Successful Replication of a LEC Device

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recap of lenr-forum.com posts, June 2021

Introduction

In March 2021 I started planning a replication of the Frank Gordon's LEC device, described at the RNBE 2020 and ICCF-23 conferences and discussed on lenr-forum.com. The most interesting feature of this device was its simplicity and apparently high reproducibility (the device was already replicated by other researchers). In designing the experiments the first concern was to exclude any parasitic effect due to electromagnetic interferences, noise, instrument drift and other conventional (but not obvious) effects. To this end a series of control experiments were designed and done before the actual replication. The second aim was to design a very simple structure that can be easily modified and reutilized in order to allow a variety of tests.

Once the structure was built, the control experiments were performed, confirming the absence of undesired effects and the instrument sensitivity and noise level. Then the active electrode was realized and the full replication was completed and tested. Compared to other previously described implementations of the LEC, the devices here reported employed an iron plating, not a palladium one. This made the process very simple and inexpensive. The obtained results were almost identical to the ones reported by Frank Gordon, confirming the high reproducibility of this experiment and the reality of the underlying effect.

The following paragraphs are partly taken from my posts on lenr-forum.com on this topic.

Structure of the device

In order to replicate the LEC, I designed a "lab rat" version of the device, i.e. a very simple structure in which one can modify things easily, without the need of rebuilding all from scratch every time. This structure is depicted in Fig. 1. Both electrodes are made from small diameter metal tubes (6 mm OD the outer one, 4 mm OD the inner one, both 1 mm thick): the working electrode (WE) can be electroplated, inserted in the counter electrode (CE) with a couple of rubber spacers, then the assembly can be sealed (with rubber fittings or epoxy). Given the dimensions, the gap between the two electrodes is 0.5 mm. The WE tube will also be used to evacuate and fill the device with hydrogen or other gases (the 4 mm tube can be directly fitted to many off-the-shelf pneumatic fittings). Different metal combinations are possible

(brass, copper and aluminium tested) and different gas pressures can be used, in order to verify how the generated voltage and current are affected.

The first step has been characterizing the control devices, i.e. devices with identical mechanical structure of the final device, but without electroplating on the WE. This provided a clear picture of the baseline behaviour. This tests gave, among other things, a clear answer to the hypothesis of simple galvanic voltage generation.

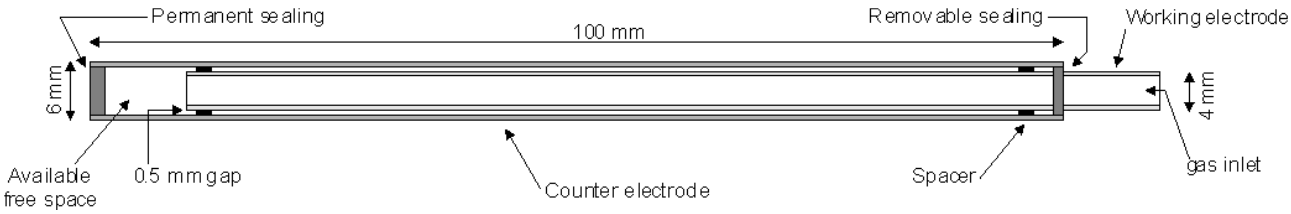

Figure 1 – Design of the test LEC device.

Experiments with control devices

I tested three control devices made with a brass WE and three different CEs: brass, aluminium and copper (see Fig. 2). The first tests were performed with air at atmospheric pressure, 23.9°C, 46% RH. Then Hydrogen and air at lower pressure has also been tested.

I used a Tektronix (Keithley) DMM6500 multimeter, that features a very high precision, customizable integration time and filtering. The instrument was set to 10 MOhm input impedance and an integration time of 20 ms + averaging of 100 samples.

At first I measured the capacitance of the three devices, since this may affect their dynamic behaviour and it is directly related to the device geometry (so it is useful for comparing them). Results were the following:

- **Brass-Brass**: 30 pF ± 10 pF
- **Brass-Aluminium**: 30 pF ± 10 pF
- **Brass-Copper**: 30 pF ± 10 pF

So, the geometry is consistent for the three devices (and it is quite in good agreement with calculations). The difference in metals was not relevant.

