluminescence spectrum is plotted here as a function of wavelength. As suggested by visual observations, the maximum intensity occurs in the blue near 476 nm.

CO_2 Consumption

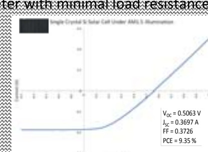


A small USB-powered sensor was used to measure the carbon dioxide (CO_2) consumption of a small algal colony. In this particular experiment, 60 mg of algae were used to scrub ~1 liter of atmosphere. In 24 hours, the CO_2 concentration decayed from 570 ppm to nearly 375 ppm before leveling off.

Schematic

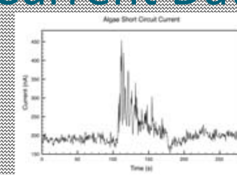


Shown above is a schematic of our experimental setup. This includes an air-pressure based delivery system that forces algae through a small gold-coated micro-fluidic channel mounted directly above a photovoltaic. Turbulent flow inside that channel causes the algae to bioluminesce, and the reflective surface directs all photons down into the solar cell. Current is recorded using a multimeter with minimal load resistance.

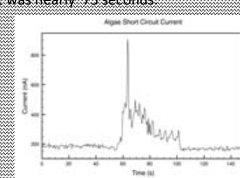


Our setup makes use of a commercially available single crystal silicon solar cell. The I-V curve shows a maximum power conversion efficiency of ~9.35%.

Current Data



The current vs. time measurement shows a clear response from the algae bioluminescence. After 105 seconds of baseline, the sharp rise in current corresponds to the onset of agitation. The maximum current value of ~450 nA occurred soon after the beginning of luminescence, and the total duration of the photocurrent was nearly 75 seconds.



A similar experiment shows a duration of 50 seconds and an even greater maximum current value of ~900 nA.

Conclusion

Here we show that *Pyrocystis fusiformis* can be used in tandem with a commercial solar cell to generate a small photocurrent and consume carbon dioxide (CO_2). This unique combination of solar and bioluminescent algal technologies could eventually lead to an efficient system that can collect and store energy for use during non-daylight hours. Our approach differs from others because storage occurs before sunlight is converted into electricity by the solar cell and is in the form of chemical potential within the algae. In addition, this storage method has the benefits of being photosynthetic, which simultaneously produces the proteins necessary for luminescence and consumes the toxic and greenhouse gas CO_2. Although this particular system has a low storage and conversion efficiency, it is not difficult to image how genetic engineering of an algal species designed specifically for this purpose could lead to a highly scalable real-world solution.

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