Are Pollack batteries possible?

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Abstract

Donut Lab has made rather bold claims about a solid state battery that they have developed. It is however difficult to understand how these claims could be consistent with the standard views of solid state physics and chemistry. In the TGD inspired quantum biology, the Pollack effect, involving new quantum physics, plays a central role. It is already known that the addition of water to natrium-vanadium batter could increase its charging capacity by almost a factor 2. Therefore it is interesting to see whether the Pollack effect as an additional element could allow what might be called a Pollack battery, perhaps consistent with the claims of DoNut Lab.

It turned out that taking the claims of the Donut Lab seriously, led to a surprisingly successful model allowing us to understand the claims about fast charging and the smallness of the swelling. Taking the claims about the generated total charged and loaded energy at face value led to the identification of the mechanism of energy storage as a phase transition increasing the dielectric constant of the target electrode in which the binding energies of the hydrogen atoms are scaled down by $1/\epsilon_r^2$. The energy stored per Pollack proton would be essentially the binding energy of a hydrogen atom and conforms with the claims of Donut Lab!

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1 Introduction

This article was motivated by the claim of Donut Lab about a breakthrough in battery technology. February 2026, Donut Lab published one of a planned series of independent VTT test reports [D1] (see this) covering fast-charge performance only. All other claimed specifications – energy density (400 Wh/kg), cycle life (100,000 cycles), extreme-temperature tolerance, safety, and cost – remain entirely unverified by any independent party.

Using Claude Cowork Deep Research, Marko Manninen has prepared a report [L29] (see this) and a Youtube video (see this) about the claims related to the Donut battery. The report compares the measured performance of the Donut Lab Solid-State Battery V1 against current lithium-ion technologies and competing solid-state efforts. All Donut Lab figures are derived from VTT test data where available; all competitor figures come from published specifications and third-party reports. Where Donut Lab data is unavailable, scenario analyses and flag assumptions are represented clearly.

What was announced was "Ultra high energy density, the fastest charging time, practically unlimited cycles, extreme safety, and lower price than lithium-ion". The reactions from professional circles have been skeptical. It is indeed difficult to see how the claims about Donut batteries could be consistent with standard condensed matter physics.

1. The claim about very rapid charging time of about 5 minutes is verified in the VTT test. This corresponds to charging rate 11 C, where 1 C corresponds to a charging time of 1 hour.

2. It was found that there is a high heat production during charging. During VTT Test #6, the cell reached ~ 90 °C under 11C charging with passive cooling only, triggering an automatic safety cutoff by the test equipment — the cell itself showed no damage or signs of thermal runaway.

3. The number of life cycles is claimed to be extremely large, about 10^5 cycle times and testing of so many cycles has been claimed to be implausible since it would require years. VTT made only 7 tests meaning 7 cycle times. The strong heating during the loading by ohmic currents is expected to cause damage to the electrode receiving the charge and this reduces the number of cycle times.

4. The claimed energy density of about 400 Wh/kg is very high. Suppose that the system consists of basic units with mass Am_p (m_p is proton mass) having atomic volume a_0^3, where $a_0 = 10^{-10}$ m. This would give an energy density of $dE/dm = 1.4 \times 10^{-10}$, where the unit $c = 1$ is used. This would mean .1 eV per proton mass $m_p \simeq 10^9$ eV.

   The energy density relates closely to the reported energy efficiency related to the counterpart of capacitor charge about 10^5 Coulombs, which is very high but consistent with that for mobile phone batteries. Note that the energy density is proportional to the dielectric constant ϵ of a dielectric possibly used between the positively and negatively charged electrons. It measures how large fraction of energy is stored as chemical energy. For a simple capacitor the energy is mere electrostatic energy.

5. Donut battery is claimed to be a solid state battery cell. VTT did not verify the chemistry of the cell. Donut patent application gives the following information about the battery.

   - Cathode with cathode material in particulate form + polymeric binder (polymeric binders are used to bind together battery materials)
   - Solid electrolyte with solid electrolyte material + polymeric binder
   - Anode with anode material in particulate form + polymeric binder

   Module is manufactured *without* use of: Prussian blue ($Fe_4[Fe(CN)_6]_3$), lead, cadmium, cobalt, nickel, mercury, manganese, sulfuric acid, organic solvents, fluorinated compounds, antimony, arsenic, beryllium, thallium, selenium, perfluorinated compounds, polyvinyl chloride, silicon, lithium, neodymium, dysprosium, lanthanum.

