The dependence of R_{int} on V is shown in Fig. 8a for the two different anolytes and the MFC with and without SS balls. In all cases R_{int} decreased as the applied cell voltage was decreased. For buffer and lactate as anolyte R_{int} showed a very large decrease when the SS balls were added to the anode compartment (curves 1 and 3). R_{int} also decreased significantly when MR-1 was added to the anolyte (curves 1 and 2). In the presence of MR-1 in the MFC with SS balls R_{int} only decreased at higher cell voltages (curves 2 and 4). The decrease of R_{int} leads to large increase of the maximum power produced by the MFCs containing SS balls without MR-1 in the anolyte (Fig. 8b) In the presence of MR-1 only a small decrease in R_{int} was observed.

The finding that R_{int} did not decrease much further when MR-1 was added to the anolyte in the cell containing the SS balls can be understood by an evaluation of the impedance spectra for the anode and the cathode at their respective OCPs and the MFC at V_o for the four cases studied in this investigation (Fig. 9). Since the impedance of the anode and the cathode are in series, the impedance of the MFC is the sum of these two impedances.

For the cell without SS balls the impedance of the MFC was very similar to that of the anode even in the presence of MR-1 (Fig. 9a and b). Therefore R_{int} has values that are close to R_p^a. For the cell with SS balls in the anode compartment R_p^a and R_{int} have significantly decreased (Fig. 9c), however R_p^a is still considerably larger than R_p^c. A very different situation occurs when MR-1 is added to anolyte A1. In this case $R_p^a < R_p^c$ and any further significant decrease of R_{int} would only be possible if the rate of the oxygen reduction reaction could be increased by an improved design of the cathode. Attempts are being made at present to achieve such improvements.

4. Summary and conclusions

EIS has been used to determine the internal resistance R_{int} of a MFC as a function of cell voltage V for two different anode configurations (with and without stainless steel balls) and two different anolytes (with and without *Shewanella oneidensis* MR-1) for a total for four test series. For all test conditions it has been found that R_{int} decreased with decreasing V which was accompanied by an increase of the maximum power P_{max} that a given MFC could produce (Fig. 8). The addition of the SS balls increased the active area of the anode thereby reducing the polarization resistance R_p^a of the anode which in turn decreased R_{int} (Eq. (1)). Addition of MR-1 to the anolyte as a biocatalyst also decreased R_p^a.

A comparison of the impedance spectra for the anode and the cathode at their OCP with the impedance spectrum of the MFC at the open-circuit cell voltage V_o showed that the impedance of the cell was dominated by the impedance of the anode except for the case where SS balls and MR-1 were added to the anode compartment (Fig. 9). For the other cases the polarization resistance of the cathode R_p^c was much lower than R_p^a due to the presence of the Pt particles on the graphite felt cathode that greatly enhance the rate of oxygen reduction. Further decreases of R_{int} which lead to increases of P_{max} can only be achieved by reducing R_p^c. This could be accomplished by increasing the active surface area of the cathode and/or by adding a biocatalyst.

Acknowledgment

This project is supported by the AFOSR MURI program, Award No. FA9550-06-1-0292, Maj. Jennifer Gresham, contract monitor.

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