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Appendix A

Figure A1 Photographic view of PEMFC single cell experimental setup.

Appendix B

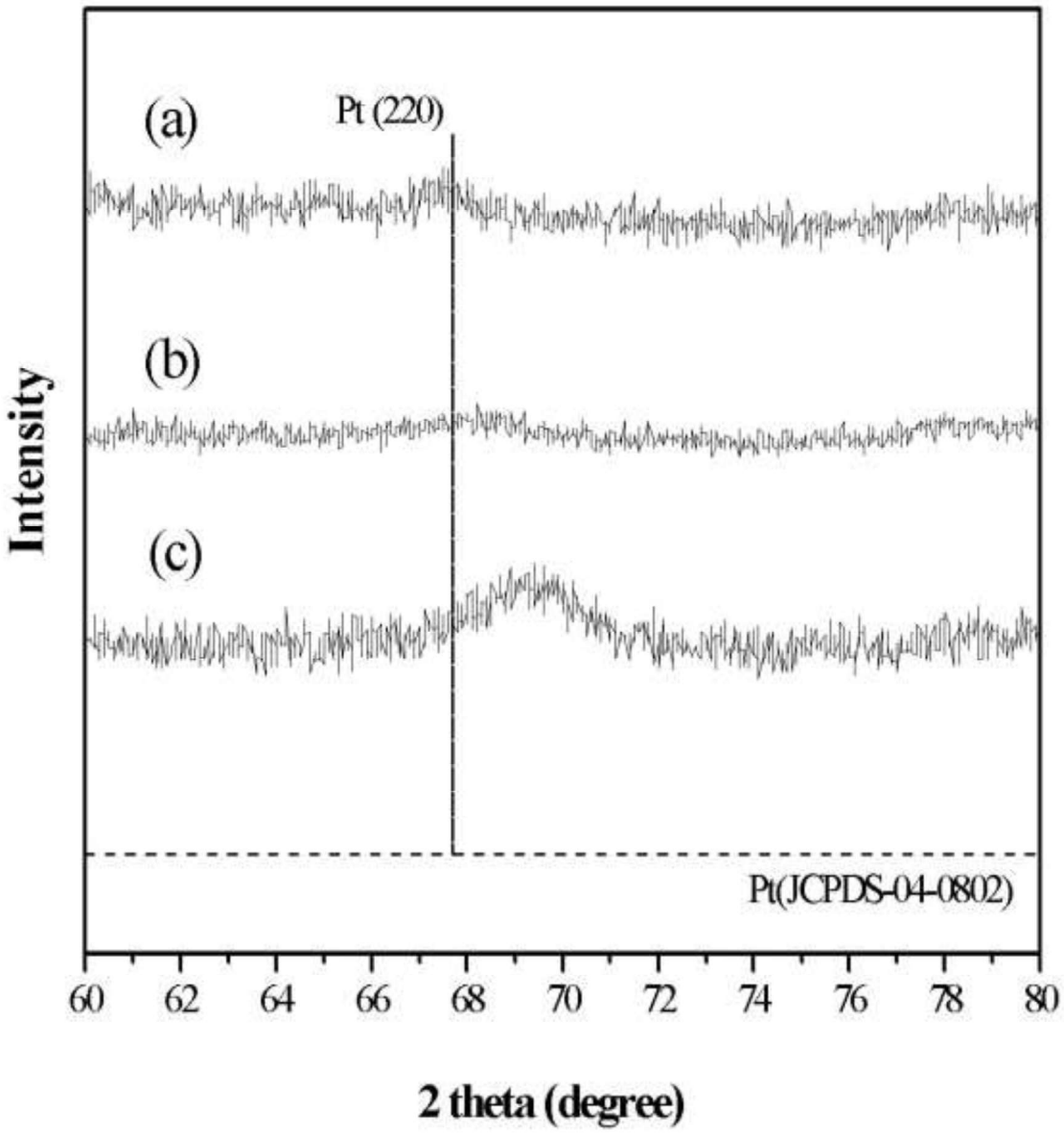

Figure B Comparison of (220) peaks of (a) Pt-Co/C_{AB}-DMSO, (b) Pt-Co/C_{AB}-DMF, and (c) Pt-Co/C_{AB}-EG electrocatalysts.