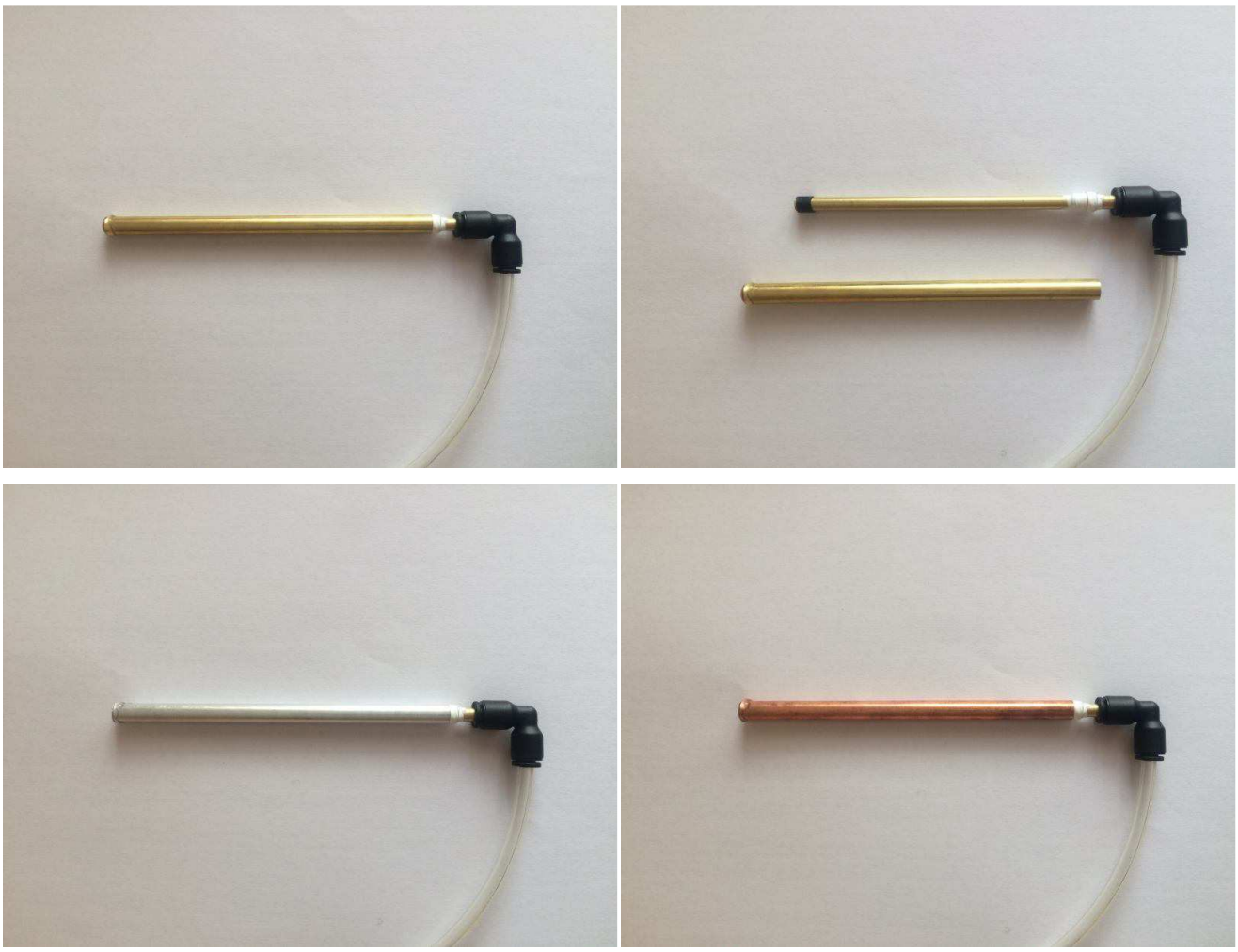

Figure 2 – Some LEC devices used for the control experiments: the inner tube (WE) is the same, the outer tube (CE) can be changed in order to test different metal pairs.

