TECHNISCHE UNIVERSITÄT MÜNCHEN

Fuel Cell

Group B412

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05.10.2009

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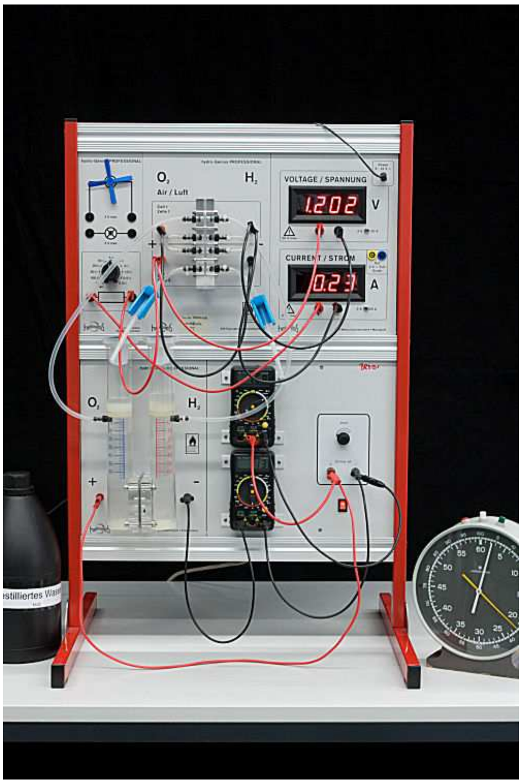
1. INTRODUCTION

A fuel cell is a galvanic element, which transforms chemical energy in electric energy. The chemical energy is stored in the oxidant, which was oxygen in the experiment. In this experiment we used a PEM – fuel cell, which had a special membrane letting only protons pass through.

2. EXPLANATION OF THE USED METHODE



PICTURE 1:EXPERIMENTAL SETUP: HTTP://WWW.PHYSIK.TU-MUENCHEN.DE/STUDIUM/BETRIEB/PRAKTIKA/ANFAENGER/BILDER/BRZ.JPG

The experimental setup of the PEM- fuel cell is quite simple. In picture 1 you can see the setup. There are an anode and a cathode, which were surrounded by a electrolyte. The hydrogen flues to the anode and the oxygen flues to the cathode. There is also a special membrane called (PEM = proton exchange membrane).

The electric power is produced in the electrodes, where hydrogen is oxidized and oxygen deoxidized. The reaction is exothermic.

Anode: $H_2 \longrightarrow 2H^+ + 2e^-$

Cathode: $O_2 + 4e^- \longrightarrow 2O^{-2}$

Reaction: $O_2 + 2H_2 \longrightarrow 2O^{-2} + 4H^+$

The protons produced at the anode diffuse through the PEM and build water with the oxygen anions.

In a closed circuit the reaction takes place continuously. In a open circuit there is a potential between anode and cathode. Furthermore no gas is spent.

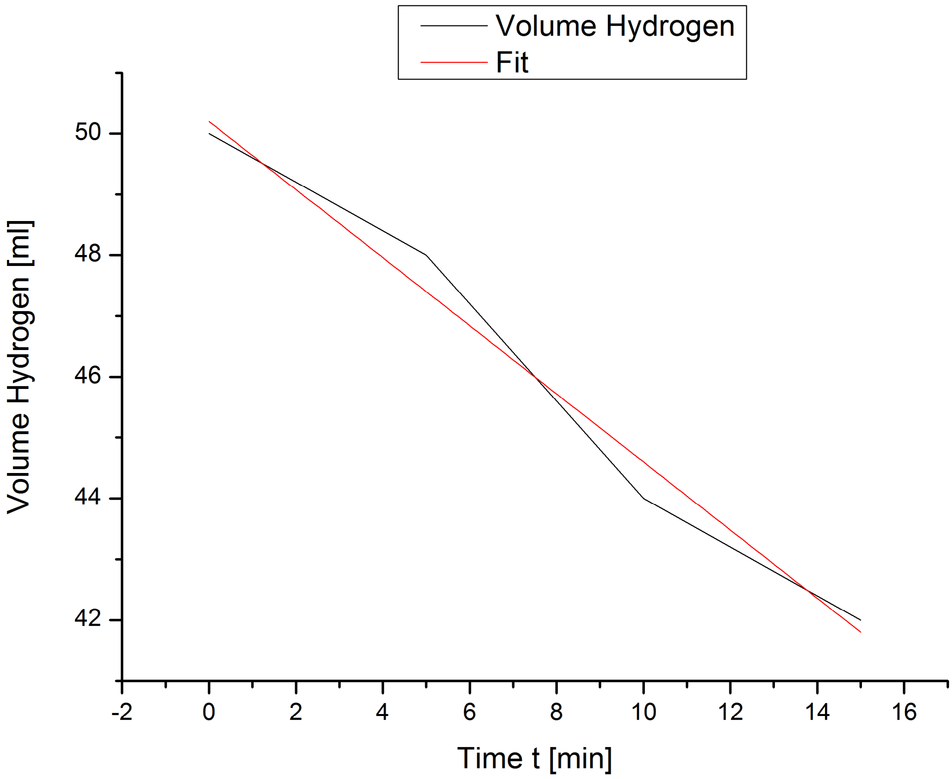
However some protons can overcome the membrane and diffuse through small vents. Consequently there is a leakage current. In order to accelerate the reaction, a platin catalysator is used. It reduces the activation energy.

