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High-current-density Microbial Fuel Cells For Wastewater Bioremediation

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A microbial fuel cell (MFC) is a bioelectrochemical system which converts chemical energy stored in organic molecules into electrical energy using the metabolism of electrogenic bacteria. In the process of generating electricity, the bacteria within a fuel cell can also electrochemically reduce heavy metal pollutants like Fe(III), Cr(VI), and U(VI) to less harmful oxidation states (Yin et al. J Hazard Mater 2022). If MFC's can be made to produce higher current density, or higher power output, they could become an economically viable means to generate electricity and eliminate harmful pollutants from wastewater streams. The efficiency of these cells depends sensitively on the electrical interaction between the electrogenic biofilm and its conductive electrode substrate. Recent results (Cao et al, Science 2021) have demonstrated that current density can be boosted by adding silver nanoparticles to a reduced graphene-oxide growth substrate to enhance charge-transfer efficiency in Shewanella oneidensis. Here we investigate the growth of Shewanella on gold electrodes, and the effect of surface roughness on bacterial loading density and current density. Gold is a desirable electrode material since it is chemically inert and can be easily patterned into microarrays using semiconductor-fabrication techniques. In previous reports, gold has achieved lower current density than carbon-based electrodes, however controlled experiments are lacking since carbon electrodes generally have rougher surfaces than evaporated gold, which can be nearly atomically flat. The effect of roughness on an electrogenic biofilm is significant, since a rough surface provides more surface area both for bacterial attachment, and also higher electroactive surface area for exchange of red-ox shuttles like riboflavin, which are critical to charge transfer in Shewanella. Both of these effects can increase the bacterial loading density and charge-transfer efficiency, respectively, which would in turn increases the overall output current density of the fuel cell. To investigate the effect of substrate roughness on current density we will grow Shewanella on gold electrodes electrochemically roughened with pulsed chronoamperometry, which will controllably and reproducibly give substrates of a desired surface roughness. We will measure the impact of surface roughness on both output current and bacterial loading density. These results provide a simple means to increase the current density of gold electrodes in Shewanella microbial fuel cells, and motivate equivalent studies of surface roughness on other electrode materials as well.

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