Appendix C

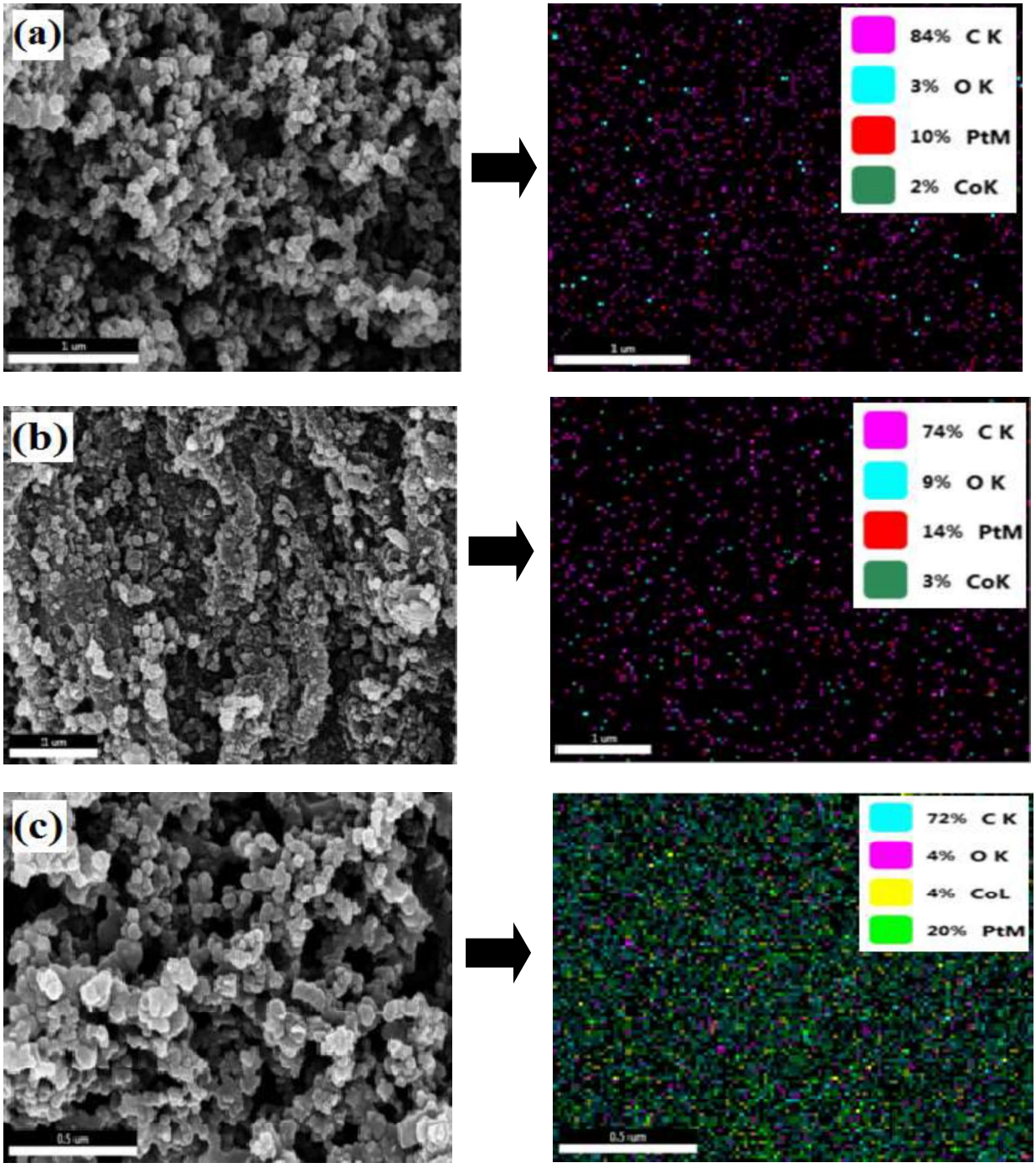

Figure C Color mapping of synthesized electrocatalyst (a) Pt-Co/C_{AB}-DMSO, (b) Pt-Co/C_{AB}-DMF, and (c) Pt-Co/C_{AB}-EG.