3. Results

3.1. Appointment of the leakage current

The leakage current can be calculeted by:

$$I_{corr} = I + I_{leak} \tag{1}$$



In the picture above the linear coherence can be seen obviously. From the incline of the fitted linear line we can calculate:

$$\left|\frac{dV}{dt}\right| = 0{,}65\,\frac{ml}{min}\ . \tag{2}$$

By using the ideal gas law:

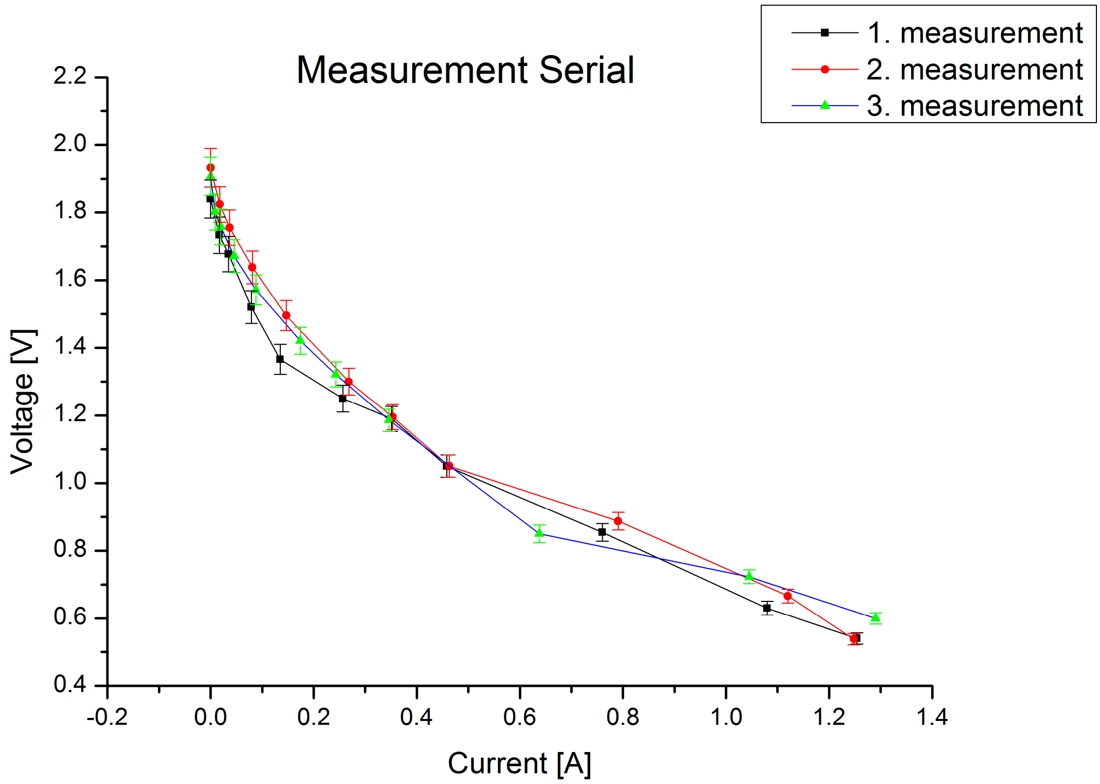
$$\left|\frac{dV}{dt}\right| = \left|\frac{d\left(\frac{Nk_bT}{p}\right)}{dt}\right| = \frac{k_bT}{p}\cdot\left|\frac{dN}{dt}\right| = 0{,}65\,\frac{ml}{min} = 1{,}1\cdot 10^{-8}\ \frac{m^3}{s} \tag{3}$$

$$I_{leck} = \left|\frac{dq}{dt}\right| = \left|\frac{dN}{dt}\right|\cdot 2\cdot e = 1{,}1\cdot 10^{-8}\ \frac{m^3}{s}\cdot\frac{p}{k_bT}\cdot 2\cdot e \tag{4}$$