The basic problem is what is called trilemma. In the framework of standard condensed matter physics, the conditions for high charging speed, large number of life cycles, and high energy density are mutually conflicting. The high charging rate, which has been verified, requires high energies so that the charging involves ohmic dissipation and large energy and momentum transfer to the electrode causing its deterioration. It is claimed that the momentum transfer during the charging is small.

The following is a kind of private brain storming session about whether TGD based physics could allow the the realization of batteries based on Pollack effect [I2, L1, I5, I3] consider from the TGD view point in [L1, L2, L15, L7, L16, L13]. I am not specialized to battery technologies and these considerations are just speculations and need not have much to do with the Donut Lab battery, except as a thought ignition and framing the energy charging, storage, and dissipation systems. The basic inspiration comes from biological analogies and the charging of the battery is regarded as an analog of photosynthesis.

The notions of field/magnetic body, the hierarchy of effective Planck constants and Pollack effect are the key elements of the model and the following gives a brief summary of h_{eff} hierarchy and Pollack effect.

1.1 Large h_{eff} phases of ordinary matter behaving like dark matter

Large h_{eff} phases of ordinary matter behaving like dark matter are in key role in the TGD inspired quantum biology.

1. In the TGD view of quantum biology, the dark matter at field/magnetic bodies with a large value of h_{eff} is in a central role. The original for the hierarchy of phases of ordinary matter labelled by the values of effective Planck constant $h_{eff} = nh_0$, with estimated to satisfy $h = (7!)^2 h_0$, came from the findings of Blackman [J1] and others about quantal looking physical and behavioral effects of ELF radiation on verterbrate brain occurring at cyclotron frequencies of endogenous magnetic field $B_{end} \simeq .2$ Gauss. h_{eff} measures the scale of quantum coherence identified as the size scale of the space-time surface.

   The number theoretic interpretation of h_{eff} as the dimension of algebraic extension of rationals and degree of corresponding Galois group emerged later and means that h_{eff} measures algebraic complexity. In TGD inspired theory of consciousness [L23, L24] h_{eff} serves as a universal "IQ" and the matter at field body behavin like dark matter would naturally control the ordinary biomatter and receives information from it (say by EEG).

2. TGD inspired quantum biology leads to a model of genetic code [K2] [L9, L4, L5, L12] in which A simple model for linear dark proton triplets predicts their states to be in a 1-1 correspondence with DNA, RNA, tRNA, and amino-acids and the numbers of codons coding for given amino-acid are predicted to be the same as for the vertebrate genetic code [K2] [L9, L4, L5, L12].

3. Especially interesting example of very large h_{eff} are phases labelled by gravitational Planck constant [L11, L10], originally introduced by Nottale [E1]. h_{gr} is proportional to the product of the masses of the systems involved. Also the electric Planck constant h_{em} [L13], proportional to the product of the charges of two systems involved, is important. Genes, cell nucleus, cell, central nervous system and its parts, and even the Earth's biosphere form evolutionary hierarchies with increasing h_{eff}. The negatively charge exclusion zones (EZs) created in the Pollack effect creating $h_{eff} = h_{gr}$ phase at the gravitational body, has a large value of h_{em} [L23, L24].

1.2 Pollack effect briefly

In the Pollack effect (PE) [I2, L1, I5, I3] negatively charged exclusion zones (EZs) are induced at the boundary between the gel phase and water by an energy feed such as IR radiation.

1. The Pollack effect would play a key role in the transfer of ordinary particles to dark phases at the field bodies [L1, L15]. p-Adic length scale hypothesis [L19, L25], for which the number theoretic vision provides a justification, makes possible quantitative predictions.

2. The negative charge of EZ is explained as a formation of flux tubes carrying dark protons, which are interpreted as dark nuclei. Every 4^{th} proton should transform to a dark proton transferred to the flux tubes to explain the observations.

   EZs are able to remove impurities from their interior in conflict with the second law of thermodynamics (SL). The TGD based explanation is that the time reversal by BSFR at the level of MB [L6] also induces an effective time reversal in long time scales at the level of ordinary bio-matter.

3. PE explains the occurrence of a charge separation in living matter. DNA has one negative charge per nucleotide, microtubules are negatively charged, the cell is negatively charged, and ATP carries 3 units of negative charge. Therefore ZEO suggests that PE plays a key role in bio-control and macroscopic SFRs play a key role in living matter.

4. Pollack effect is expected to occur at quantum critical temperature $T_P \sim 300$ K for the Pollack effect involved with the transformation of nucleons to their dark counterparts at magnetic flux tubes. Dark nuclei would transformed to ordinary nuclei liberating almost all nuclear binding energy.

