An Origami Paper-Based Bacteria-Powered Battery for On-Chip Biosensors

The research will design and optimize a paper-based, bacteria-powered battery that can be integrated into paper-based microdevices to power on-board components. Paper has distinct advantages for fluid manipulation and analytical-clinical testing in applications such as point-of-care and point-of-use testing, particularly in low-resource settings. The proposed paper-based biobattery fuses the art of origami and the technology of Microbial Fuel Cells (MFCs) to generate power from microbial metabolism such that one drop of bacteria-containing liquid can deliver energy to next-generation paper-based systems. Every environment like soiled puddles or sewage has liquids that contain microorganisms that are sufficient for operating paper-based biobatteries. The proposed research therefore potentially has great social and economic impacts. It will enable low-cost diagnostic/analytical biosensors optimized for use under the most challenging environmental conditions. The project will address scientific education as the research outcomes will be shared through conferences and journals, and integrated into post-secondary courses as well as K-12 outreach.

This research will advance the potential of paper battery to be fully integrated in paper-based microfluidic systems to power on-board components. The proposed origami technique will provide a series/parallel connection method for paper-based bacteria-powered batteries to produce a targeted power output that, upon adding a drop of bacterial-containing liquid will simply operate by capillary force through 3-D microfluidic pathways within the paper layers. For operation, the battery stack will be unfolded to expose all air-cathodes to the air, thereby maximizing their cathodic reactions. The goals of the research include gaining in-depth understanding of bacteria’s potential within a paper matrix and gauging bacterial ability to provide rapid electricity generation. The scope of investigation includes validating design footprints and bacterial combinations, when optimized will create a novel energy conversion technology based on paper. The potential benefits of bacteria-powered battery design include 1) a viable alternative power source for interfaced, paper-based analytical/diagnostic devices, 2) develop powered paper-based biosensing assays in easy-to-use packages, 3) increase fundamental understanding of bacterial transport and associated extracellular electron transfer mechanisms through a paper matrix, and 4) origami technique will establish and validate a platform precedent for battery stacks to be connected either in series or in parallel.