Appendix D

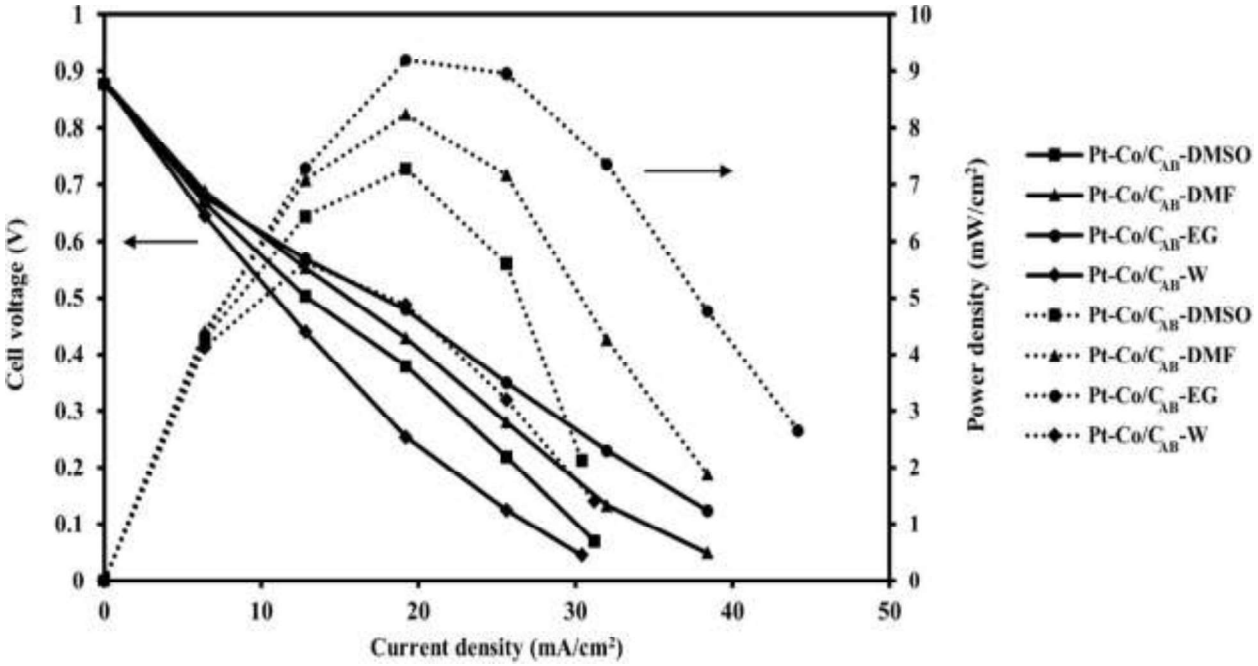

Figure D1 Polarization and power density curves for commercial anode Pt/C_{HSA} electrocatalyst of loading 1 mg/cm^2 and synthesized cathode Pt-Co(1:1)/C_{AB}-DMSO, Pt-Co(1:1)/C_{AB}-DMF, Pt-Co(1:1)/C_{AB}-EG and Pt-Co(1:1)/C_{AB}-W electrocatalysts of loading 1 mg/cm^2 respectively, in proton exchange membrane fuel cell at the operating temperature of 33 ^oC; Dotted line – power density curves; Solid lines – polarization curves.