   T_P could be near the Hagedorn temperature for gravitational monopole flux tubes (for the TGD view of the notion of gravitational Planck constant. [L11, L10]). At the level of chemistry, the Pollack effect would naturally correspond to the flip of a topological qubit having as its bit values OH and O^- + dark proton [L17] and this means that it has many generalizations.

It has become clear that of Pollack effect can be generalized considerably [L13]. A mechanism providing the energy needed to kick ordinary protons to dark protons at the monopole flux tubes. Photons are one such mechanism but one can imagine large number of mechanisms of this kind. This suggests that Pollack effect is plays a key role in quantum biology [L22, L2, L7, L16, L13, L21].

Also "cold fusion" identified in TGD as dark fusion at the monopole flux tubes of the magnetic body could involve Pollack effect [L18]. One can also speculate with the role of generalized Pollack effect in making possible conscious computers as hybrids of classical and quantum computers [L17, L20].

1.3 The recent model for the Pollack battery

The model for the Pollack battery developed through many twists and turns and several breakthroughs in the understanding of the physical interpretation of TGD were required [L26]. The recent view of the charging of the Pollack battery would be as follows.

So, let us take the claims of Donut Lab [L29] seriously and look for what follows.

1. The number N_p of Pollack protons can be estimated from the transferred charge of $Q = 10^5$ Coulombs as $N_p = Q/e$. The claimed value for the stored energy $E = 400$ Wh. That would be equivalent to a proton energy $E_p = E/N_p=$ 13.8 eV. For a Pollack battery this energy would be the energy gained by the Pollack electron when accelerated at the monopole flux tube in a voltage =13.8 V without dissipation. In a normal battery, the energy is dissipated quite thoroughly in Ohmic conduction.

   The energy transferred by the Pollack effect would be smaller by a factor of 1/8 if the voltage is assumed to be 1.5 Volts. 8 of these four-layer units would be needed.

2. Then comes an important observation without which I would never have arrived at the recent model. The claimed 13.8 eV per Pollack electron corresponds to the binding energy 13.7 eV of a hydrogen atom! Is this a mere coincidence?

3. This induces the idea is that the Pollack protons on the target electrode induce a phase transition which increases the relative dielectric constant ϵ_r from, say, 1 to 80, its value for water. These phase transitions are very common in condensed matter physics.

4. The electrostatic energy of the electric field of an insulator is proportional to ϵ_r^2. However, this energy is completely insignificant.

5. For the atoms of an insulator, the standard description predicts a reduction in the scale of the energy levels. The charge is screened and effectively reduces to e/ϵ_r. The energy levels E_n of a hydrogen atom are proportional to the product of the two charges, and scale as $E_n \rightarrow E_n/\epsilon_r^2$. The upper limit $\epsilon_r = 100$ of ϵ_r gives a reduction factor of 10^{-4}. The atomic states are energetically close to ionization.

   That is, in the phase transition that Pollack protons would induce, energy would be released that is very close to the hydrogen atom binding energy of 13.7 eV per Pollack proton! This is exactly what follows by taking the claims of Donut Lab seriously. The phase transition generating a dielectric would store the electrostatic energy during the charging.

6. What would happen in a phase transition that increases the dielectric constant ϵ_r? The necessary energy would come from the electrostatic energy of the field used for charging. Each Pollack proton would produce a hydrogen atom whose binding energy would be reduced by a factor of $1/\epsilon_r^2$. For example, the conversion of OH^- ions to H_2O in a background with $\epsilon_r = 1/80$ formed in the transition, comes to mind.

7. There was also the problem of whether the accelerated Pollack protons give too much momentum to the target electrode. Would that explain the reported swelling, which was in the order of 4 per cent? It turned out that a simple estimate gives a completely negligible force, which is as much as ten orders of magnitude smaller than the estimate of the swelling force given by Google LLM, which is of order 10^5 N.

   The situations simply cannot be compared. In a standard battery, the currents are ohmic and produce swelling and also heating through dissipation. For a Pollack battery, electrons travel in flux tubes and would transfer impulse and energy directly to the target electrode.

I have not previously taken the standard description of insulators quite seriously in this way although it works. It turned out that TGD offers an elegant first principle description of insulators using spacetime surfaces.

1. While building a model for the Allais effect [L26], I realized that the universal solutions of field equations that I found 47 years ago come to the rescue. They correspond to "warped" embedding of Minkowski space as a surface of $H = M^4 \times CP_2$, come to rescue.

