

ON CURRENT DENSITY AND EXCESS POWER DENSITY IN ELECTROLYSIS EXPERIMENTS

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Abstract

Results of a study of an electrolytic device that can produce excess power are presented. The power calibration procedure used for the experiments and the data analysis procedure is briefly described in this paper. Different combinations of cathode and electrolyte were investigated. Thin foils of different pure metals and thin spattered layers of different pure metals on different substrates were used as cathodes. Excess power results, the power density and details on the combinations of cathode and electrolyte are also presented. The results reveal that a higher excess power density was obtained using thin film metal cathodes than thin foils. Another interesting result is that the excess power density appears to be correlated with the current density along the cathode. Although the data points are in ranges that are different of each other with orders of magnitude, the slopes of the lines that are fitted on the data points comparable, within the experimental errors.

1. Introduction

After the early announcement made by Fleischman and Pons stating that they recorded excess power from an electrolytic cell many attempts were done both to reproduce the experiment and to search for other combinations of cathode-electrolyte-anode that might produce excess power [1]. The experimental work presented in this article is one of them.

The calorimeter and the power calibration procedure are briefly presented in the first section. The second section presents briefly the data analysis procedure and the error calculation. They are presented in detail in [2]. The results are discussed in the last section.

2. Power calibration

The cell consisted of a Dewar vessel, 350 ml volume. Inside the vessel an 80 ml beaker was placed, coated by a glass fiber blanket to reduce the heat loss. A rubber cap having the external part insulated by a glass fiber blanket covered the vessel. The cathode, anode and thermocouple are suspended under the rubber cap. The cell stands on a plastic thermal insulator. The schematic of the cell is presented in [3].

Experiments were carried on to analyze cathodes that generate excess power therefore a procedure for assessing as precise as possible the power inside a cell was first established. Briefly it consists of finding the equation that provides the power inside the cell as a function of the temperature difference between inside and outside the cell. The equation that provides the power calibration derived using the procedure described before, for one of the three cells employed in this work, is:

$$P = 0.0013 * (\Delta t)^2 + 0.0594 * (\Delta t) \quad (1)$$

The cell was surrounded by room air. The cell constant is 15 ± 0.3 °C/W. This value shows that the calorimeter is very sensitive. Some other cell constants presented in the literature are 11 °C/W [4] or 0.83 °C/W [5].

3. Data analysis

Different metals or thin metal layers were used as cathodes and a Platinum wire as anode. The current (I) and the voltage across the cell (U) were recorded together with the temperatures inside and outside the cell. Equation (1) expresses the total power generated in the cell and therefore dissipated by the cell, regardless the source, as a function of the difference of the temperature inside the cell and outside the cell. I define this total power dissipated by the cell as the actual output power, or output power and I write it as P_A .

The equation that describes the dissociation power is:

$$P_D = 1.48 * I \text{ for } H_2 O ; P_D = 1.54 * I \text{ for } D_2 O \quad (2)$$

and can be found in many papers like [6].

The corrected input power, P_{JC} , (3), can be calculated as the difference of the Joule power and the dissociation power and is that part of the input power that heats the cell.

$$P_{JC} = P_J - P_D \quad (3)$$

The input Joule power, P_J (4) was calculated as the voltage across the cell times the current.

$$P_J = U * I \quad (4)$$

The excess power P_E was calculated with (5) as the difference of the actual output power and the corrected input power. If a cell has a temperature difference higher then the one expected when the corrected Joule power is applied, the higher temperature difference is produced by the excess power.

$$P_E = P_A - P_{JC} \quad (5)$$

The air temperature changed during day and night time, which caused the temperature of the electrolyte to follow the changes with a delay. A final comparison employs time average values of the powers defined here. The averages were computed and are presented in table II.

The f ratio is defined as the ratio of the average excess power and the average Joule power as in (6).

$$f = \frac{\langle P_E \rangle}{\langle P_J \rangle} \quad (6)$$

The f ratio describes correctly the experiment in respect to the excess power. If the experiment is conducted using two inactive electrodes, like Platinum electrodes, the f ratio will be a 0 (within experimental errors). The f ratio values of the experiments described in this work are presented in Table II.