The second measurements were on open circuit voltage. The instrument was connected in either ways to the devices (WE with the positive probe, CE with the negative one, and then vice versa), and the result was the same for the three devices. The readings were the following:

- **Brass-Brass:** 0.01 mV ± 5 uV
- **Brass-Aluminium:** 0.01 mV ± 5 uV
- **Brass-Copper:** 0.01 mV ± 5 uV

This is very important: it imply that the devices do not generate any spontaneous voltage, even when different metals are used together. This is a first confirmation that the voltage observed in the LEC by Frank

Gordon et al. is not due to galvanic effects or other common phenomena. These numbers can be considered the noise floor of the instrumentation and setup for the voltage measurement.

The third measurement was on the capability of the device to conduct a current when an external voltage is applied. I connected the devices to a DC voltage ranging from -60 V to +60 V in step of 5 V, and measured the current. The result was the following (independent from the applied voltage):

- **Brass-Brass:** 0 uA ± 0.5 nA [from -60 V to +60 V]
- **Brass-Aluminium:** 0 uA ± 0.5 nA [from -60 V to +60 V]
- **Brass-Copper:** 0 uA ± 0.5 nA [from -60 V to +60 V]

In other words the devices does not conduct current. This result is actually a second important confirmation that the original LEC has something unique: not only it generates a voltage, but it is also able to conduct a current (either spontaneous, either under an external stimulus). This is remarkable, also considering that in the original LEC the electrode gap is bigger than the one I tested.

I repeated the measurement at a lower pressure (down to about 300 Torr), still air only. Same setup and same measurements, just to verify the influence of decreasing gas pressure.

The results were the same. Gas pressure in this range do not significantly affect spontaneous voltage and currents.

However, in order to observe very fine effects, I tried to quantify the forced current through the device, pushing the instrumentation to its maximum resolution (I did this by taking longer measurements and averages). This time I got some stable values. With an external applied voltage of ± 60 V the current through the device is about ± 250 pA (the sign is the same as the voltage). When decreasing the voltage, the current decreases linearly. Below 20 V the instrument had no sufficient resolution and noise margin to measure it. So, about 100 pA can be considered the instrumentation and setup noise floor for current measurements.

Once I got stable measurements, I verifyed again the effect of decreasing the pressure. The result was that the current also decreased. At first this surprised me (I intuitively expected the opposite), but I found in the literature that it is exactly what should happen in this range of voltages, distances and pressures, where conduction is only due to stochastic phenomena (this is beautifully described in the first chapter of "*Conduction of electricity through gases*" by J.J. Thomson).

I completed the tests on the control devices by measuring voltages and currents with hydrogen instead of air. The results were almost the same:

- **Open circuit voltage:** 0 mV ± 0.025 mV, independently from metals and pressure
- **Current @ ±60V:** 0 uA (± 90 pA), independently from metals, slightly decreasing with pressure

These results are quite robust: a device with the structure of the LEC, with an untreated WE electrode, does not generate a spontaneous voltage and, most important, is not capable of conducting a meaningful current (in this voltage range). This behaviour is not affected by the employed metals, by the type of gas (air and hydrogen tested), and gas pressure (range tested 300 to 760 Torr). The behaviour of the control device is exactly the one expected from the theory.

The spontaneous voltage and the capability of conducting a current of the original LEC device, cannot be explained by galvanic or other bimetallic effects or by electrochemical potentials, since all these elements are also present in the tested control devices.

Final remark: measuring very small DC voltages with high impedances (indeed an open circuit) can be very challenging because of noise, RFI, EMI and other environmental factors. The readings where even sensitive to my movements inside the lab when no proper precautions were used. For this reason it is important to use a measurement impedance of maximum 10 MOhm (better 1 MOhm), and a long integration/filtering so to recover the DC component from multiple samples (not the RMS!). Measuring currents across a relatively lower load (in the order of 100 kOhm) and deriving the voltage may be an even more robust approach.

