Development of Portable Microscale Power Generation Devices using Electrogenic Bacteria

Abstract

Microbial Fuel Cells (MFCs) can effectively harness the electrons generated from the degradation of the organic matter to produce bioelectricity. The present work focusses on the development of portable, miniaturized MFCs as an endeavor to develop self-sustainable power sources. Four such unique MFCs, namely, a micro-sized MFC using polydimethyl siloxane, a miniature MFC using plexiglass, a portable MFC incorporating a planar reference electrode, and a novel, air-breathing Paper-based MFC (PMFC) have been fabricated. Among them, the as-fabricated PMFC employing pencil stoked graphite electrodes yielded a maximum power density of 8.75 W/m^3 using *Shewanella putrefaciens* as the biocatalyst. Owing to the instant electricity generation potential of the PMFCs, power generation of PMFCs is further improved deploying tailor-made conductive formulations. For the first time, the use of a commercially available eyeliner is proposed as conductive ink for the preparation of freestanding paper electrodes. Thorough compositional analysis revealed that the unique blend of amorphous carbon and iron oxides in eyeliner caused 20 % improvement in power generation as compared to graphite electrodes. Further, Pt nanoparticles are used as cathode catalysts to foster the oxygen reduction kinetics in the device. Consequently, the power generation increased four-fold yielding a maximum power of 35 µW and voltage of 800 mV for every 400 µL of the bacterial culture injected, lasting for 2 h. However, for PMFCs to drive real-world applications, a voltage of at least 2 V and a few milli-Watts of power is essential. Thus, to boost the power output, stacking of 10-unit PMFCs was done in three different configurations namely parallel, series and a combination of both. Furthermore, a customized energy harvesting circuit is coupled to the PMFC stack to harvest the energy and to account for the fluctuations caused by bacterial activity. The harvested charge from PMFCs is then stored into a supercapacitor and a wireless Internet of Things (IoT) temperature sensor was powered for 30 s. We believe that the current endeavours of the thesis can pave the way for “bacteria powered IoT devices” in future by unlocking the potential of microbes.

Keywords: microbial fuel cells; bacteria; electrodes; internet of things.