They do not involve gravitational or gauge fields, but they are warped, which means that they are tilted to the direction of $M^4 \times S^1 \subset H$. The angular coordinate of S^1 is given by $\Phi = \omega t$ implying that the time component g_{tt} of the induced metric decreases from 1 to $1 - R^2\omega^2$. The speed of light reduces to $c_\# = \sqrt{(}1 - R^2\omega^2) < c$.

2. The warped space-time surfaces are quantum critical against the change of $c_\#$. A vibrating thin metal plate serves as a good analogy. The metal plate corresponds now to the $M^2 \subset M^4$. Warping generalizes to Hamilton-Jacobi structure [L14] so that the notion applies also to non-vacuum extremals. The quantum criticality would be a geometric correlate for that of quantum phase transitions.

   This has several applications:

   (a) $c_\#/c$ corresponds in a natural way to the velocity parameter β_0 of the gravitational Planck constant GMm/β_0, whose identification has been a long standing mystery. This can be applied to the Allais effect [L26], which General Relativity cannot explain.

   (b) The speed of light also decreases for insulators. Refractive index is given by $n = c_\#/c$. Dielectric constant is given by $\epsilon_r = 1/n^2 = (c_\#/c)^2$. The transition $c \rightarrow c_\#$ would occur when the system becomes an insulator. Could the atoms of the insulator be on a different space-time sheet, characterized by $c_\# > c$? Water would be the most important example of this.

In the sequel the idea of Pollack battery will be discussed thoroughly from various perspectives and the structure of the article reflects the process leading to the recent view, involving many side tracks.

2 Could the notion of Pollack battery make sense?

I have considered the possibility that the Pollack effect plays a central role in electrolysis, which is the key effect in the chemistry of batteries. The following is an attempt to build a model for a battery based on the Pollack effect.

2.1 What could Pollack battery mean?

The claimed properties of the Donut battery can be used as guidelines in speculations. Something new making possible the rapid charging and the resolution of the trilemma and Pollack effect could be the missing element. I have discussed its generalization and possible applications to biology [L11, L13] and also to develop some speculative ideas about living computers [L17, L20]. It is best to proceed by inventing objections and be ready to challenge which is believed to be known about batteries and electrolytes.

2.1.1 Evidence for the importance of the Pollack effect in the case of batteries

The recent finding reported in ScienceDaily (see this) that addition of water to a Sodium-Vanadium battery increases its charge capacity almost by a factor 2, suggests that the Pollack effect for water is in an essential role in this case. Note however that the presence of the gel phase would be necessary.

What is nice is that Sodium and Vanadium are not rare metals unlike Li. Researchers found that keeping water inside a key sodium-ion battery material nearly doubled its charge storage. It also charges faster and stays stable for hundreds of cycles. This discovery could make lithium obsolete. The same material can also desalinate seawater into drinking water.

1. Could the Pollack effect occur at the electrode becoming negatively charged or in the counterpart of electrolyte between the electrodes?

2. The Pollack effect generates negatively charged EZs in water. This should also occur in the general case. In the case of the Pollack battery, the negative charge would be generated at the electrode, which provides the dark positive ions. A small value of $\Delta E = E - E_{opp}$

can prevent the transfer of negative charge by ohmic conduction. The value of E could be increased during charging.

There is evidence for the change of the arrow of time at the electric field body for EZ, which suggests a large value h_{em} [L23, L24]. If also the negative ions are in large $h_{eff} = h_{em}$ phase (proportional to the charge of the electrode), the transfer could occur without dissipation but is prevented if the sign of the $\Delta E = E - E_{opp}$ is wrong.

3. The huge dielectric constant ϵ (as large as 10^6) strongly suggests that chemical energy storage dominates over electrostatic energy storage. This storage would naturally occur to the electrolyte serving also the role of the gel phase acting as a catalyst. Note that Pollack effect could be catalyzed also by hydrophilic polymers. The energy storage would be chemical as in biosystems and the electrolyte would take the role of proteins and lipids. This suggests that the solid state electrolyte should be an organic material able to store metabolic energy. Carbon polymers carrying energy in carbon-carbon and carbon-hydrogen bonds is what suggests itself.

2.1.2 Generalized Pollack effect as an explanation for the fast charging?

The fast charging could be understood if the ions are generated by the Pollack effect or its generalization at the second electrode. Protons or perhaps even alkali ions could be generated by the generalized Pollack effect. In the presence of an electric field the positively charged ions would travel to the second electrode in the electric field (note that for static electric fields the voltage is the same along the space-time sheet for ordinary matter and for the magnetic flux tube).