The obtained sensitivity and noise level however allow to detect with great confidence voltages in the order of mV and current in the order of uA (the order of magnitudes reported for the LEC).

Tests on the active LEC

The device used for the active tests is exactly the same tested before as control. The only difference is the co-deposition process, involving the plating of a thin layer of iron on the brass WE tube.

Electroplating / co-deposition process

The working electrode (WE) was gently rubbed with fine sandpaper and cleaned with alcohol, then it was placed in the electrolytic cell.

The cell was realised with a test tube, with four 1 mm iron wires surrounding the WE. The iron wires were connected to positive voltage while the WE was connected to negative (ground). The electrolyte was 1/4 HCl 20%, 3/4 tap water. No $FeCl_2$ was added: Fe++ ions were directly obtained from the anode wires.

The current was set by finely (manually) regulating the power supply voltage. The cell is shown in Fig. 3 (please note that the leads colour is inverted, but the applied polarity was right).

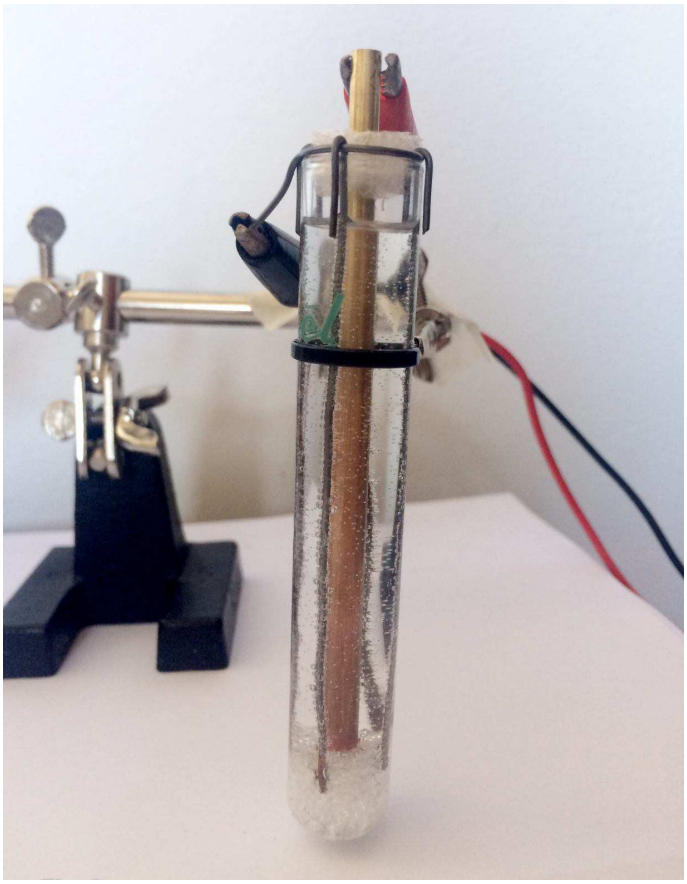

Figure 3 – Electrolytic cell used for the co-deposition process. Starting of the process.

The current was set and maintained as follows, according to Frank Gordon's indications:

8:00 - 8:35:	0.7 mA	(80 uA/cm^2, 0.167 V)
8:35 - 9:05:	1.7 mA	(190 uA/cm^2, 0.254 V)
9:05 - 12:00:	16 mA	(1.8 mA/cm^2, 0.375 V)
12:00 - 16:00:	25 mA	(2.8 mA/cm^2, 0.450 V)

Temperature was 26.4°C, 45%RH at the beginning of the process, 26.6°C, 51%RH at the end.

At 15:30 the electrode appeared as shown in Fig.4 (it became black quite abruptly).

