

This is a preprint of:

Di Stefano, A. *Experimental Observation on the Lattice Energy Converter*. in *ICCF24 Solid-state Energy Summit*. 2022. Mountain View, CA.

This file also includes the PowerPoint slides from the presentation.

The video of the presentation is here:

ICCF24 Presents: Antonio Di Stefano - Experimental Observations on the Lattice Energy Converter

<https://www.youtube.com/watch?v=hjkNBxzRYUE>

Paper about the lattice energy converter (LEC) by Gordon and Whitehouse are here:

Gordon, F. and H.J. Whitehouse, *Lattice Energy Converter*. *J. Condensed Matter Nucl. Sci.*, 2022. **35**: p. 30-48 <http://lenr-canr.org/acrobat/BiberianJPjcondensedzh.pdf#page=36>.

Gordon, F. and H.J. Whitehouse, *Lattice Energy Converter (LEC) (PowerPoint slides)*, in *LENR Workshop in memory of Dr. M. Srinivasan*. 2021: Indian Institute of Technology Kanpur <http://lenr-canr.org/acrobat/GordonFlatticeene.pdf>.

Here is a video by Gordon:

Part 1 : UNDERSTANDING LENR – LATTICE ENERGY CONVERTER (LEC)

<https://www.youtube.com/watch?v=yO-KIGKVHkI>

Experimental Observation on the Lattice Energy Converter

*Antonio Di Stefano*¹

ICCF24, July 27th 2022 – Draft preprint paper

Introduction

In March 2021 the author started a replication of the Frank Gordon's and Harper Whitehouse's Lattice Energy Converter (LEC), as described at the RNBE 2020 conference and later at ICCF23 and subsequently discussed in detail on lenr-forum.com. The most interesting feature of this device was its simplicity and apparently its 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, instrumentation drift and other conventional (but not obvious) effects. To this end, a series of control experiments were designed and performed 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 conventional effects and the good instrumentation 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 employs 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 and Harper Whitehouse, confirming the high reproducibility of this experiment and the reality of the underlying effect.

Structure of the device

In order to replicate the LEC, it was designed a "laboratory" version of the device, i.e. a very simple structure which can be easily modified, without the need of entirely rebuilding the device. 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). For the given dimensions, the gap between the two electrodes is 0.5 mm. The WE tube is also used to evacuate and fill the device with hydrogen or other gases (the 4 mm tube can be directly fitted

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into many off-the-shelf pneumatic fittings). Different metal combinations are possible (brass, copper and aluminium were tested) and different gas pressures can be used, in order to verify how the generated voltage and current are affected.

The first step was characterizing the control devices, i.e. a devices with identical materials and mechanical structure of the active 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.

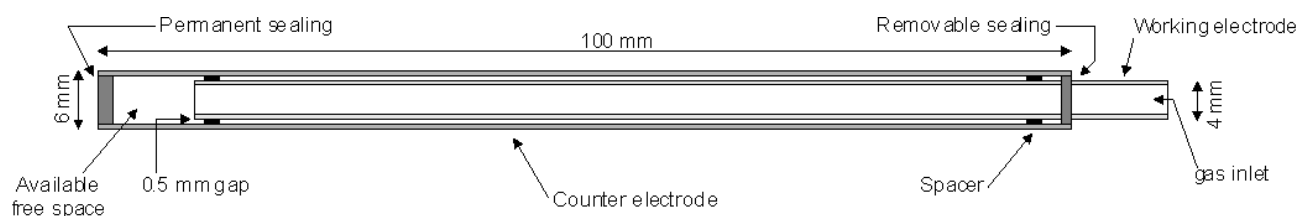


Figure 1 – Design of the test LEC device.

Experiments on the control devices

Three control devices were tested, made with a brass WE and three different metal for the 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 have also been tested.

A Tektronix (Keithley) DMM6500 multimeter was used, featuring 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 (50 Hz mains) + averaging of 100 samples.

At first the capacitance of the three devices where measured, since this may affect their dynamic behaviour and it is directly related to the device geometry (it was 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 was consistent for the three devices, and the capacitance was in good agreement with calculations. The difference in metals was not relevant.