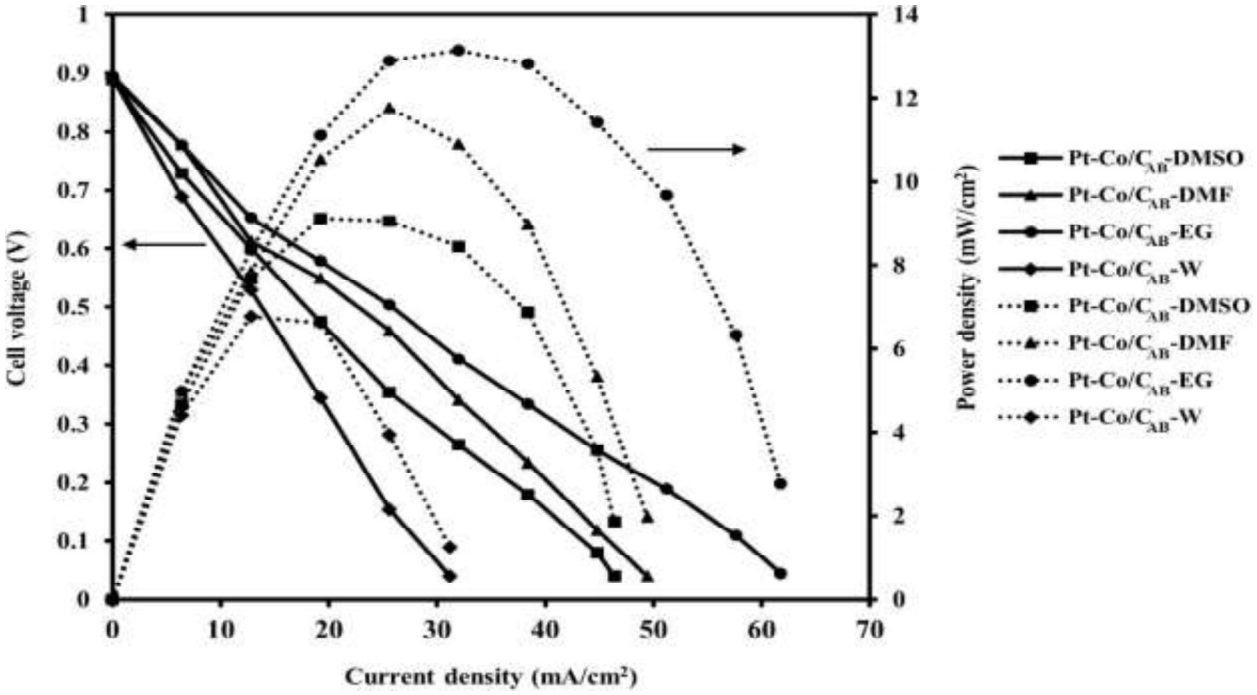

Figure D2 Polarization and power density curves for commercial anode Pt/C_{HSA} electrocatalyst of loading 1 mg/cm^2 and synthesized cathode Pt-Co(1:3)/C_{AB}-DMSO, Pt-Co(1:3)/C_{AB}-DMF, Pt-Co(1:3)/C_{AB}-EG and Pt-Co(1:3)/C_{AB}-W electrocatalysts of loading 1 mg/cm^2 respectively, in proton exchange membrane fuel cell at the operating temperature of 33 ^oC; Dotted line – power density curves; Solid lines – polarization curves.

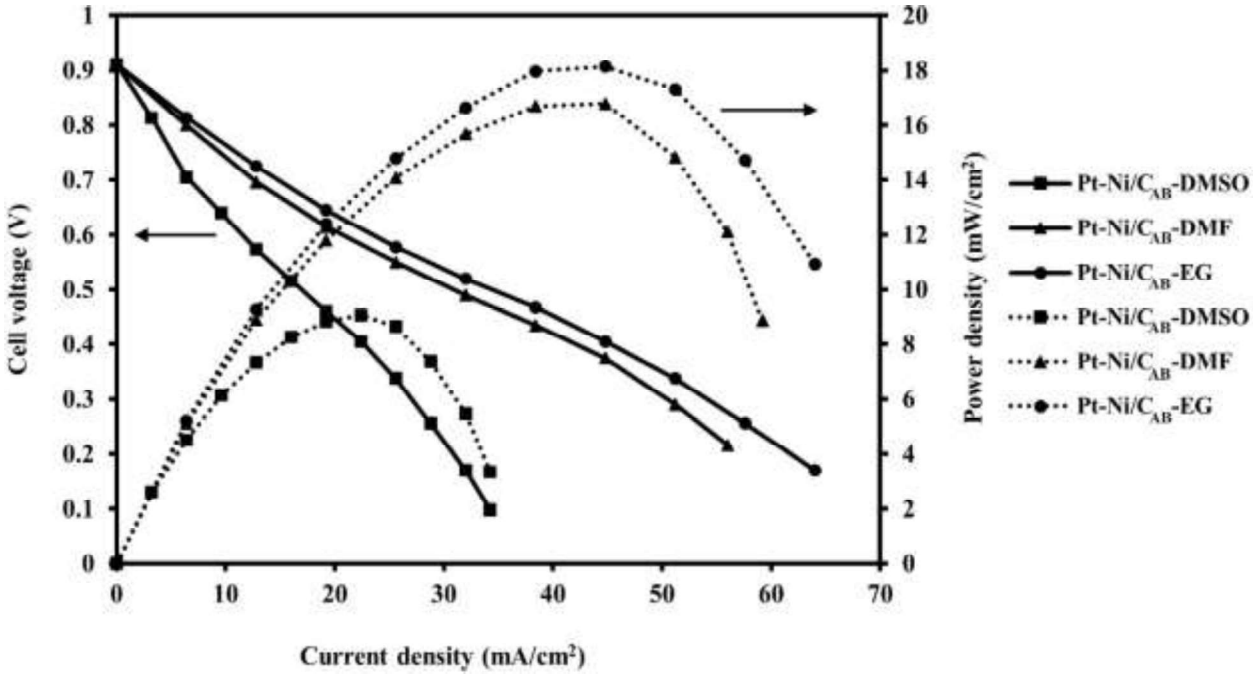

Figure D3 Polarization and power density curves for commercial anode Pt/C_{HSA} electrocatalyst of loading 1 mg/cm^2 and synthesized cathode Pt-Ni(1:1)/C_{AB}-DMSO, Pt-Ni(1:1)/C_{AB}-DMF and Pt-Ni(1:1)/C_{AB}-EG electrocatalysts of loading 1 mg/cm^2 respectively, in proton exchange membrane fuel cell at the operating temperature of 33 ºC; Dotted line – power density curves; Solid lines – polarization curves.