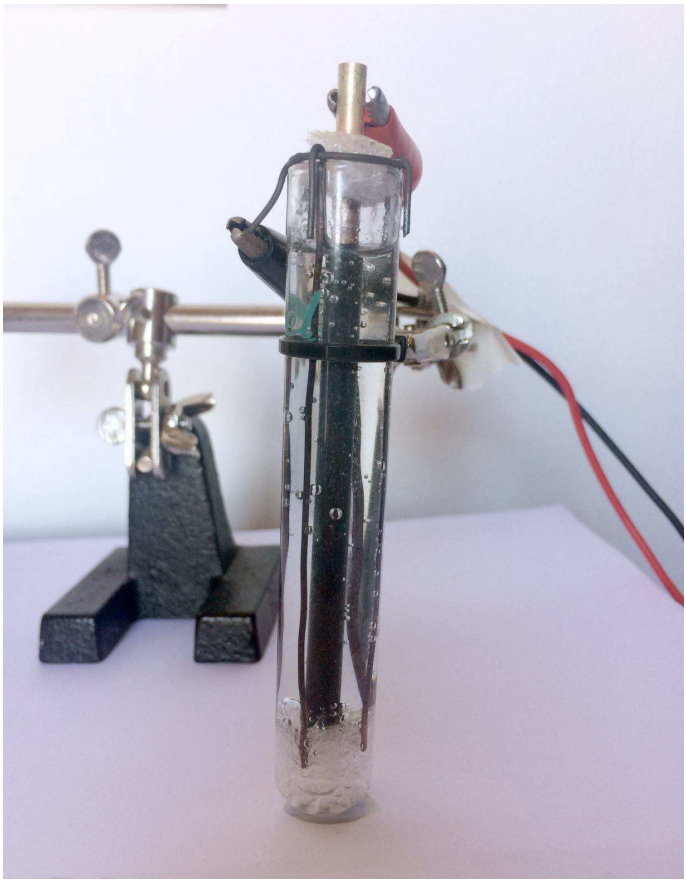

Figure 4 – Appearance of the WE at the end of the co-reposition process.

Preliminary test

The plating process was ended at 16:00, the power supply disconnected and the WE was extracted, rinsed with tap water and dried accurately with soft paper towel. The plating appeared quite uniform, well attached to the brass substrate and with a fine porosity. The thickness was not measurable (probably less than 10 um). An unexpected phenomenon was noted while taking out the WE from the cell: the WE, as well as the iron wires, became magnetised attracting each other. This is not easy to explain considering the very small currents involved and the opposite current paths, that should almost cancel out the generated magnetic field.

The WE was inserted into the brass counter electrode (CE) in air at atmospheric pressure. No hydrogen was added. The voltage was measured with a multimeter with 10 MOhm input impedance.

The initial reading was close to 0 mV, then, in tens of seconds, it started rising and stabilizing around 242 mV. This was a clear indication that the device was generating a voltage (the noise level was about 1 mV). This immediately triggered other tests and experiments, that were carried out in another lab. The device was closed but not permanently sealed, in order to allow further experiments. These were done as fast as possible, in order to prevent the oxidation of the Fe plating and/or hydrogen desorption.

Voltage measurements

The first test was to accurately measure the open circuit voltage and short circuit current of the device, using the brass CE as well as the aluminium and copper ones. The positive probe of the multimeter (10 MOhm impedance) was connected to the WE, the negative to the CE. Signs of voltages and currents reflects this choice. The voltage of device with the brass CE was **-307 mV**, the short circuit current was **-2.4 uA**. The voltage of the aluminium CE was **223 mV**, and the current **1.5 uA**. The voltage of the copper CE was **-234 mV** with a **-0.69 uA** short circuit current. The voltage of the brass CE increased slowly over time, so probably also with the other two metals higher figures would be obtained by extending the measurement time. During this experiment the peak voltage with brass CE was about 330 mV, as shown in Fig.5.