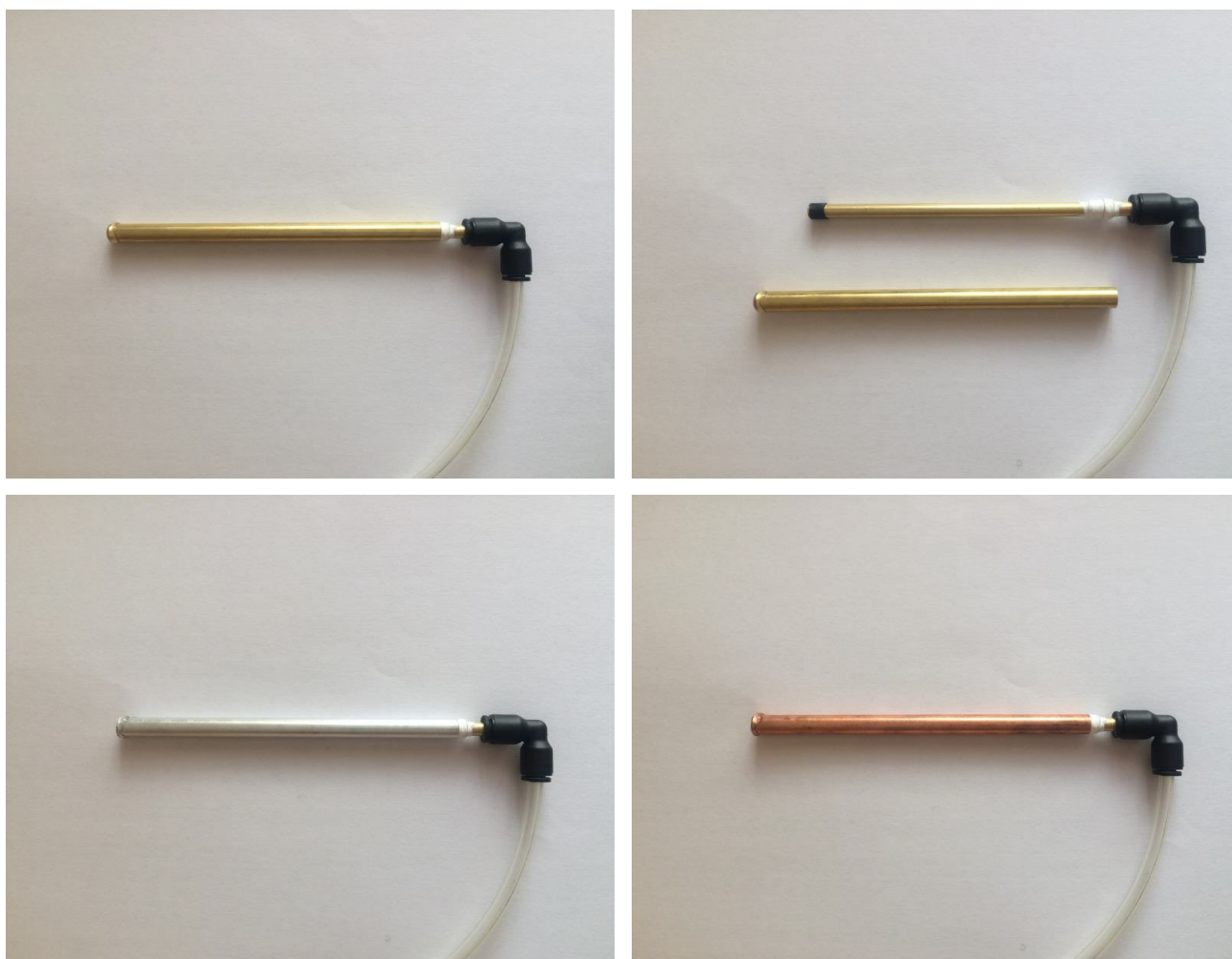


Figure 2 – Some LEC devices used for the control experiments: the inner tube (WE) is the same, the outer tube (CE) can be changed in order to test different metal pairs.

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), obtaining almost the result for the three devices. The readings were the following:

- **Brass-Brass:** 0.01 mV \pm 5 μ V
- **Brass-Aluminium:** 0.01 mV \pm 5 μ V
- **Brass-Copper:** 0.01 mV \pm 5 μ V

This was an important result: it imply that the devices do not generate any spontaneous voltage, even when different metals are used together. This was a first confirmation that the voltage observed in the LEC by the inventors is not due to bimetallic, galvanic or chemical effects, or other conventional phenomena.

These numbers can be considered the noise floor of the instrumentation and setup for the voltage measurement.

The third measurement was done on the capability of the device to conduct a current when an external voltage is applied. A DC voltage ranging from -60 V to +60 V in step of 5 V was connected to the device, and the current measured. The following results were obtained (independently from the applied voltage):

- **Brass-Brass:** $0 \mu\text{A} \pm 0.5 \text{ nA}$ [from -60 V to +60 V]
- **Brass-Aluminium:** $0 \mu\text{A} \pm 0.5 \text{ nA}$ [from -60 V to +60 V]
- **Brass-Copper:** $0 \mu\text{A} \pm 0.5 \text{ nA}$ [from -60 V to +60 V]

This data essentially imply that the devices do not conduct current. This result is actually a second important confirmation that the original LEC has a unique behaviour: according to the inventors 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 tested here.

All these measurements were repeated 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.

A further attempt was done to better quantify the forced current through the device, pushing the instrumentation to its maximum resolution. This was done by taking longer measurements and averages. This allowed to obtain stable values at very low currents. With an external applied voltage of $\pm 60 \text{ V}$ the current through the device was about $\pm 250 \text{ pA}$ (the sign follows 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.

With this higher resolution setup, the effect of decreasing the pressure was again tested. The result was that the current slightly decreases with the pressure. At first this result was unexpected, but as found in the literature, this 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).

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

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

These results are very robust: a device with the structure of the LEC, with a untreated WE electrode, does not generate a spontaneous voltage and, most importantly, 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 (tested range from 300 to 760 Torr). The behaviour of the control device is exactly the one expected from the theory.

Again, 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 should also present in the 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 were even sensitive to movements inside the lab when no proper precautions were taken. 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. 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 μ A (the order of magnitudes expected from the LEC).