A thorough error analyses was done and is presented in [3]. Table I, reproduced from [3] presents the random error in calculating the powers and the factors previously defined.

Variable	P_J	P_A	P_{JC}	P_E	Δt	f
Random error, %	1.1	2.1	2.1	15	1	17

Table I – random percentage errors of the variables defined in this section

4. Results

Three cells were built, accordingly to the schematic presented in [2]. The first two of them did not have the rubber cap insulated therefore their sensitivity is lower than for the third cell. For each of the cells a power calibration was performed before the experiments. The anode consisted of a Pt wire. Table II presents the cathode type, anode and electrolyte.

Exp	Cathode	Anode	Electrolyte
1	Ni foil	Pt wire	Li_2SO_4 in H_2O , 1M
2	Ni foil	Pt wire	Li_2SO_4 in H_2O , 1M
3	Ni foil	Pt wire	Li_2SO_4 in H_2O , 1M
4	Alumina substrate, Ti + Ni thin films	Pt. wire	Li_2SO_4 in D_2O , 1M
5	Alumina substrate, Ti plus Ni thin films	Pt. wire	Li_2SO_4 in D_2O , 1M
6	Alumina substrate, Ti + Pd + Ni thin films	Pt. wire	K_2CO_3 in H_2O , 1M
7	Ni foil + Ti thin layer	Pt. wire	K_2CO_3 in H_2O , 1M
8	Quartz slide as substrate + Ni thin film + Pd thin layer	Pt. wire	K_2CO_3 in H_2O , 1M
9	Ni foil as substrate + Ti thin film + Pd thin film	Pt. wire	K_2CO_3 in H_2O , 0.5M
10	Ni foil as substrate + Ti thin film + Pd thin film	Pt. wire	K_2CO_3 in H_2O , 0.5M

Table II - cathode type, anode and electrolyte

The first cell was used to perform experiments with a 0.127 mm Nickel foil cathode and 1M K_2CO_3 in H_2O as electrolyte. The second cell was used for electrolyzing D_2O on multi-layer metal cathode sputtered on ceramic substrate. The third cell, the most sensitive, was used for electrolyzing H_2O on cathodes having metal layers sputtered on nickel substrate. Table III presents the values of the input Joule power, the dissociation power, the corrected input power, the excess power, the cathode volume power density and the f factor.

Exp.	P_J , W	P_{JC} , W	P_A , W	P_D , W	P_E , W	W/cm ³ (cathode)	f, %
1	0.115	0.06	0.144	0.055	0.084	0.24	73
2	0.139	0.074	0.11	0.065	0.036	0.28	26

3	0.758	0.455	0.763	0.303	0.308	1.32	41
4	0.101	0.085	0.122	0.015	0.037	5.68	37
5	0.192	0.171	0.209	0.021	0.038	74.3	20
6	0.104	0.072	0.091	0.032	0.019	113.3	18
7	0.102	0.051	0.101	0.051	0.05	0.17	49
8	0.075	0.054	0.069	0.021	0.015	112.1	20
9	0.101	0.051	0.096	0.05	0.045	0.08	45
10	0.215	0.119	0.184	0.096	0.065	0.16	30

Table III –Values of the variables defined in the previous section and the f ratio values.

Excess energy above the estimated errors was detected both for thin film cathode and thin foil cathode experiments. The excess power ratio is lower than that reported in [4], [7] but is higher than the ratio presented in [8] and comparable with the results in [9], in experiments that were similar to a certain degree with those described in this work.

An interesting feature that was revealed is that the excess power density on cm³ of cathode was several hundred times higher for thin film cathodes than for thin foil cathodes. The bigger volume excess power density on thin film cathodes than on thin foil cathodes suggests that a simple way to scale up the device to hundreds or thousands of Watts might be the use a tight packing ratio of the thin films in the cell volume.