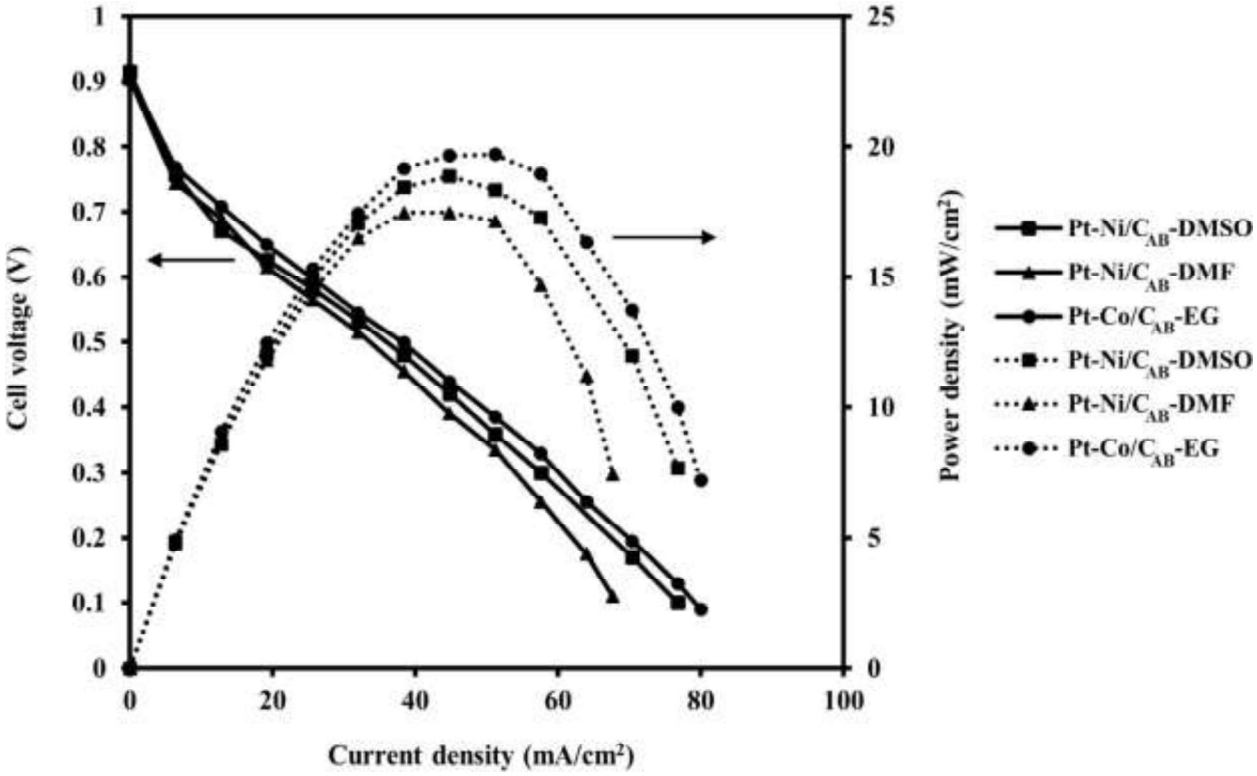

Figure D4 Polarization and power density curves for commercial anode Pt/C_{HSA} electrocatalyst of loading 1 mg/cm^2 and synthesized cathode Pt-Ni(1:1)/C_{AB}-DMSO, Pt-Ni(1:1)/C_{AB}-DMF and Pt-Ni(1:1)/C_{AB}-EG electrocatalysts of loading 1 mg/cm^2 respectively, in proton exchange membrane fuel cell at the operating temperature of 33 ºC; Dotted line – power density curves; Solid lines – polarization curves.

Appendix E

Table: Operating cell voltage, current density and corresponding power density for all 17 experiments obtained from BBD arrangements.