Since the value of h_{eff} is large, dissipation would be small and could be even absent if the analog superconducting is in question. Therefore the travel time would be very short and could make rapid charging possible. In the simplest classical model the particle would experience the analog of free fall in the approximately constant gravitational field of Earth.

What is nice is that in the case of a Pollack capacitor the electrodes could consist of the same material.

2.1.3 Electrolyte in gel phase is needed as a catalyst of Pollack effect

The ordinary Pollack effect for water involves a gel phase bounded with the water. Presumably it acts as a catalyst for the Pollack effect. The electrolyte is a good candidate for a catalyst and should consist of organic matter, some kind of polymer. In ordinary batteries, the electrolyte is believed to act as a storage of chemical energy. Is this condition consistent with the catalyst property?

In standard chemistry it is thought that catalyst provides temporarily the energy needed to overcome the potential wall preventing the reaction to proceed rapidly. Could the electrolyte in gel phase provide temporarily the energy to kick proton the magnetic body? Does the catalyst return to the original state or to an excited state in which case it could store energy chemically, which seems to be necessary? Could this transform the gel phase to ordinary phase so that the battery would age?

2.1.4 How is the energy stored?

1. The simplest Pollack battery would involve electrolyte as a mere catalyst; it would not store energy as chemical energy. This option is unrealistic.

   Ohmic conductivity makes possible the transfer of currents in the electrolyte and the storage of energy as electric energy. Taking into account the contribution of the electric energy means the replacement of the electric energy $CU^2/2$ with electric plus chemical energy $\epsilon_r CU^2/2$. For water the value is in the range 78-80. Doped semiconductors/polymers can have dielectric constant exceeding values 10^6.

   This suggests that the chemical storage of energy dominates over the electrostatic storage so that the charging by Pollack effect should transfer energy to the electrolyte acting also as a catalyst in gel phase (also hydrophilia could be enough for to catalyze Pollack effect). The chemical energy storage to the excited states of the catalyst, gradually destroying the gel phase, is what comes to mind. The ohmic diffusion of protons to the electrolyte could modify the chemisty or the electrolyte and give rise to chemical energy storage.

Donut LAB claims that their battery is a solid state battery. Also polymers in solid state can act as catalysts. The question is of whether they can catalyze Pollack effect, perhaps by providing monopole flux tubes carrying the dark ion currents making quantum tunnelling possible.

2. Could one consider any other storage mechanisms? Here biology suggests an idea: in the case of DNA and cell, interpreted as stable exclusion zones, the magnetic body serves as a stable storage of dark protons. This is due to the formation of dark nuclei as bound states of dark protons preventing reverse Pollack effect.

   Could it be possible to store the energy of the battery to the magnetic body instead of chemical storage to the electrolyte? Could the very large value of di-electric constant possible for batteries (as high as $\epsilon_r \sim 10^6$) actually reflect the storage of the energy at the magnetic body?

2.1.5 The energy source for the generalized Pollack effect?

1. Photons as energy source needed to kick protons or even alkali ions to the magnetic body are missing now also thermal photons could do this (the efficiency increases temperature range 80-100 °C). The kicking requires energy ΔE_P, which is expected to be not far from .05 eV [L17]. The electrostatic energy in the voltage between electrodes should therefore act as the fundamental energy source during the charging of the battery. This energy could be transformed to chemical energy or possibly some other forms of energy, say at the magnetic body. Could cyclotron states with a large value of h_{eff} be considered?

2. The dark protons should end up to the second electrode, already during the charging or at least when the stored energy is used. If the dark proton behaves classically, it accelerates in the electric field and gains the energy $\Delta E_c = e\Delta V$. The problem is that the dark proton (or alkali ion) could transform to an ordinary proton already before the electrode. When it transforms to an ordinary proton at the electrolyte or electrode it gives its energy $\Delta E_c + \Delta E_P$ and its momentum to the electrode. This is expected to cause heating and degradation of the electrode.

2.1.6 Could Pollack effect occur by quantum tunnelling?

If a long scale quantum coherence is involved, one can ask whether the Pollack effect could take place by quantum tunnelling. Note that biocatalysis requiring a gel phase could be an alternative description for quantum tunnelling.

1. Suppose that the energy gain $e\Delta V$ between the location P of the Pollack effect - either second electrode, call it E_2 or position inside electrolyte - and second electrode, call it $\Delta E_{max} = e\Delta V_{max}(P, E_2)$, equals to the energy ΔE_P needed to transform the proton to dark proton. This gives the condition $\Delta E_{max} = \Delta E_P$.

