Demo Abstract: Powering an E-Ink Display from Soil Bacteria

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ABSTRACT

This demo showcases the power delivery potential of soil-based microbial fuel cells. We build a prototype energy harvesting setup for a soil microbial fuel cell, measure the amount of power that we can harvest, and use that energy to drive an e-ink display. Microbial fuel cells are highly sensitive to environmental conditions, especially soil moisture. In near-optimal, super moist conditions our cell provides approximately 100 μW of power at around 500 mV, which is ample power over time to power our system several times a day. In sum, we find that the confluence of ever lower-power electronics and new understanding of microbial fuel cell design means that "soil-powered sensors" are now feasible. There remains, however, significant future work to make these systems reliable and maximally performant.

This demo is a working copy of the system presented at LP-IoT'21 [6].

CCS CONCEPTS

• **Hardware** → *Renewable energy*; *Platform power issues*; *Emerging architectures*.

KEYWORDS

microbial fuel cell (MFC), biobattery, energy harvesting, low power

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1 INTRODUCTION

Power is a perennial challenge for real-world sensor deployments. To support scale, devices need to last long periods of time with little to no supporting infrastructure or maintenance. Existing wide-area sensing systems rely on batteries or harvest the required energy, most often from solar or wind sources. One problem with solar, wind, and other common sources of power is that they are not always available or reliable. This has led to growing interest in new, non-traditional energy scavenging sources.

The burgeoning set of low-power energy harvesting chips now available can harvest power from voltage sources as low as 25 mV.[1] While most of these energy harvesters target thermoelectric, piezoelectric, RF, and solar energy sources, their ability to extract power from low-voltage sources facilitates the exploration of novel energy sources, like tree trunks [2], and the re-visitation of old ideas, such as microbial fuel cells (MFCs). MFC harvesting has been studied in wastewater management [1, 4, 9], but there has not been a similar focus for soil MFCs. We re-examine the viability of soil MFCs to produce sufficient power to be useful for sensor applications. Specifically, due to the low but relatively constant power available, we find that soil MFCs may be a good fit for the new "reliable but intermittent" sensor class [2].

MFCs are made of electrogenic bacteria that release electrons as they metabolize their food. Normally, these bacteria use metals in the soil as electron acceptors, but they will readily colonize an electrically conductive anode, allowing us to capture the electrons they expel. As the source of power is the activity of living organisms, MFC performance can vary drastically based on local environmental conditions. Towards real-world applications, then, this demo is just step one. We explore a best-case soil MFC to see if it is capable of powering modern sensors. We see a long line of exciting future work towards the question of what it would take to realize viable and reliable soil MFCs everywhere.

Before diving in, we wish to draw distinction between MFCs as a new energy scavenging opportunity versus MFCs as a new "renewable" energy source. Logan et al. [5] argue for the standardization of terminology when describing MFCs. Specifically, unless the medium or nutrients that an MFC uses to generate electricity are refreshed somehow, the apparatus should be referred to as a *biobattery* rather than a fuel cell. The cell we use in this demo is self-contained, thus a biobattery. We will refer to it as such.

2 DESIGN AND IMPLEMENTATION

Figure 1 provides an overview of the architecture and realization of our prototype system. For our biobattery we use a commercial off-the-shelf Mudwatt that uses galvanically inert carbon felt electrodes [3]. We use commercial soil with known parameters for our cell (Figure 1c for details)

To grow the initial colony, we follow the instructions provided by the Mudwatt. We place 1 cm of soil in the container and then install the anode at that level. We then bury the anode below an additional 5 cm of soil. Finally, we place the cathode on top of the soil, where it is exposed to the ambient air. The Mudwatt required approximately three weeks of constant watering to mature and produce consistent power.

After reaching maturity, with a constant 2.2 kΩ load our Mudwatt produces 100 μW of power in steady-state. The peak open-circuit voltage we observe is around 700 mV. This limits the energy harvesters we can use. Following the 2021 survey done by Jagtap [2], we choose an ADP5091 development kit to harvest power

[1] Examples include the MCRY12-125Q-42DI and related chips from MATRIX.

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