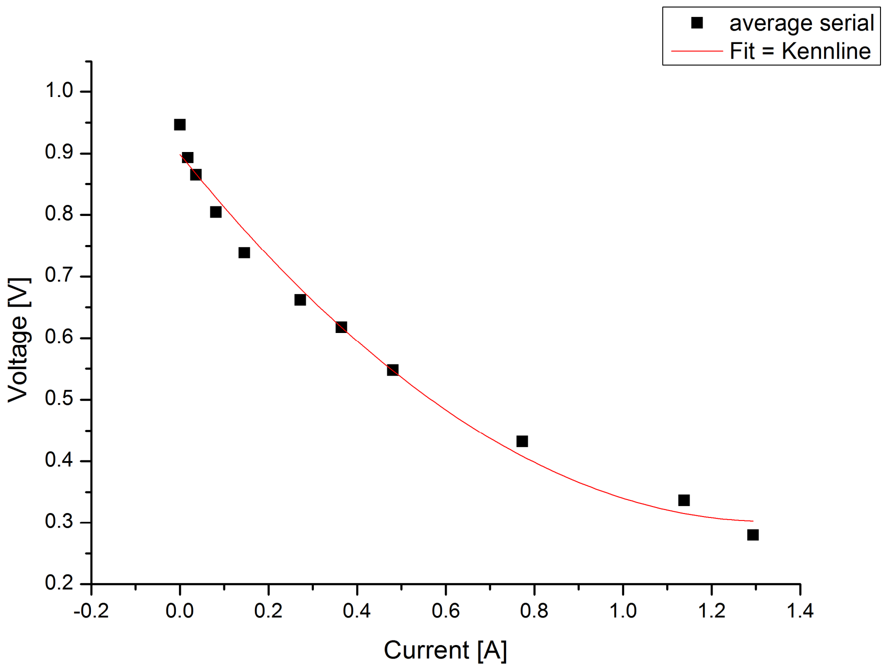
$$\boldsymbol{I_{leck} = 0{,}086\ A}$$

3.2. Measurement of the characteristic curve without any limitation of the stream of Volumina

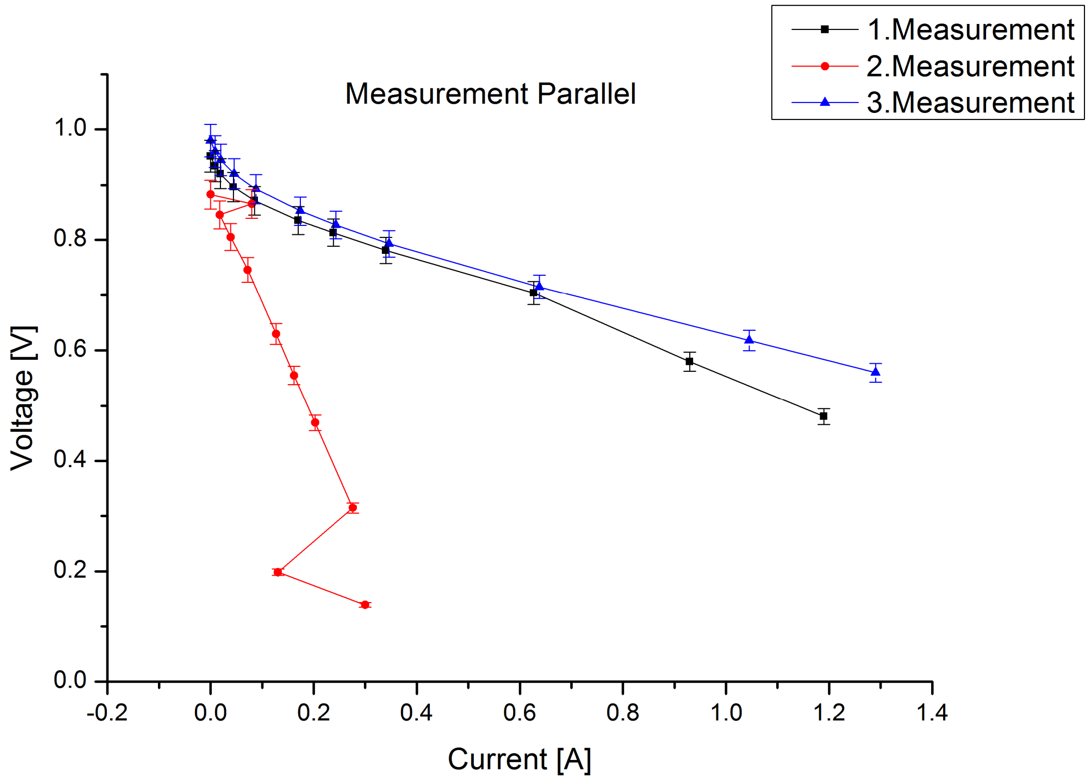
At first the fuel cell got into a serial circuit:



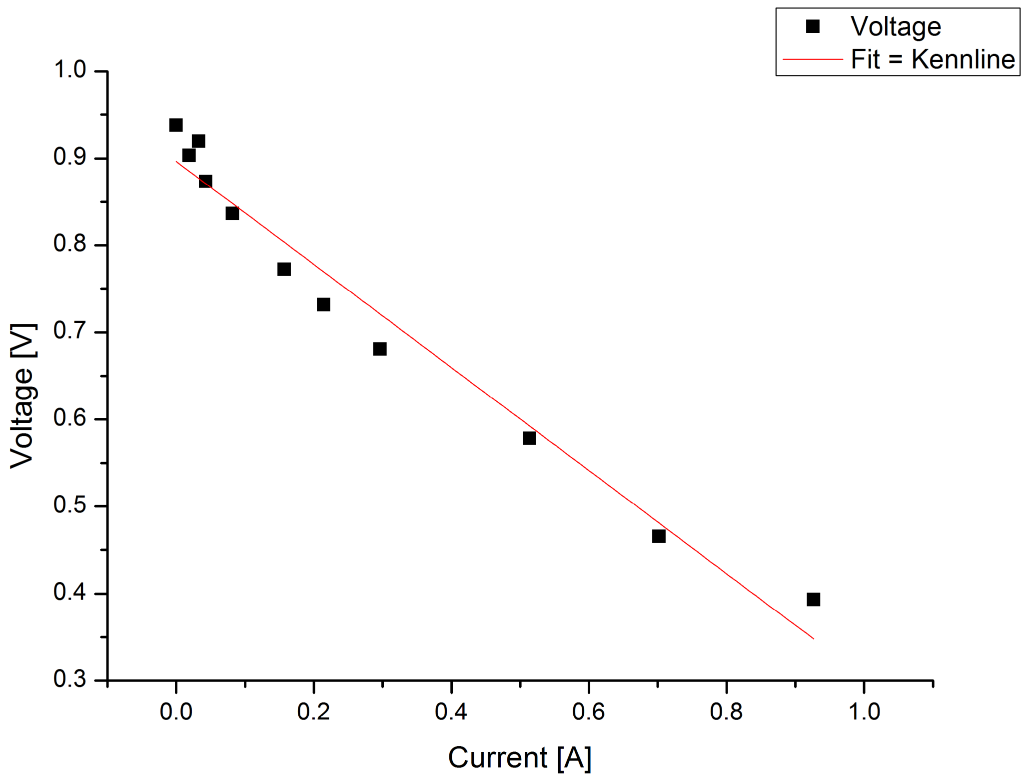
To this graphic belongs the following characteristic curve:



By using the fuel cell in a parallel circuit you get this picture:

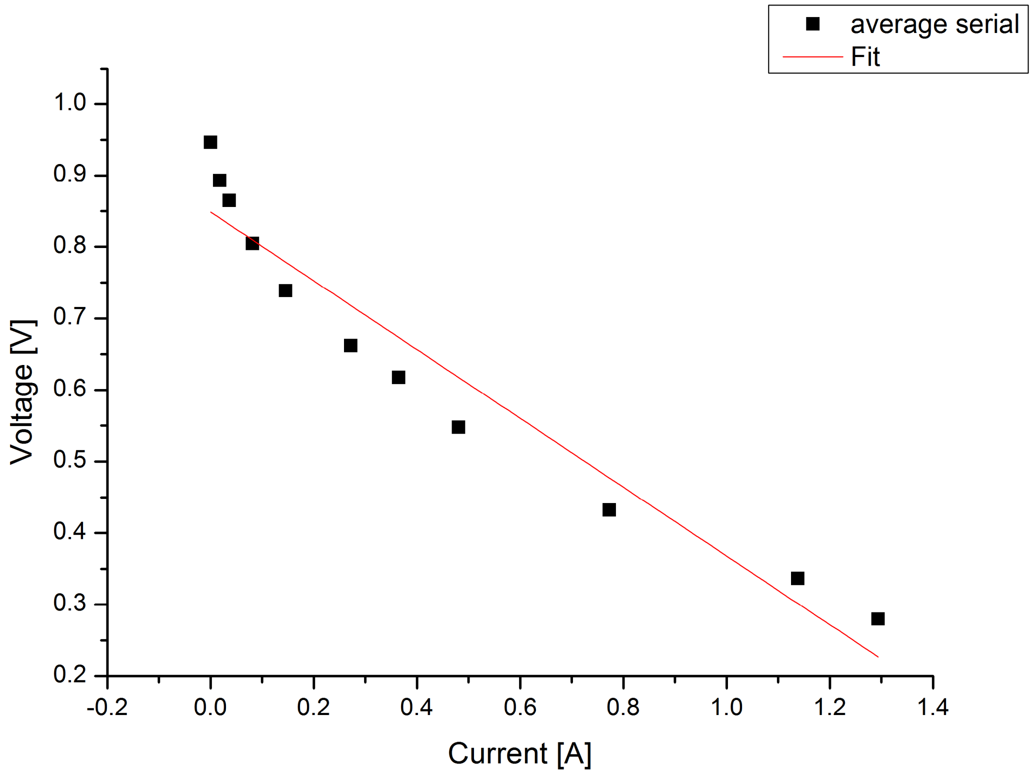


And as a characteristic curve the following picture:



3.3. Internal resistance of a fuel cell

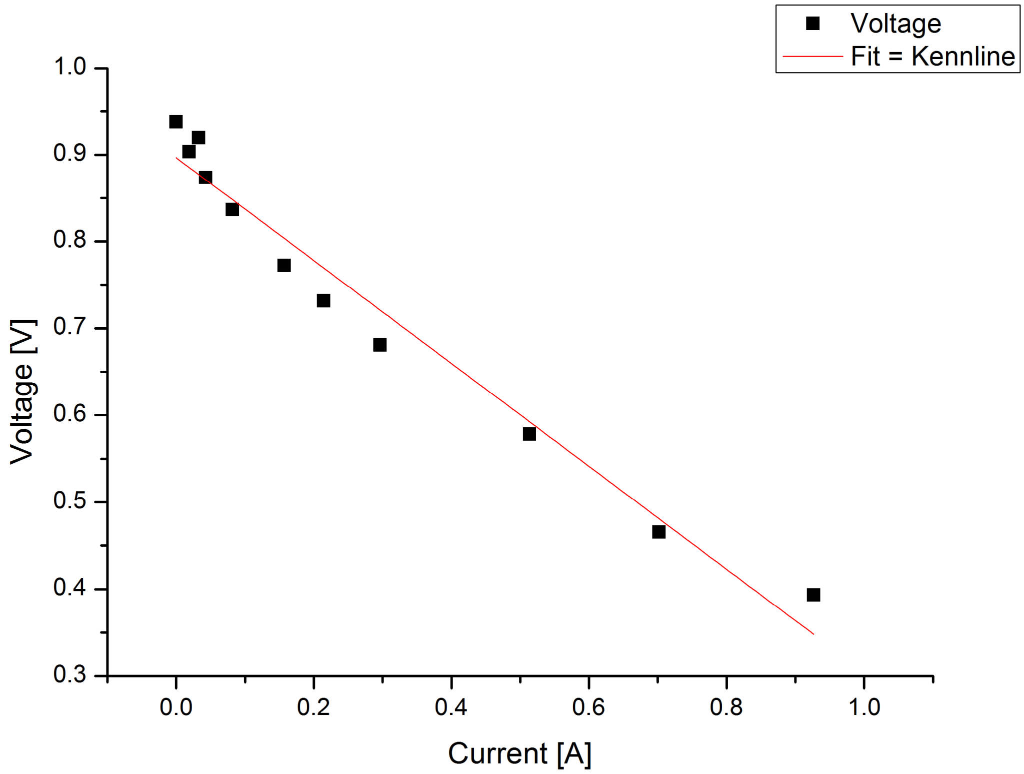
By using a linear fit you get the internal resistance of the cell. At first we look at the serial circuit:



From the characteristic curve you get the incline of 0,48. It is a serial circuit, so you have to divide the incline of the linear fit by two to get the internal resistance.

$R_{cell-serial} = (0{,}24 \pm 0{,}04)\Omega$

In the same way you get the internal resistance of the parallel circuit:



At the parallel circuit the incline is about 0,59. To get the internal resistance of one cell, you have to multiplicate the incline with two. So you get the following result:

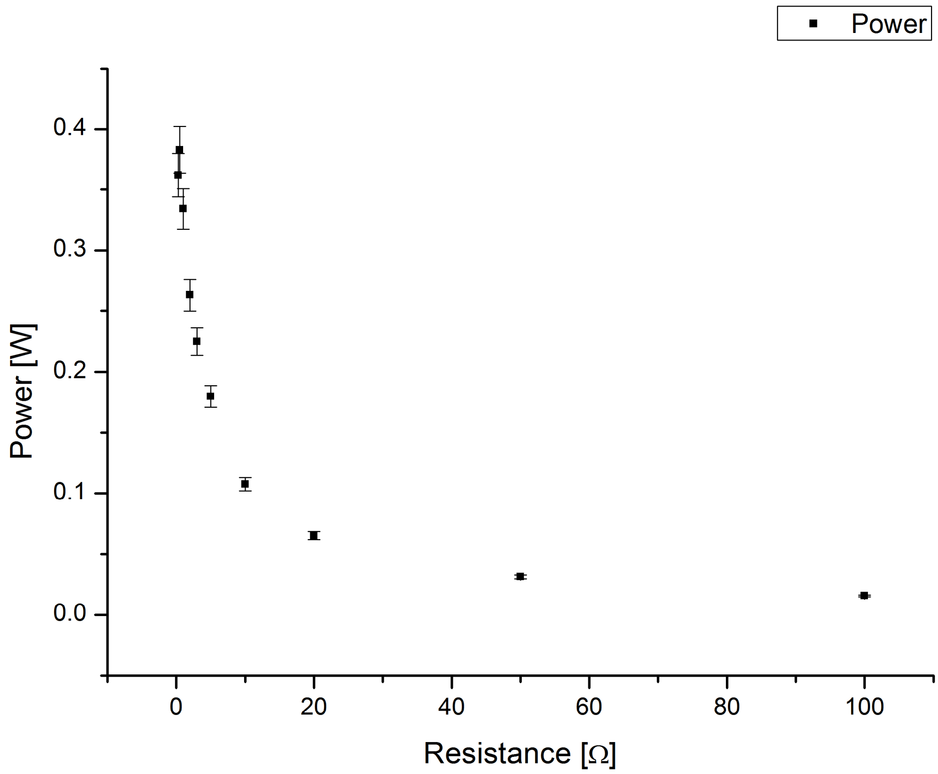
$R_{cell-parallel} = 1{,}18\ \pm 0{,}04\Omega$

3.4. Power of fuel cell

Now we look at the power in connection to the resistance:

Serial circuit:

R in Ω	open	100	50	20	10	5	3	2	1	0,5	0,3
I in A	1,893	1,786	1,730	1,610	1,477	1,324	1,235	1,095	0,864	0,673	0,559
U in V	0	0,018	0,036	0,081	0,146	0,272	0,364	0,480	0,773	1,138	1,294
P in W	0	0,032	0,063	0,130	0,215	0,360	0,450	0,526	0,668	0,766	0,724