Tests on the active LEC

The device used for the active tests was exactly the same tested before as control. The only difference was 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 at 20% concentration, 3/4 tap water. No FeCl₂ 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.

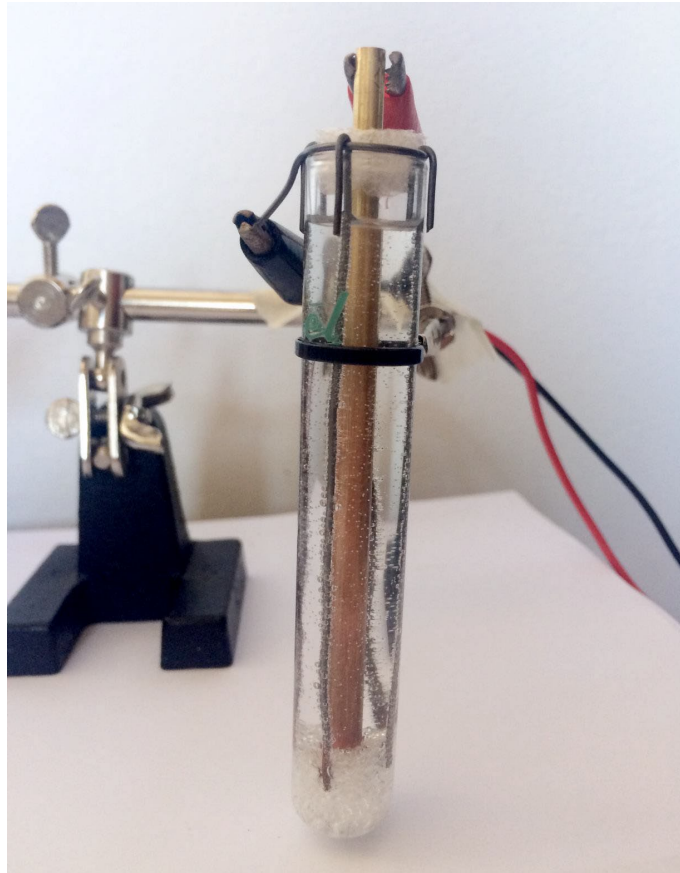


Figure 3 – Electrolytic cell used for the co-deposition process. Starting of the process. Note: the leads colour appear inverted in this picture, but the applied polarity was right.

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

8:00 - 8:35:	0.7 mA	(80 $\mu\text{A}/\text{cm}^2$, 0.167 V)
8:35 - 9:05:	1.7 mA	(190 $\mu\text{A}/\text{cm}^2$, 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).

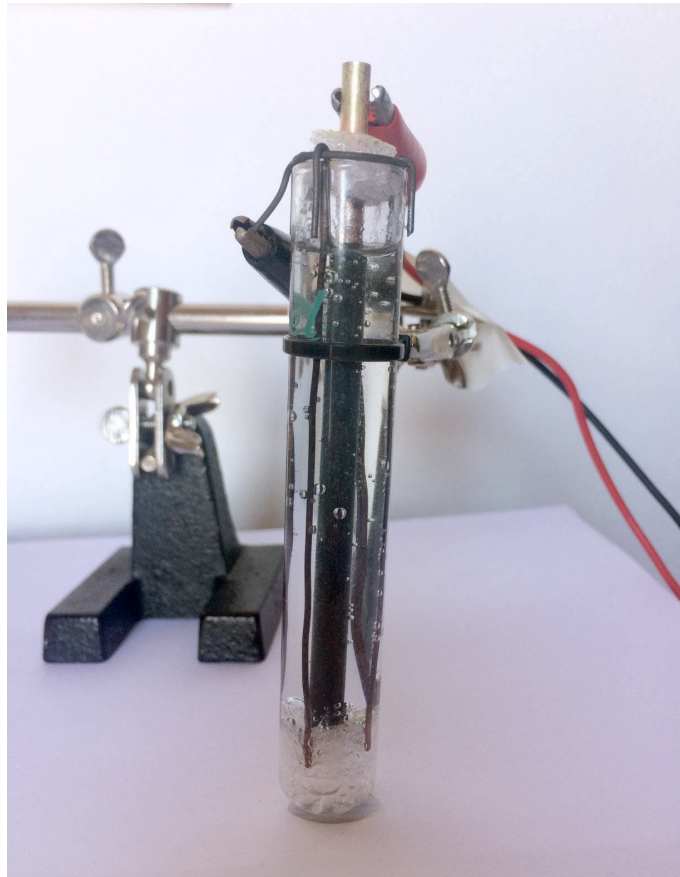


Figure 4 – Appearance of the WE at the end of the co-reposition process.

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 very fine porosity. The thickness was not measurable (estimated on the order of 10 μm). An unexpected phenomenon was noticed 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 then 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 M Ω 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. 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 μ A**. The voltage of the aluminium CE was **223 mV**, and the current **1.5 μ A**. The voltage of the copper CE was **-234 mV** with a **-0.69 μ A** short circuit current. The voltage of the brass CE increased slowly over time, so probably also with the other two metals higher value 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 ICCF23, showing an internal resistance in the order of 120 Kohm (Fig. 6).