   This condition does not allow the transformation of the dark proton to ordinary proton before it has reached the second electrode. After this the dark proton can transform to an ordinary proton and gains energy ΔE_P and corresponding momentum. Therefore it causes minimal recoil effects at the electrode. The protons too near to the target electrode cannot reach it and for $e\Delta V_{max}(E_1, E_2) = \Delta E_P$ the protons can be transferred only from E_1 to E_2 only.

2. The positive electrode generates an opposing electric field E_{opp} causing a gradually increasing opposing electric force. It is enough to have a gradually increasing electric field ΔE, which exceeds this opposing electric field. The dark positive ions would experience the force $\Delta E = E - E_{opp}$. This would save energy in charging and minimize the effects caused at the positive electrode. The positive ions could be transferred with minimal energy and momentum transfer to the positive electrode. ΔE could be much weaker than the electric field E_{opp} between the electrodes defining the voltage of the battery. This would minimize the damage to the electrode.

2.1.7 How to maximize the capacity of the battery?

A large charge for the capacitor-like system is required. One can consider two options.

1. The surface areas of the separate electrodes could be maximized by folding to form an accordion-like structure. There would be a continuous separator, which enhances efficiency, increases safety, and manages volume changes better than winding. It seems that this is not the case now.

2. Biology suggests a different solution to the problem. Folder the entire capacitor. In the cell, the interior and exterior are analogous to the plates of the capacitor. Cell membrane is a highly folded connected structure consisting of two lipid layers to which one could assign the opposite charges.

   Interestingly, the cortex is also highly folded, which supports the idea that the surface area and the associated charge are maximized for both cells and cortex to increase the value of the total charge. This ensures maximum value of electric Planck constant h_{em} proportional to the total charge of the bilayer and serving as a universal IQ in TGD inspired theory of conscious experience [L23, L24].

   The idea is that the standard capacitor plate is replaced with a very thin, highly folded bilayer with layers taking the role of oppositely charged capacitor plates. These bilayers are insulated from each other by using a polymer so that dielectric breakdowns do not occur between the electrodes. The polymer could serve as the electrolyte and and as catalyst when in gel phase.

2.1.8 So: what could the Pollack battery look like?

The first guess for the structure of the Pollack battery would be as follows.

1. Both electrodes would be of the same material allowing Pollack effect. The battery would be a highly folded membrane like structure analogous to a cell membrane.

2. The electrolyte between the electrodes would be partially in gel phase and act as a catalyst for the Pollack effect. It would also store energy to the excited states of the catalyst. Presumably this would spoil the gel phase property and lead to the aging of the catalyst.

3. Charging by Pollack effect could involve quantum tunneling between the electric field used for the charging. This could be a counterpart for the description in terms of a catalyst providing temporarily the energy needed to overcome the potential barrier for the Pollack effect.

2.2 Biosystems as role models for Pollack batteries

Could one take biological systems as role models in attempts to guess what the Pollack battery could look like? Pollack effect plays a key role in the TGD inspired quantum biology and occurs for cells and DNA/RNA. Membrane bounded biological structures act as batteries. Also the charge separation for DNA-magnetic body pairs defines a charge separation and therefore a battery in an abstract sense. Water is essential for the Pollack effect in the living system. Is it needed? As already noticed, the addition of water can almost double the charge capacity of Na-Va batteries.

1. The positive electrode and electrolyte should allow the Pollack effect in which alkali ions are transformed to dark ions at the magnetic body of the system. Cell membrane is a battery and many alkali ions are involved (H^+, Li^+, Na^+, K^+, Ca^{2+}, Mg^{2+},..) [J1]

2. An energy source replacing photons is needed and the voltage used to charge the battery could do the job. The cell membrane potential is analogous to the voltage of the battery and the generation of nerve pulse is analogous to discharging followed by charging.

   The dark alkali ions, such as Li^+, could flow in the charging voltage from the cathode and electrolyte to the opposite electrode with very small ohmic resistance. This would be essential for rapid charging.

3. Gel phase is needed for the Pollack effect in water. In the case of cell membranes, gel-sol phase transition creates gel phases. This suggests that the organic polymer forming the electrolyte should be in gel phase, at least during the charging. Also the other electrode or both of them could be organic polymers.