So we get P_{max} at 0,5 Ω :

$$P_{max-serial} = (0{,}766 \ \pm 0{,}006)\ W$$

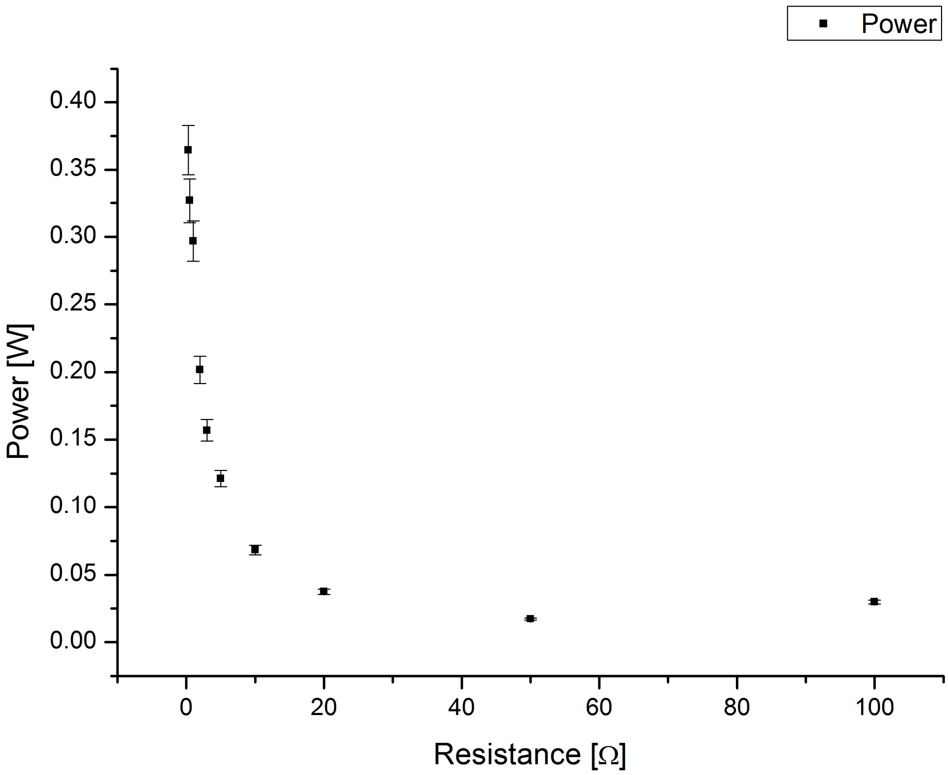
The aberration gets calculated by:

$$\Delta P_{\max-sys} = \left|\Delta U_{sys} \cdot \left[\frac{\partial P}{\partial U}\right]\right| + \left|\Delta I_{sys} \cdot \left[\frac{\partial P}{\partial I}\right]\right| = 0{,}006\ W \tag{7}$$

Parallel circuit:

R in Ω	open	100	50	20	10	5	3	2	1	0,5	0,3
I in A	0,938	0,920	0,903	0,874	0,836	0,772	0,732	0,681	0,578	0,466	0,393
U in V	0	0,033	0,019	0,043	0,082	0,157	0,214	0,296	0,514	0,702	0,927
P in W	0	0,030	0,017	0,038	0,068	0,121	0,157	0,202	0,297	0,327	0,364

So the largest power of the parallel circuit is at 0,3 Ω.



3.5. Electrical-chemical efficiency

To calculate the efficiency you use this formula:

$$\epsilon_{elect} = \frac{U}{E_0} = -\frac{zF}{\Delta G} \cdot U$$

$z = 2$

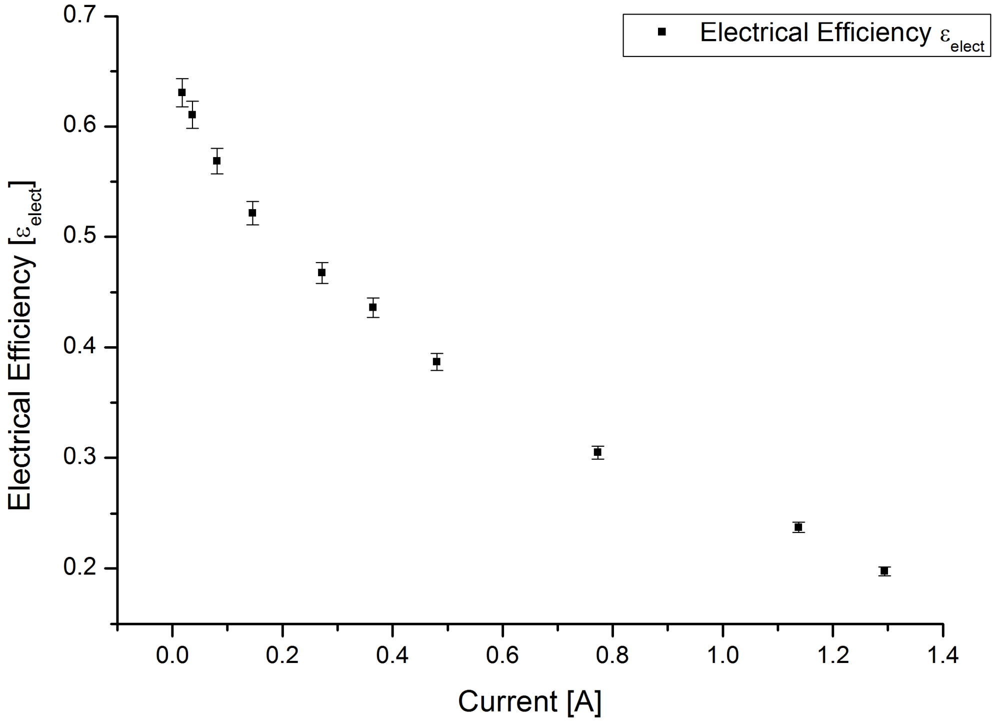
$$F = 9{,}6485 \cdot 10^7 \frac{C}{kmol}$$