Open circuit voltage (mV)			Short circuit current (uA)		
Br-Br	Br-Al	Br-Cu	Br-Br	Br-Al	Br-Cu
-307	223	-234	-2.4	1.5	-0.69

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

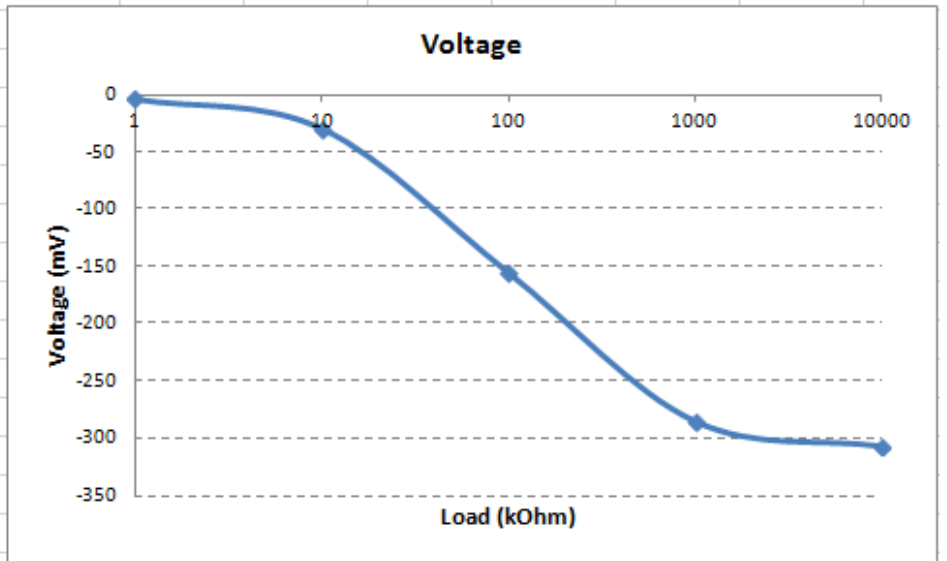


Figure 6 – Open circuit voltage and short circuit current for the three devices ("Br" standing for Brass), and loaded voltage plot.

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 apparently able to conduct a meaningful amount of current, so the external voltage range was limited to ± 10 V, in order to avoid to damage the device (e.g. desorb the hydrogen or damaging the co-deposited layer). Maximum current at 10 V was about 136/140 μ A, compared to less than 100 pA measured on the control device: the active device was 6 order of magnitude more conductive. It can be noted from the plot that the current tend toward a saturation at higher voltage: this is important because it is indicative of a true gas conduction phenomenon with limited charge carriers and not other type of conduction (through metal, electrolyte, etc).