Run	Experimental conditions			Experimental results		
	A - Cathode electrocatalyst loading (mg/cm^2)	B - Cell temperature (^oC)	C - H_2 flow rate (ml/min)	Cell Voltage (V)	Current density (mA/cm^2)	Power density (mW/cm^2)
1	1	50	40	0.78	6.44	5.02
				0.69	12.80	8.83
				0.65	19.26	12.52
				0.61	25.61	15.62
				0.56	32.23	18.05
				0.52	38.25	19.89
				0.46	45.20	20.79
				0.4	51.20	20.48
				0.32	58.13	18.60
				0.28	64.93	18.18
				0.25	71.52	17.88
				0.22	76.45	16.82
				0.18	82.28	14.81
				0.14	89.57	12.54
2	1	60	50	0.79	6.42	5.07
				0.76	12.71	9.66
				0.73	19.10	13.94
				0.70	25.56	17.89
				0.67	32.15	21.54
				0.65	38.40	24.96
				0.62	45.10	27.96
				0.6	51.37	30.82
				0.58	57.40	33.29
				0.56	63.77	35.71
				0.53	70.92	37.59
				0.51	76.80	39.17
				0.49	82.53	40.44
				0.46	90.17	41.48
				0.44	95.57	42.05
				0.41	103.15	42.29
				0.39	107.41	41.89
				0.36	115.83	41.7
				0.34	120.53	40.98
				0.31	127.16	39.42
				0.28	133.93	37.50
				0.26	138.08	35.90
				0.22	149.23	32.83
				0.19	156.84	29.80
				0.16	161.00	25.76

Run	Experimental conditions			Experimental results		
	A - Cathode electrocatalyst loading (mg/cm^2)	B - Cell temperature (^oC)	C - H_2 flow rate (ml/min)	Cell Voltage (V)	Current density (mA/cm^2)	Power density (mW/cm^2)
3	0.75	70	50	0.71	6.44	4.57
				0.68	12.79	8.70
				0.64	19.20	12.29
				0.60	25.52	15.31
				0.56	32.23	18.05
				0.52	38.33	19.93
				0.48	44.60	21.41
				0.45	51.31	23.09
				0.41	57.88	23.73
				0.37	63.84	23.62
				0.32	70.41	22.53
				0.28	77.89	21.81
				0.25	82.52	20.63
				0.20	90.95	18.19
				0.16	96.63	15.46
				0.12	103.25	12.39
4	0.75	50	50	0.71	6.39	4.54
				0.68	12.79	8.70
				0.64	19.14	12.25
				0.59	25.78	15.21
				0.55	32.00	17.60
				0.50	38.64	19.32
				0.46	45.20	20.79
				0.42	51.33	21.56
				0.38	57.45	21.83
				0.34	63.82	21.7
				0.3	70.40	21.12
				0.26	77.08	20.04
				0.22	82.82	18.22
				0.17	91.18	15.5
				0.14	93.93	13.15
5	1	60	50	0.79	6.42	5.07
				0.76	12.71	9.66
				0.73	19.10	13.94
				0.7	25.56	17.89
				0.67	32.15	21.54
				0.65	38.40	24.96
				0.62	45.10	27.96
				0.6	51.37	30.82
				0.58	57.40	33.29
				0.56	63.77	35.71
				0.53	70.92	37.59
				0.51	76.80	39.17
				0.49	82.53	40.44
				0.46	90.17	41.48
				0.44	95.57	42.05

5	1	60	50	0.41	103.15	42.29
				0.39	107.41	41.89
				0.36	115.83	41.70
				0.34	120.53	40.98
				0.31	127.16	39.42
				0.28	133.93	37.50
				0.26	138.08	35.9
				0.22	149.23	32.83
				0.19	156.84	29.80
				0.16	161.00	25.76
Run	**Experimental conditions**			**Experimental results**		
	A - Cathode electrocatalyst loading (mg/cm^2)	**B - Cell temperature (^oC)**	**C - H_2 flow rate (ml/min)**	**Cell Voltage (V)**	**Current density (mA/cm^2)**	**Power density (mW/cm^2)**
6	0.75	60	40	0.71	6.39	4.54
				0.68	12.85	8.74
				0.61	19.33	11.79
				0.56	25.38	14.21
				0.51	31.75	16.19
				0.45	38.58	17.36
				0.4	44.58	17.83
				0.36	50.92	18.33
				0.3	58.37	17.51
				0.26	64.50	16.77
				0.21	69.05	14.50
				0.17	76.82	13.06
				0.12	85.25	10.23
7	1	50	60	0.78	6.40	4.99
				0.67	12.81	8.58
				0.63	19.32	12.17
				0.59	25.69	15.16
				0.55	32.11	17.66
				0.51	38.39	19.58
				0.47	44.43	20.88
				0.43	50.72	21.81
				0.39	57.00	22.23
				0.34	64.76	22.02
				0.3	70.87	21.26
				0.26	77.08	20.04
				0.21	84.00	17.64
				0.16	86.81	13.89
				0.09	91.78	8.26
8	0.75	60	60	0.71	6.42	4.56
				0.68	12.75	8.67
				0.62	19.23	11.92
				0.58	25.60	14.85
				0.54	32.06	17.31
				0.5	38.24	19.12
				0.46	44.50	20.47
				0.41	51.44	21.09
				0.37	58.05	21.48