$$\Delta G^0 = 237{,}3 \frac{kJ}{mol}$$

You have to calculate with the half of the detected voltage and the full current at the seriela current. By the parallel circuit you have to calculate the other way around.

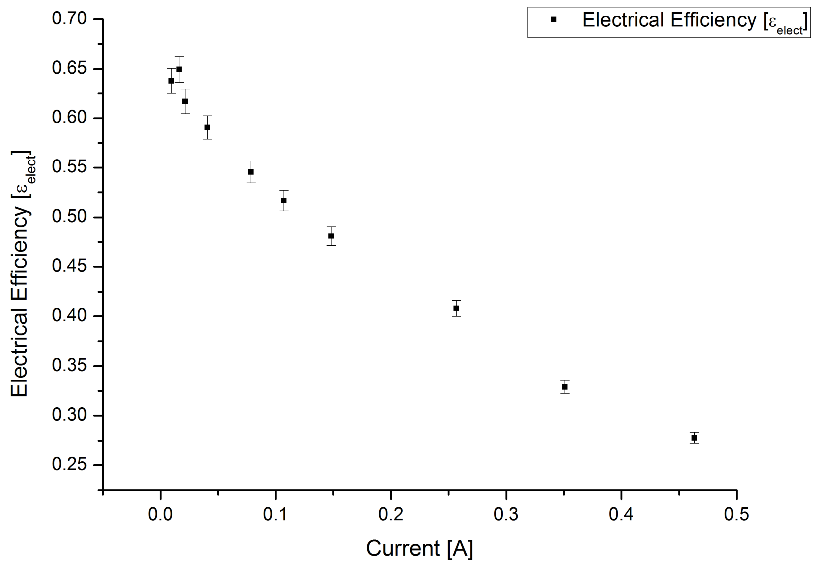
Serial circuit:

I in A	0,947	0,893	0,865	0,805	0,739	0,662	0,618	0,548	0,432	0,337	0,280
U in V	0	0,018	0,036	0,081	0,146	0,272	0,364	0,480	0,773	1,138	1,294
efficency	0,668	0,631	0,611	0,568	0,522	0,467	0,436	0,387	0,305	0,238	0,197



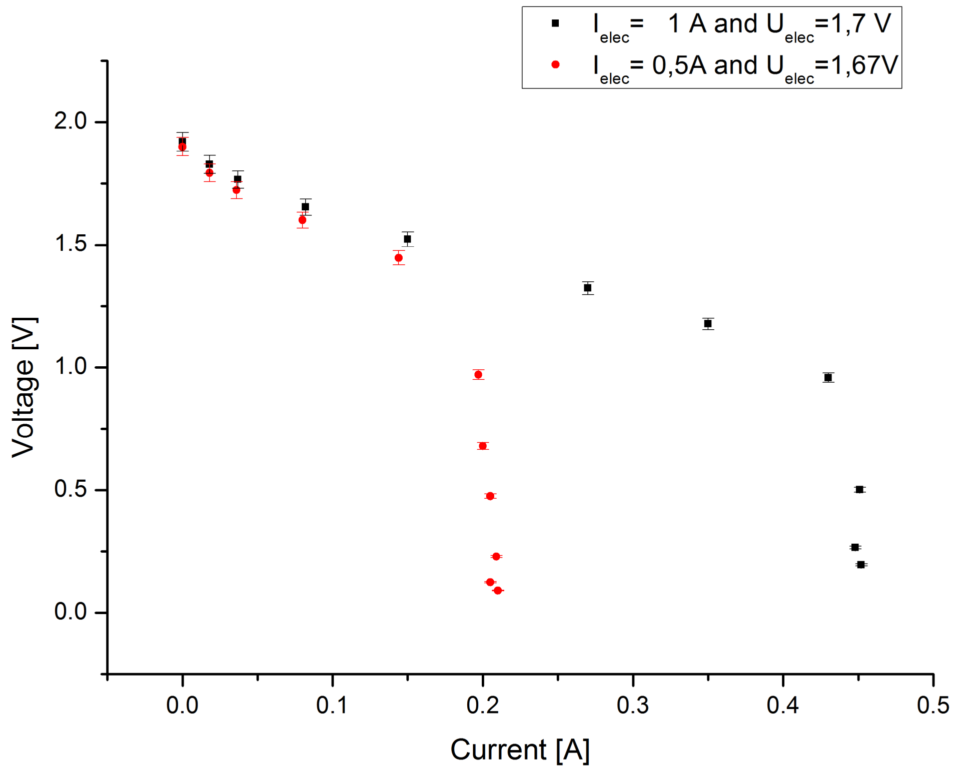
Parallel circuit:

I in A	0	0,016	0,010	0,022	0,041	0,079	0,107	0,148	0,257	0,351	0,463
U in V	0,938	0,920	0,903	0,874	0,836	0,772	0,732	0,681	0,578	0,466	0,393
efficiency	0,662	0,649	0,638	0,617	0,591	0,545	0,517	0,481	0,408	0,329	0,278



3.6. Measurement of the characteristic curve with limitation of the stream of Volumina

The first graph is without leakage current:



3.7. Efficiency of the complete experiment

The efficiency gets calculated by the following formula:

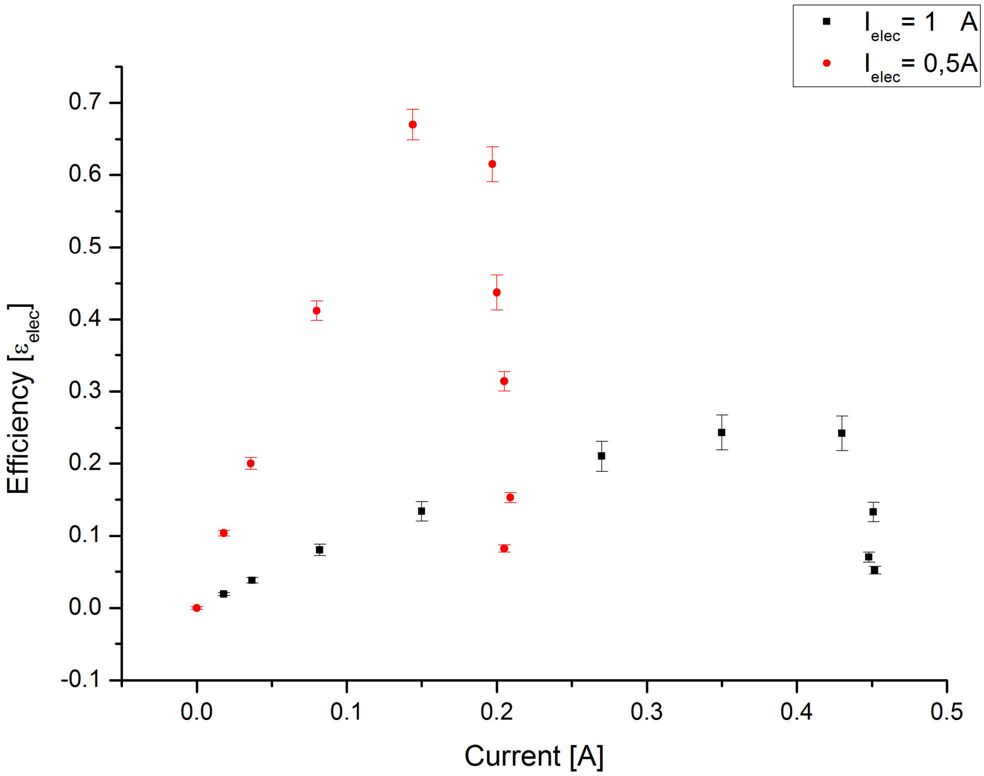
$$\varepsilon_{experiment} = \frac{W_{fuel-cell}}{W_{elektrolyseur}} = \frac{U \cdot I \cdot t}{U_{elektrolyseur} \cdot I_{elektrolyseur} \cdot t}$$

· $I_{elektrolyseur}$=1A

R in Ω	100	50	20	10	5	3	2	1	0,5	0,3
U in Vt	1,827	1,766	1,654	1,523	1,323	1,178	0,958	0,501	0,265	0,195
I in A	0,018	0,037	0,082	0,15	0,27	0,35	0,43	0,451	0,448	0,452
efficiency	0,019	0,038	0,080	0,134	0,210	0,243	0,242	0,133	0,070	0,052

· $I_{elektrolyseur}$=0,5A

R in Ω	100	50	20	10	5	3	2	1	0,5	0,3
U in V	1,9	1,793	1,723	1,601	1,446	0,97	0,679	0,475	0,228	0,124
I in A	0	0,018	0,036	0,08	0,144	0,197	0,2	0,205	0,209	0,205
efficiency	0	0,104	0,200	0,412	0,670	0,615	0,437	0,314	0,153	0,082



4. Summary

The experiment showes the function of a fuel cell.

5. Sources

1. M. Saß. “Umgang mit Unsicherheiten”. 09.07.08.
2. M. Saß. “Thermodynamik – Brennstoffzelle“. 20.04.09.