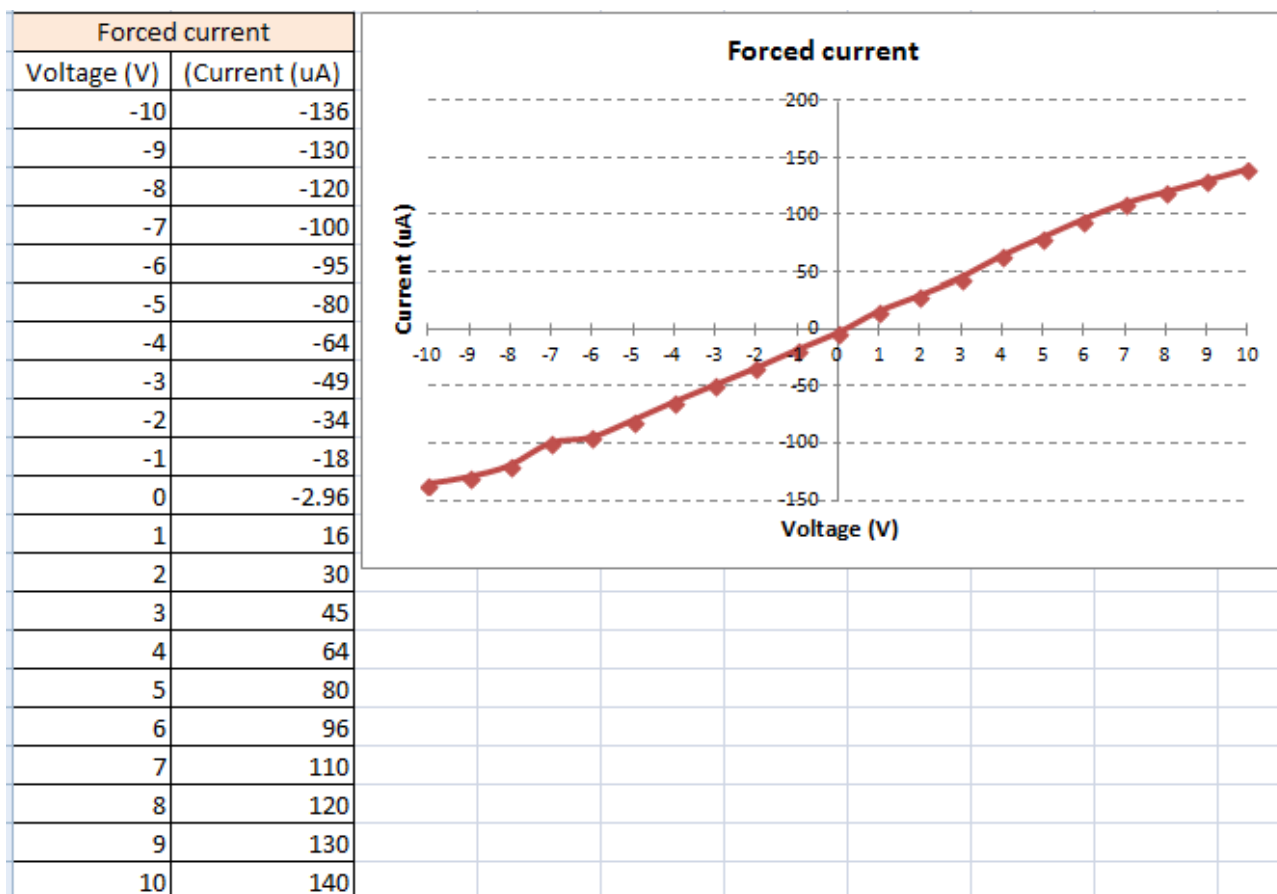


Figure 7 – Current plot by applying an external voltage ranging from -10 V to +10 V.

Additional experiments

In order to verify the capability of the device to generate useful power/energy, the LEC was connected to a 100 uF 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 μ J. 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 visible (by naked eye) fluorescence or phosphorescence was excited in the materials.

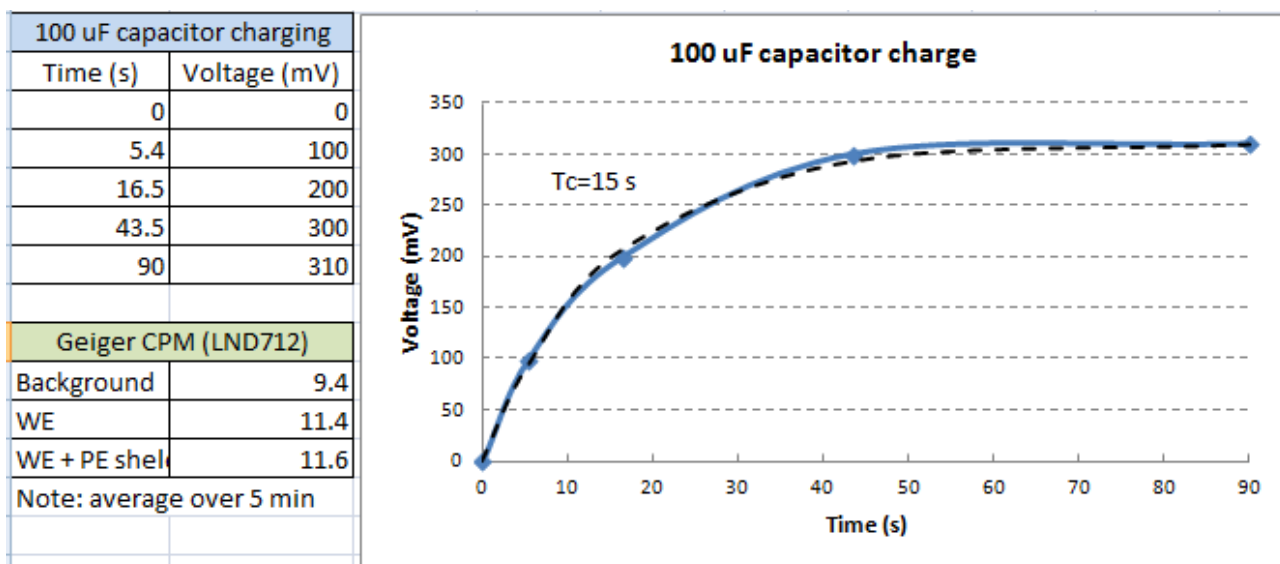


Figure 8 – Results for the capacitor charging experiment and for the Geiger-Muller counter measurements.

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 (the measured voltage was 50 mV or less). It is not clear if this effect was due to oxidation, hydrogen desorption or both. 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 can 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 some tens to some 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, and are not wet). 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.

Experimental Observations on the Lattice Energy Converter

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ICCF24 July 27 - 2022



Summary

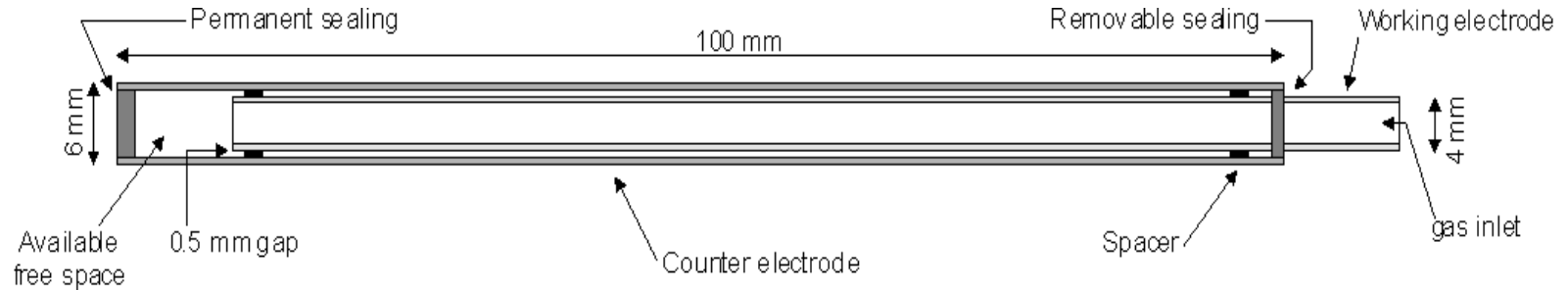
- Preliminary control testing
- Replication of the LEC
- Experiments and observations
- Conclusions