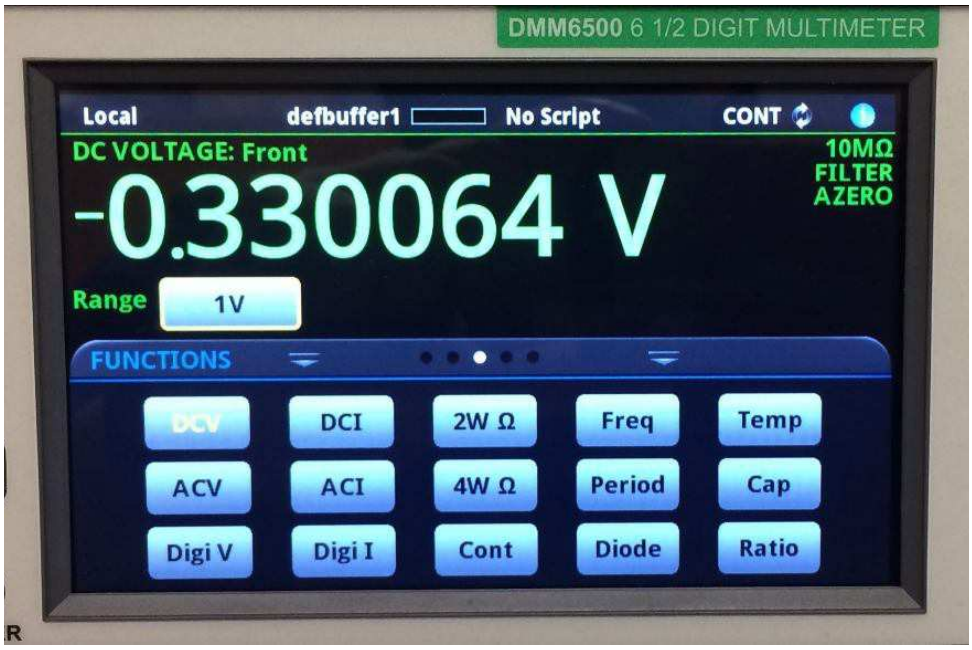

Figure 5 – Open circuit voltage measured on the brass - brass device after some time from the beginning of the tests.

Another test was done by loading the device (only brass CE from now on) with various resistors. The result is shown in the attached Voltage plot. The behaviour is exactly the one reported by Frank Gordon at ICCF-23, showing an internal resistance in the order of 100 Kohm (Fig. 6).

Open circuit voltage (mV)		
Br-Br	Br-Al	Br-Cu
-307	223	-234

Short circuit current (uA)		
Br-Br	Br-Al	Br-Cu
-2.4	1.5	-0.69

oltave vs Load	
Load (kOhm)	Voltage (mV)
10000	-307
1000	-285
100	-155
10	-29
1	-3.3

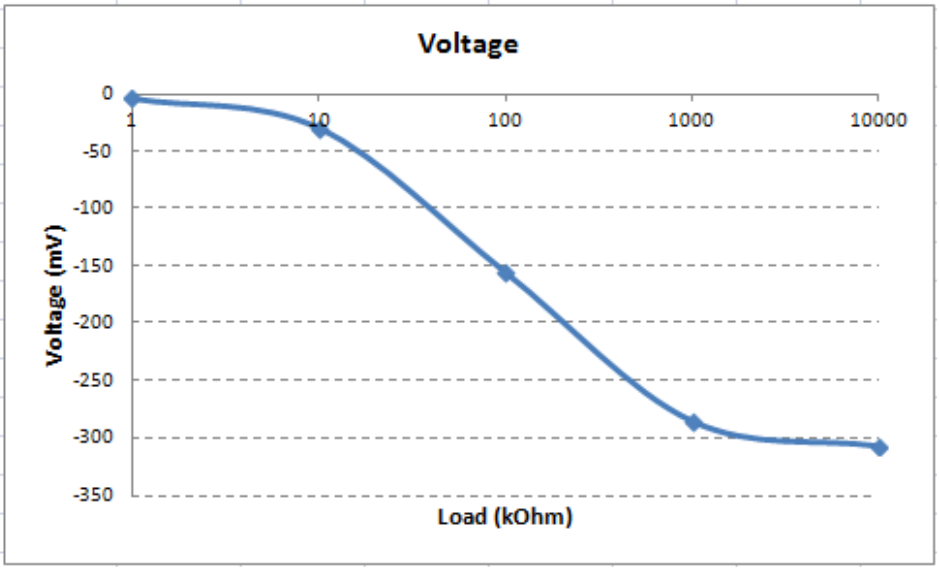

Figure 6 – Open circuit voltage and short circuit current for the three devices ("Br" standing for Brass), and loaded voltage plot.