4. Intriguingly, DNA/RNA nucleotides involve negatively charged phosphate giving DNA and RNA constant negative charge density. In this case the dark phase is stable and the proposal is that binding energy of the dark nuclei formed from dark protons (binding energy is much smaller than for ordinary nuclei) guarantees the stability. These dark nuclei would be essential for "cold fusion" [L8, L18]. The interpretation could be in terms of the exclusion zone (EZ) characterized by a large electric Planck constant h_{em} proportional to the charge of the codon or gene. This predicts a hierarchy of phases with increasingly longer quantum coherence length and h_{em} serving as a measure of algebraic complexity and defining a universal "IQ". Similar hierarchy is predicted also for membrane like structures enclosing negative charged interior (cell organelles such as mitochondria, cell nucleus, cell, neutron,...) [L23, L24].

2.2.1 Cell, neuron and ordinary battery as Pollack batteries?

Could it be thought that the second electrode of a Pollack battery and perhaps even a regular battery would be identified as its magnetic body!

1. Let's assume that charging occurs by quantum tunneling so that at the end the external charging voltage is set to zero. What happens? Does conservation of energy force the formation of bound states as dark nuclei on the magnetic body of the second electrode as assumed. It would fit the "cold fusion" model [L8, L18].

2. What happens when an external load, which slightly reduces the battery voltage, is connected to the battery? Current should start flowing as electrons through the load and cause the reverse Pollack effect. How would that happen? If negatively charged nanotube based electrode contains -C-O$^-$ as charge carriers would donate electrons that would travel to the positively charged electrode, where positive dark protons associated with dark nuclei would form atoms (proton → H) and drop down onto the electrode as ordinary hydrogen atoms. The charge of the magnetic body would and the voltage would gradually decrease. If cold fusion occurs, the dark nucleus transforms to ordinary nucleus rather than ordinary hydrogen atoms.

3. Also a normal cell would be a Pollack battery. Now there would be many different alkali ions involved. The magnetic body of mitochondria would mainly contain protons. In energy metabolism producing ATP from ADP, the electrons energized by the chemical energy of sugars would release energy as they pass through the cell membrane and fuse with dark protons to form hydrogen atoms that would then flow through the cell membrane back and provide their energy to form ATP from ADP in a nano-machinery analogous to a rotating shaft of power plant.

4. What about neurons and nerve pulses? Nerve pulse would correspond to the discharging and recharging of a Pollack battery taking place in milli-second time scale. This would happen when the voltage falls below a critical voltage, not when it exceeds it (dielectric breakdown), as common sense suggests. Why is this so? I have tried to understand this and made suggestions.

   Is this related to the system being formed by tunneling? What happens if the voltage decreases? The Coulomb energy of positive charges decreases. Does the conservation of energy also now force a current that collapses the voltage very rapidly? There would be a catastrophically fast battery discharge followed by a recharging. Is the charging by quantum tunneling related to this? Wouldn't it be possible to get to an energetically possible state and decreasing the voltage would only make the situation worse?

5. How is the normal battery discharged? How it can be made to happen very quickly. Is a high compensating voltage needed? Going to Google led to a surprising discovery: all batteries are characterized by a phenomenon known as self discharge! They spontaneously discharge when the voltage is below a certain value (see this).

2.2.2 It is enough that polymer is hydrophilic

The problematic assumption that a gel phase for electrolyte is needed turned out to be too strong as I learned from Esa-Juhani Ruoho whose sent an excellent article by Thomas Brown [I4] discussing the relationship between icosahedral geometry and Pollack effect. In the usual Pollack effect, it is actually enough to have a hydrophilic polymer instead of a gel, and there are many of these. Hydrophilic polymers are possible also in the solid state as Google says.

1. Hydrophilicity favors certain amino acids on the surface of the protein that borders on water. Roughly one half of the amino acids are hydrophilic. When proteins fold, proteins arrange themselves in water in such a way that hydrophobic amino acids border the cavities inside and hydrophilic amino acids face the water.
2. There are 11 key hydrophilic amino acids.
   - 6 polar uncharged: Serine (Ser, S), Threonine (Thr, T), Asparagine (Asn, N), Glutamine (Gln, Q), Tyrosine (Tyr, Y), and Cysteine (Cys, C).
   - 3 positively charged (basic) : Lysine (Lys, K), Arginine (Arg, R), Histidine (His, H).
   - 2 negatively charged (acidic): Aspartic acid (Asp, D), Glutamic acid (Glu, E).
3. Their key properties are as follows.
   - They are highly soluble in water because their side chains can form hydrogen bonds.
   - Protein Structure: They are typically found on the surface of globular proteins, interacting with the aqueous environment.
   - Catalysis: Charged hydrophilic amino acids (like His, Asp, Glu, Lys) are crucial in the active sites of enzymes, facilitating chemical reactions.
   - They are "water-loving" in contrast to hydrophobic amino acids (like Val, Leu, Ile, Phe, Trp) which prefer to be inside the protein, away from water.