Step 1: testing for artifacts

- Reasons for thorough control testing:
 - Apparent similarity with conventional technologies
 - Presence of a bimetallic system and temperature gradients
 - Potential electrochemical effects
 - Possible (non obvious) gas phase reactions / interactions?
 - Measurement issues
 - Small signals, noise, EMI/RFI, DC instrumental drift, etc.

The dummy LEC

Building a LEC device but without the active layer



- Made with two small coaxial brass tubes
- Device length: 100 mm
- Gap between electrodes: 0.5 mm
- Rubber spacers and sealing
- Easy to assemble and disassemble
- Interchangeable CE (outer electrode)
- Brass, Copper and Aluminum CE tested



Tests on the dummy LEC

Tests with air and hydrogen from 300 to 760 Torr
using a high resolution and low noise instrument (Keithley DMM6500)

Open circuit voltage:

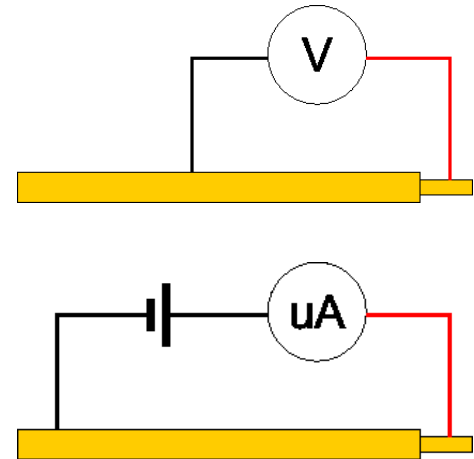
- Brass-Brass: $0.01 \text{ mV} \pm 5 \mu\text{V}$
- Brass-Copper: $0.01 \text{ mV} \pm 5 \mu\text{V}$
- Brass-Aluminum:
(No spontaneous current)

Close circuit forced current:

- Applied voltage: $\text{from } -60 \text{ V to } +60 \text{ V}$
- Brass-Brass: $0 \mu\text{A} \pm 0.5 \text{ nA}$
- Brass-Copper: $0 \mu\text{A} \pm 0.5 \text{ nA}$
- Brass-Aluminum: $0 \mu\text{A} \pm 0.5 \text{ nA}$

Conclusion:

- 1) The basic LEC structure is incapable of generating a voltage or conducting a current
- 2) The instrumental sensitivity is in the order of $1 \mu\text{V}$ and $<1 \text{ nA}$



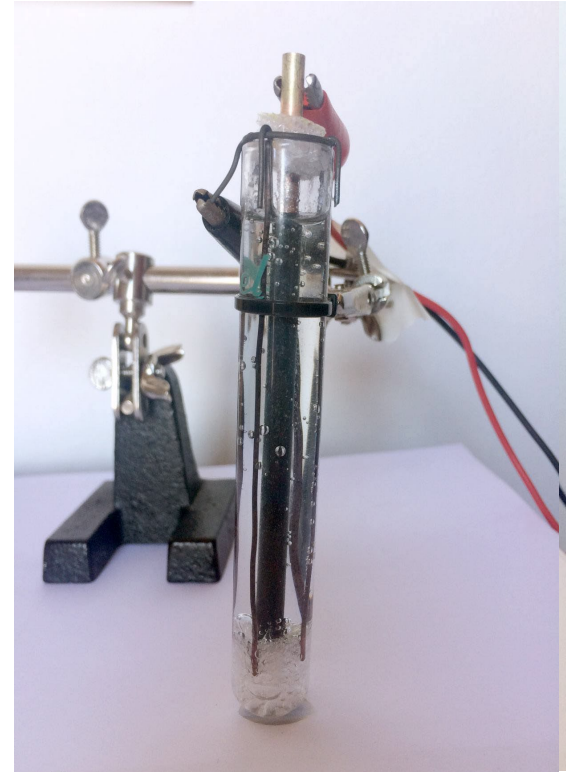
Step 2: adding the active layer

The brass WE was electroplated with Fe:

- Electrolyte: 1/4 HCl 20%, 3/4 tap water
- Soft white iron wires as anode
- Average current density: 1 mA/cm²
- Voltage: less than 0.5 V
- Time: about 8 hours

Observations:

- First 6 hours: visible hydrogen evolution
- Last 2 hours: deposition of a black layer
- The black layer was matte and magnetized (probably containing magnetite nanocrystals)