8	0.75	60	60	0.34	64.00	21.76
				0.30	70.63	21.19
				0.27	77.67	20.97
				0.23	82.83	19.05
				0.17	90.12	15.32
				0.13	95.23	12.38
Run	**Experimental conditions**			**Experimental results**		
	A - Cathode electrocatalyst loading (mg/cm^2)	**B - Cell temperature (^oC)**	**C - H_2 flow rate (ml/min)**	**Cell Voltage (V)**	**Current density (mA/cm^2)**	**Power density (mW/cm^2)**
9	1.25	60	60	0.75	6.4	4.80
				0.67	12.8	8.51
				0.62	19.2	11.90
				0.59	25.6	14.98
				0.54	32	17.31
				0.50	38.4	19.20
				0.46	44.8	20.74
				0.43	51.2	21.96
				0.38	57.6	22.12
				0.34	64	22.02
				0.31	70.4	21.47
				0.28	76.8	21.12
				0.24	83.2	19.88
				0.20	89.6	17.83
				0.16	96	15.65
				0.12	105.83	12.70
				0.09	113.67	10.23
10	1	60	50	0.79	6.42	5.07
				0.76	12.71	9.66
				0.73	19.10	13.94
				0.7	25.56	17.89
				0.67	32.15	21.54
				0.65	38.40	24.96
				0.62	45.10	27.96
				0.6	51.37	30.82
				0.58	57.40	33.29
				0.56	63.77	35.71
				0.53	70.92	37.59
				0.51	76.80	39.17
				0.49	82.53	40.44
				0.46	90.17	41.48
				0.44	95.57	42.05
				0.41	103.15	42.29
				0.39	107.41	41.89
				0.36	115.83	41.7
				0.34	120.53	40.98
				0.31	127.16	39.42
				0.28	133.93	37.5
				0.26	138.08	35.9
				0.22	149.23	32.83
				0.19	156.84	29.8

10	1	60	50	0.16	161.00	25.76
				0.13	162.54	21.13
Run	**Experimental conditions**			**Experimental results**		
	A - Cathode electrocatalyst loading (mg/cm^2)	**B - Cell temperature (^oC)**	**C - H_2 flow rate (ml/min)**	**Cell Voltage (V)**	**Current density (mA/cm^2)**	**Power density (mW/cm^2)**
11	1.25	60	40	0.76	6.36	4.83
				0.67	12.70	8.51
				0.62	19.05	11.81
				0.58	25.38	14.72
				0.52	31.94	16.61
				0.48	38.40	18.43
				0.44	44.50	19.58
				0.4	51.08	20.43
				0.35	57.11	19.99
				0.30	64.00	19.20
				0.26	69.58	18.09
				0.20	75.65	15.13
				0.14	82.57	11.56
12	1	60	50	0.79	6.42	5.070
				0.76	12.71	9.66
				0.73	19.10	13.94
				0.7	25.56	17.89
				0.67	32.15	21.54
				0.65	38.40	24.96
				0.62	45.10	27.96
				0.6	51.37	30.82
				0.58	57.40	33.29
				0.56	63.77	35.71
				0.53	70.92	37.59
				0.51	76.80	39.17
				0.49	82.53	40.44
				0.46	90.17	41.48
				0.44	95.57	42.05
				0.41	103.15	42.29
				0.39	107.41	41.89
				0.36	115.83	41.7
				0.34	120.53	40.98
				0.31	127.16	39.42
				0.28	133.93	37.5
				0.26	138.08	35.90
				0.22	149.23	32.83
				0.19	156.84	29.8
				0.16	161.00	25.76
				0.13	162.54	21.13
13	1.25	70	50	0.76	6.36	4.83
				0.68	12.71	8.64
				0.63	19.24	12.12
				0.60	25.52	15.31
				0.56	32.23	18.05