Current measurements

The capability of the active device of conducting a current was tested, as previously done with the control devices, by applying an external voltage. The result is shown in the Current plot (Fig. 7). The device was able to conduct a meaningful amount of current, so the external voltage range was limited to ± 10V, in order to avoid to damage the device (e.g. desorb the hydrogen). Maximum current at 10V was about 136/140 uA, compared to less than 100 pA measured on the control device: the active device is 6 order of magnitude more conductive. It can be noted from the plot that the current tend toward a saturation at higher voltage, this however was not explored during this experiments.

Forced current	
Voltage (V)	(Current (uA)
-10	-136
-9	-130
-8	-120
-7	-100
-6	-95
-5	-80
-4	-64
-3	-49
-2	-34
-1	-18
0	-2.96
1	16
2	30
3	45
4	64
5	80
6	96
7	110
8	120
9	130
10	140

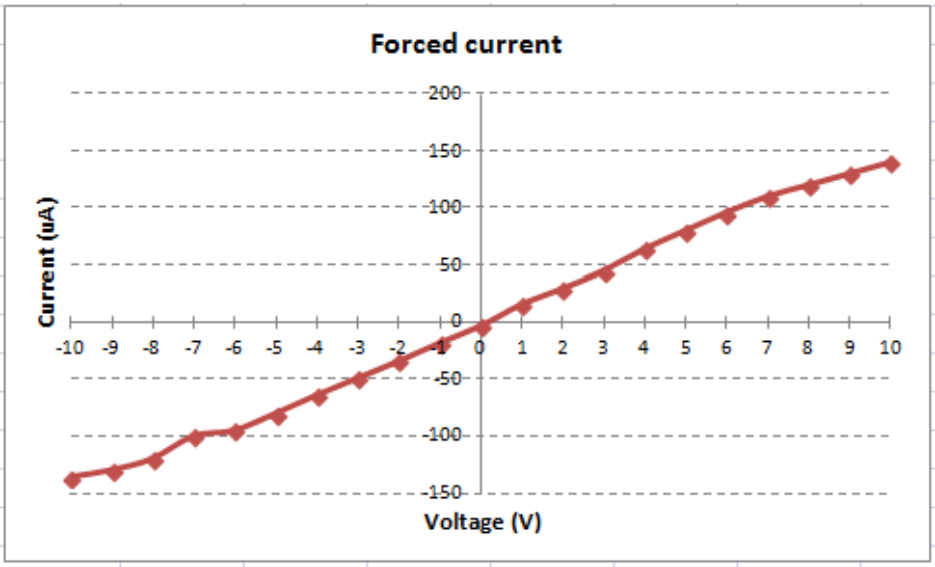

Figure 7 – Current plot by applying an external voltage ranging from -10 V to +10 V.

Additional experiments

In order to verify the capability of the device to generate useful power/energy, the LEC was connected to a 100uF electrolytic capacitor, and the charging process was monitored. The result is shown in Fig. 8. The capacitor was fully charged in about 90 seconds, it was disconnected and separately measured. The stored voltage was 309 mV, so the stored energy was 4.7 uJ. The time constant of the charging curve was 15 s. The time constant is equal to the RC product of the circuit, so the internal R of the LEC is about 150 kOhm. This is in good agreement with the load plot.

Another test was done on the naked WE (in air), with a Geiger-Muller counter (LND712 tube, mica window, alpha sensitive), in order to detect potential radiations. The counts for background, for sample and for sample + plastic shield are reported in the plot: no meaningful evidence of radiation were found.

Lastly, the naked CE was left in air and in the darkness for about 1 hour, in contact with a glow-in-the-dark plastic strip containing ZnS(Ag) and some fluorescent substances. No fluorescence or phosphorescence was visibly excited in the materials.