Testing the active LEC

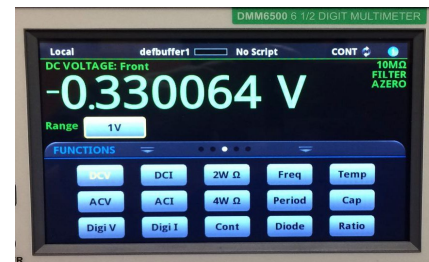
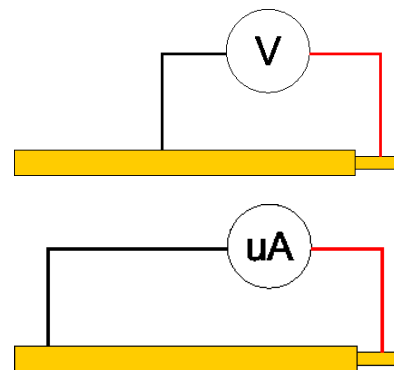
The active LEC showed a very different behavior!
...even when tested in air only (no hydrogen).

Voltage and current measurements:

Open circuit voltage (mV)			Short circuit current (uA)		
Brass-Brass	Brass-Al	Brass-Cu	Brass-Brass	Brass-Al	Brass-Cu
-307	223	-234	-2.4	1.5	-0.69

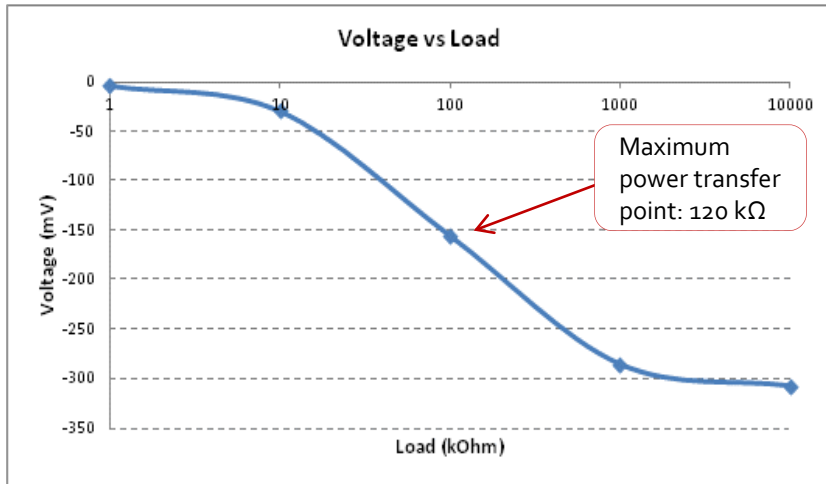
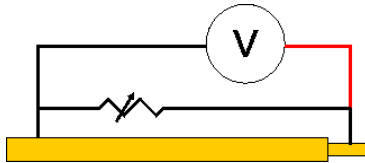
Observations:

- The voltage increased slowly after assembly (few minutes)
- When Aluminum CE is used the polarity is reversed
- Tests with Aluminum and Copper probably didn't had the time to reach the regime

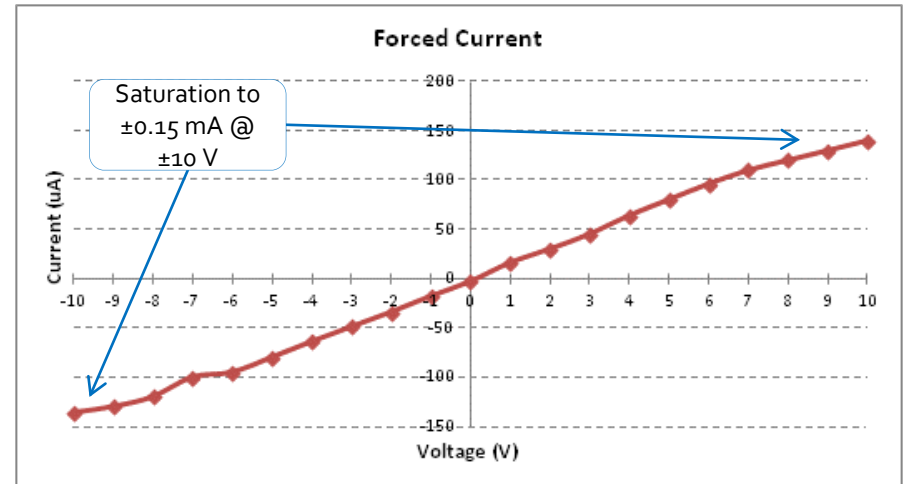
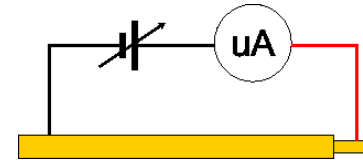


Load test and forced current

Voltage vs Load (from 10 MΩ to 1 kΩ)