13	1.25	70	50	0.51	38.55	19.66
				0.48	44.33	21.28
				0.43	51.21	22.02
				0.39	57.74	22.52
				0.36	64.72	23.30
				0.32	70.19	22.46
				0.29	75.48	21.89
				0.26	82.88	21.55
				0.22	89.59	19.71
				0.18	98.11	17.66
				0.14	101.64	14.23
Run	**Experimental conditions**			**Experimental results**		
	A - Cathode electrocatalyst loading (mg/cm^2)	**B - Cell temperature (^oC)**	**C - H_2 flow rate (ml/min)**	**Cell Voltage (V)**	**Current density (mA/cm^2)**	**Power density (mW/cm^2)**
14	1	70	60	0.79	6.35	5.02
				0.70	12.71	8.90
				0.65	19.05	12.38
				0.60	25.60	15.36
				0.57	32.00	18.24
				0.54	38.33	20.70
				0.51	44.71	22.80
				0.48	51.21	24.58
				0.46	57.48	26.44
				0.42	64.14	26.94
				0.39	70.23	27.39
				0.35	77.69	27.19
				0.31	82.94	25.71
				0.27	88.59	23.92
				0.23	96.43	22.18
				0.19	100.79	19.15
				0.14	111.93	15.67
15	1	60	50	0.79	6.42	5.07
				0.76	12.71	9.66
				0.73	19.10	13.94
				0.70	25.56	17.89
				0.67	32.15	21.54
				0.65	38.40	24.96
				0.62	45.10	27.96
				0.6	51.37	30.82
				0.58	57.40	33.29
				0.56	63.77	35.71
				0.53	70.92	37.59
				0.51	76.80	39.17
				0.49	82.53	40.44
				0.46	90.17	41.48
				0.44	95.57	42.05
				0.41	103.15	42.29
				0.39	107.41	41.89
				0.36	115.83	41.70

15	1	60	50	0.34	120.53	40.98
				0.31	127.16	39.42
				0.28	133.93	37.50
				0.26	138.08	35.9
				0.22	149.23	32.83
				0.19	156.84	29.8
				0.16	161.00	25.76
				0.13	162.54	21.13
Run	**Experimental conditions**			**Experimental results**		
	A - Cathode electrocatalyst loading (mg/cm^2)	**B - Cell temperature (^oC)**	**C - H_2 flow rate (ml/min)**	**Cell Voltage (V)**	**Current density (mA/cm^2)**	**Power density (mW/cm^2)**
16	1	70	40	0.79	6.39	5.05
				0.67	12.81	8.58
				0.63	19.32	12.17
				0.59	25.73	15.18
				0.55	32.05	17.63
				0.51	38.47	19.62
				0.47	44.81	21.06
				0.43	50.60	21.76
				0.39	56.87	22.18
				0.34	64.38	21.89
				0.31	70.39	21.82
				0.27	75.37	20.35
				0.21	83.19	17.47
				0.16	89.63	14.34
				0.11	96.91	10.66
17	1.25	50	50	0.75	6.40	4.82
				0.67	12.81	8.58
				0.62	19.20	11.96
				0.59	25.61	14.98
				0.54	31.99	17.18
				0.50	38.39	19.08
				0.46	44.80	20.61
				0.42	51.21	21.61
				0.38	57.61	21.89
				0.34	64.00	21.44
				0.30	70.40	20.98
				0.26	76.82	20.28
				0.22	83.21	17.89
				0.18	89.61	16.04

LIST OF PUBLICATIONS FROM WORK

Journals:

1. Singh A.P., Paramanik H., "Solvothermal synthesis of Pt-Co/C cathode electrocatalyst for oxygen reduction reaction (ORR) in low temperature fuel cells', *Indian Journal of Chemical Technology*, 2019, v. 26, pp. 312-320.

2. Singh A.P., Sharma S., Pramanik H., "Studies on the effect of solvent for the synthesis of low-cost and efficient Pt-Co/C_{AB} cathode electrocatalyst to enhance the performance of a hydrogen-based PEMFC", *The Canadian Journal of Chemical Engineering*, 2023, v. 101, pp. 4460-4479.

3. Singh A.P., Pramanik H., "Synthesis of low cost cathode electrocatalyst Pt-Ni/CAB using DMSO as a solvent for low temperature proton exchange membrane fuel cell application", *The Canadian Journal of Chemical Engineering*, 2024, v. 114(11), pp. 4007-25.

Conferences:

1. Singh A.P., Sharma S., Pramanik H., "Studies of cathode electrocatalyst performance using two-cell stack of Proton Exchange Membrane Fuel Cell (PEMFCs)." ASREEM 2021.