100 uF capacitor charging	
Time (s)	Voltage (mV)
0	0
5.4	100
16.5	200
43.5	300
90	310

Geiger CPM (LND712)	
Background	9.4
WE	11.4
WE + PE shel	11.6
Note: average over 5 min	

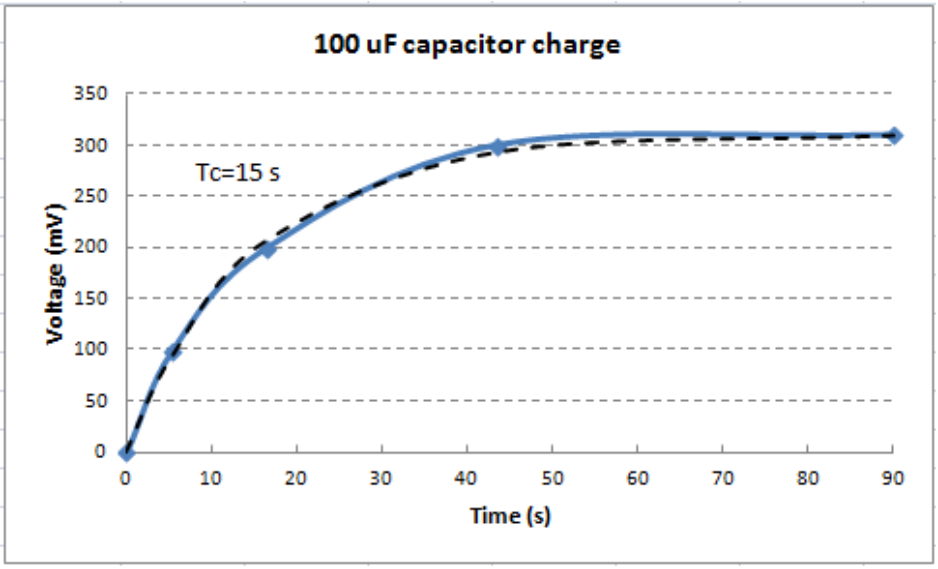

Figure 8 – Results for the capacitor charging experiment and for the Geiger-Muller counter measurements.

Final considerations

All the tests made were limited by the short time available before signs of oxidation (rusting) appeared on the iron WE plating layer. Probably this effect can be reduced if the WE is sealed with hydrogen inside the CE. The day after the experiment, the condition of the WE was that shown in Fig. 9, where visible oxidation can be noted. In this condition the LEC performance decreases (voltage was 50 mV or less). It is not clear if this effect was due to oxidation or hydrogen desorption. Tests with Ni or Pd plating should provide some insight on this.

Figure 9 – Oxidation appearing on the WE after exposing to air (mainly left).

Conclusions

A working LEC device was successfully replicated. The entire process was not difficult or critical in any way. The capability of the LEC of conducting a current should only be explained by the emission or generation of ions by the WE. The kind of emission of the WE remains unknown and require further investigation. The capability of the device of conducting a current in both directions imply that the same amount of charges of both signs are present in the gas. These are most probably generated in the gas itself by the radiation. In order to ionise the gas (air, in this case) this radiation must have an energy at least in the order of tens to hundreds eV. The generated voltage varied with the employed metal pairs, and changed its sign when aluminium was used. This is in accordance with electrode potentials (considering as iron the WE). This may imply that the voltage generation can be explained by some relatively conventional electrochemical process (even if the environment and conditions are not conventional at all). The ionization however cannot be explained with conventional (electro)chemical processes, requiring an energy that is generally beyond the chemical range. So the ability of ionising the gas is the most surprising and interesting characteristic of the LEC. By the way, the observed phenomena are in accordance with the ones described by Rout and Srinivasan on deuterated palladium samples (Rout et al. "*Reproducible, anomalous emissions from palladium deuteride/hydride*". Fusion Technol., 1996. no. 30, p. 273.), except the fact that in this case ionization of air was confirmed and directly measured. Finally some magnetic anomalies were noted during the production and test of the LEC, that also need to be better investigated.