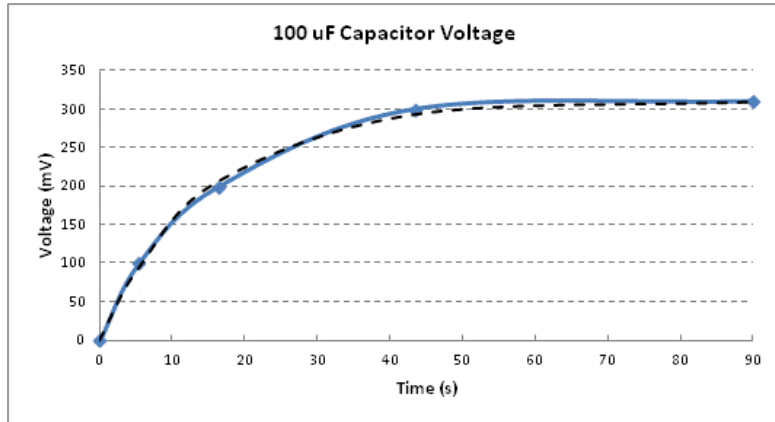


Forced current (from -10 V to +10V)



Additional experiments

Charging a capacitor



- Capacitance value: 100 μF
- Time to charge: 90 s
- Time constant: 15 s
- Internal resistance: 150 $\text{k}\Omega$
- Energy: 4.7 μJ

Radiation measurements

- The active WE was set in close proximity of a GM alpha-sensitive tube (LND712): no radiations were detected

Geiger CMP (LND712)	
Background	9.4
WE	11.4
WE + PE shield	11.6
Integration time: 5 min	

Possible reasons: radiation is not of a usual type (alpha, beta, gamma), or its energy is relatively low (< 1 keV), or it is emitted only from few hot spots

- The active WE was set in upon ZnS(Ag) glow-in-the-dark plastic strip and a some UV fluorescent plastics: no visible fluorescence or phosphorescence were excited (by naked eyes, not photomultiplier used)

Further observations

Voltage is reversed when an Al CE is used

- Similar behavior is obtained in an analog electrochemical system (5% NaCl solution). This may indicate that the generated voltage is due to the difference in **electrode potential** or **work function** of employed metals. The voltage generation is so a secondary effect, the primary being the gas ionization (that can be directly measured by the forced current).

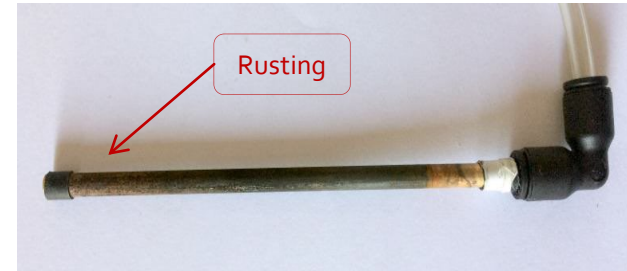
Open circuit voltage (mV)		
Fe-Brass	Fe-Al	Fe-Cu
-236	262	-265

Iron plating oxidizes at a very fast rate

- The useful life of the device is about one day, or a few days if hydrogen is used.

The co-deposition process is necessary

- If a Fe (or Fe plated) WE is electrolytically loaded with hydrogen, no active behavior is obtained.

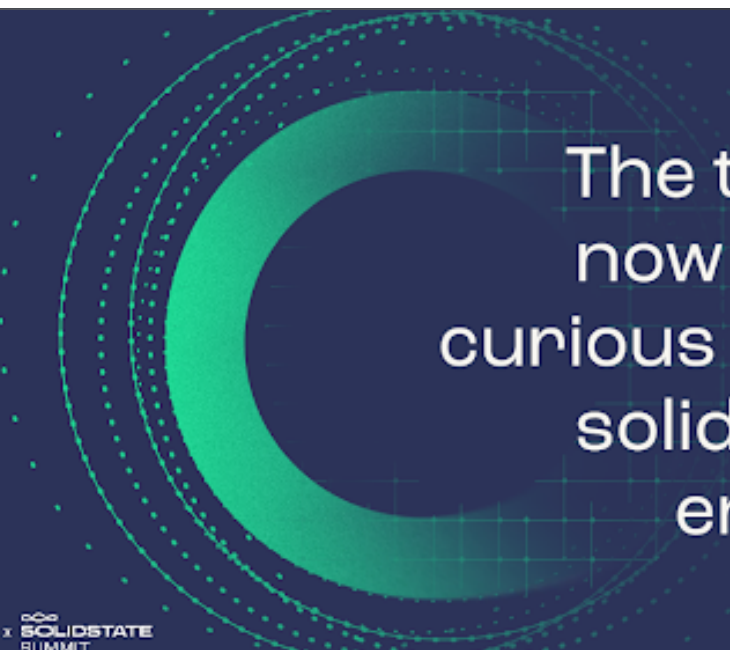


Conclusions

- The LEC behavior cannot be explained by conventional effects
- The repeatability and replicability is very high
- Electrical measurements suggest a gas ionization occurs inside the devices
- The energy required to ionize the gases is $> 10\text{-}20$ eV (i.e. not chemical)
- The voltage generation is a second order effect due to the ionization
- Characterization should be done on the current more than on the voltage
- The nature of the ionizing radiation need further investigation
- Power output is comparable to a commercial betavoltaic battery
- There are many possible directions to scale up the energy/power output

Thank you for your attention!

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The time is
now to get
curious about
solid-state
energy.