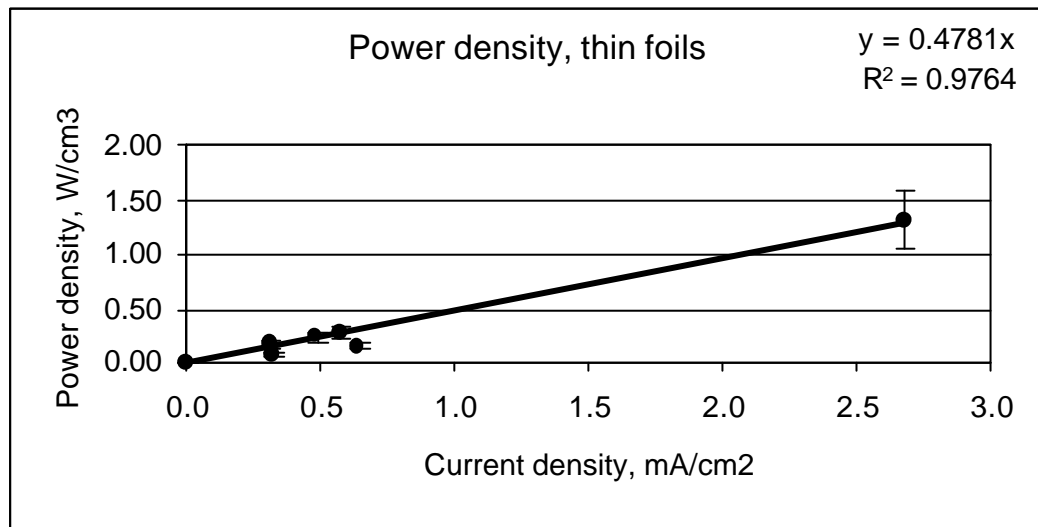


Figure 1 – Current density along the cathode for thin foil cathodes

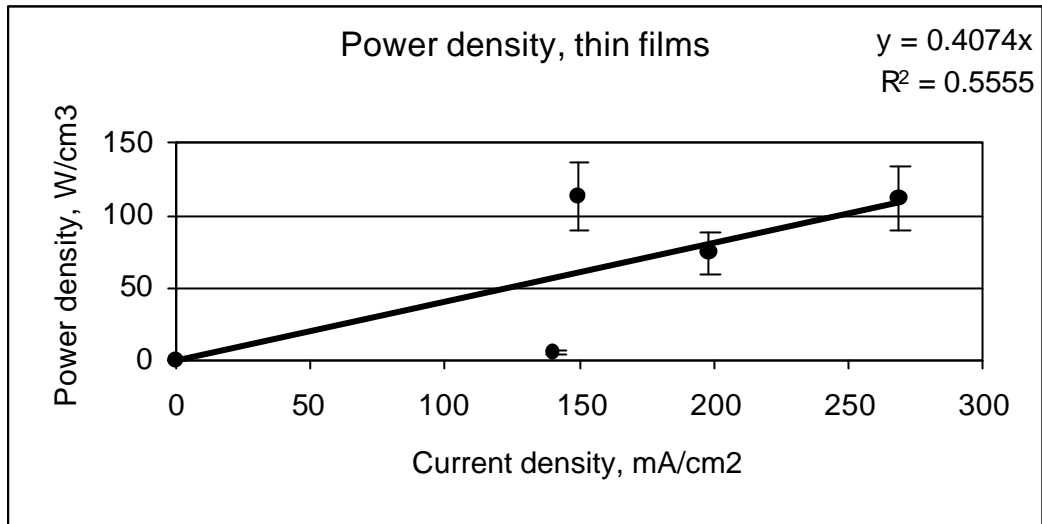


Figure 2 - Current density along the cathode for thin film cathodes

The plots of the excess power volume density versus current density along the cathode, presented in Figure 1 for thin foils and in Figure 2 for thin films reveal another interesting feature of the experimental data. The slopes of the lines plotted through the data points are the same, within the experimental errors, despite the different ranges of the current density values for the two kind of cathodes.

This plots in Figures 1 and 2 suggest another way that might solve the main practical problem that electrolytic devices have, that is upscaling the device, by designing a cathode that both loads Hydrogen isotopes in big amount and presents a high current density along the cathode.

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