

Contents

PREFACE	xi
1. INTRODUCTION	1
1.1. Energy needs / 1	
1.2. Energy and the challenge of global climate change / 2	
1.3. Bioelectricity generation using a microbial fuel cell—the process of electrogenesis / 4	
1.4. MFCs and energy sustainability of the water infrastructure / 6	
1.5. MFC technologies for wastewater treatment / 7	
1.6. Renewable energy generation using MFCs / 9	
1.7. Other applications of MFC technologies / 11	
2. EXOELECTROGENS	12
2.1. Introduction / 12	
2.2. Mechanisms of electron transfer / 13	
2.3. MFC studies using known exoelectrogenic strains / 18	
2.4. Community analysis / 22	
2.5. MFCs as tools for studying exoelectrogener / 27	
3. VOLTAGE GENERATION	29
3.1. Voltage and current / 29	
3.2. Maximum voltages based on thermodynamic relationships / 30	
3.3. Anode potentials and enzyme potentials / 36	
3.4. Role of communities versus enzymes in setting anode potentials / 40	
3.5. Voltage generation by fermentative bacteria? / 41	
4. POWER GENERATION	44
4.1. Calculating power / 44	
4.2. Coulombic and energy efficiency / 48	
4.3. Polarization and power density curves / 50	

4.4.	Measuring internal resistance /	54	
4.5.	Chemical and electrochemical analysis of reactors /	57	
5.	MATERIALS		6
5.1.	Finding low-cost, highly efficient materials /	61	
5.2.	Anode materials /	62	
5.3.	Membranes and separators (and chemical transport through them) /	68	
5.4.	Cathode materials /	76	
5.5.	Long-term stability of different materials /	83	
6.	ARCHITECTURE		8
6.1.	General requirements /	85	
6.2.	Air-cathode MFCs /	86	
6.3.	Aqueous cathodes using dissolved oxygen /	95	
6.4.	Two-chamber reactors with soluble catholytes or poised potentials /	97	
6.5.	Tubular packed bed reactors /	102	
6.6.	Stacked MFCs /	104	
6.7.	Metal catholytes /	105	
6.8.	Biohydrogen MFCs /	108	
6.9.	Towards a scalable MFC architecture /	110	
7.	KINETICS AND MASS TRANSFER		11
7.1.	Kinetic- or mass transfer-based models? /	111	
7.2.	Boundaries on rate constants and bacterial characteristics /	112	
7.3.	Maximum power from a monolayer of bacteria /	116	
7.4.	Maximum rate of mass transfer to a biofilm /	118	
7.5.	Mass transfer per reactor volume /	122	
8.	MECS FOR HYDROGEN PRODUCTION		12
8.1.	Principle of operation /	125	
8.2.	MEC systems /	127	
8.3.	Hydrogen yield /	131	
8.4.	Hydrogen recovery /	132	
8.5.	Energy recovery /	134	
8.6.	Hydrogen losses /	142	
8.7.	Differences between the MEC and MFC systems /	145	
9.	MFCs FOR WASTEWATER TREATMENT		14
9.1.	Process trains for WWTPs /	146	
9.2.	Replacement of the biological treatment reactor with an MFC /	149	
9.3.	Energy balances for WWTPs /	154	
9.4.	Implications for reduced sludge generation /	157	
9.5.	Nutrient removal /	158	
9.6.	Electrogenesis versus methanogenesis /	159	

10. OTHER MFC TECHNOLOGIES	162
10.1. Different applications for MFC-based technologies /	162
10.2. Sediment MFCs /	162
10.3. Enhanced sediment MFCs /	166
10.4. Bioremediation using MFC technologies /	168
11. FUN!	171
11.1 MFCs for new scientists and inventors /	171
11.2 Choosing your inoculum and media /	174
11.3 MFC materials: electrodes and membranes /	175
11.4 MFC architectures that are easy to build /	176
11.5 MEC reactors /	180
11.6 Operation and assessment of MFCs /	181
12. OUTLOOK	182
12.1 MFCs yesterday and today /	182
12.2 Challenges for bringing MFCs to commercialization /	183
12.3 Accomplishments and outlook /	184
NOTATION	186
REFERENCES	189
INDEX	199