Does a nanotube with -OH inserts at the defects of the nanotube at which C=C bond is transformed to a C-C bond make it a water-like compound as far as Pollack effect is considered? If so, the Pollack effect would correspond to a transition -OH $\rightarrow O^-$ + dark proton at the flux tube also in this case.

Could hydrogen bonds form between the hydrogens of the nanotube and some atoms of the solid state polymer? Hydrogen bonds form between a hydrogen atom covalently bonded to a highly electronegative atom (typically Nitrogen, Oxygen, or Fluorine) and another electronegative N, O, or F atom on a nearby molecule. This suggests that the solid state polymer should contain N, O or F. N and O look the most plausible. All above mentioned polymer candidates, i.e. polyethylene oxide polymer, $LiCF_3SO_3$ salt, and silane-treated Al_2O_3 (Al_2O_3-ST) ceramic filler) contain oxygen atoms.

2.3 Some brave guesses

Just for fun, one can make brave amateurish guesses about the actualization of the Pollack battery.

2.3.1 Polymer based batteries as Pollack batteries

1. There exists a large class of polymer based batteries (see this). Lithium polymer battery serves as a representative example (see this). In this case, the cathode providing positive alkali is Lithium Iron Phosphate $LiFePO_4$. It is not clear whether the Donut battery involves Lithium or not. One could however also consider other alkali atoms instead of Li.

   Also DNA and RNA have one negatively charged phosphate ion per nucleotide. The finding that the addition of phosphates increases the otherwise pure conductivity of the system, suggests that dark Li^+ ions associated with EZ can act as current carriers.

2. The electrolyte could consist of polyethylene oxide polymer, $LiCF_3SO_3$ salt, and silane-treated Al_2O_3 (Al_2O_3-ST) ceramic filler. Polyethylene (plastic) is a simple hydrocarbon of form ...-(CH_2)-... Its oxide contains oxygen atom periodically to give -C-O-C-....One can also consider other alkali atoms instead of Li and also the possibility that the electrolyte involves Li atoms but Li ions are not charge carriers.

3. It is found that the charging capacity of the Donut battery is best in the range 80-100 ^{circ}C (350-370 K) [L29]. At this temperature the thermal energy is .035-.037 eV and of the same order of magnitude as the electrostatic energy of the cell membrane. This suggests that thermal photons also contribute to the Pollack effect.

4. What is fascinating is that the performance of a given Donut battery is reported to improve in repeated tests. Could the Donut batteries share with biology also the possibility of self organization and evolution. Evolution is predicted to occur in all scales in the TGD Universe [L23, L24].

5. In water bounded by a gel for which Pollack effect certainly occurs. As already noticed, the addition of water to Sodium-Vanadium battery increases the charge storage capacity by a factor of almost 2 and also the charging becomes faster (see this). The addition of water between bilayers of a folded capacitor-like system consisting of a catalyst in a partial gel phase could be considered.

2.3.2 Could a modification of Carbon Nanotube serve as the electrode material?

The claim that Li ions are not involved as charge carriers, inspires the consideration of more exotic options. There is a claim (see this) that chemical batteries cannot have the claimed similar behavior at 30 °C and 80 °C (Arrhenius equation) (see this).

A further claim is that Donut Lab uses Spintronic Nanocarbon, which also has magnetic structure, which would naturally relate to the needed monopole magnetic flux tubes as charge carriers. Spintronic nanocarbons utilize carbon-based materials like graphene and nanotubes for manipulating electron spin, offering low-power, high-speed, and durable computing alternatives to traditional electronics.

1. Could a modification of CNT (see this) serve as a building block of the second electrode or even both electrodes of the Pollack battery? For the latter option the battery would be a completely symmetric structure, a kind of flip-flop.

2. What about electrolyte (say polyethylene oxide polymer, $LiCF_3SO_3$ salt, and silane-treated Al_2O_3 (Al_2O_3-ST) ceramic filler)? Could it take only the role of the gel phase? This would conform with the claim that Li ions are not charge carriers.

CNT has an aromatic ring with six C atoms as a basic building block. Each C atom has a double bond with one of the neighboring 3 carbons associated with an aromatic ring.

1. It is known that -OH groups can be added to the defects (C=C is replaced with C-C) associated with the aromatic rings and the surface of CNTs so that they could serve as seats of Pollack effect in TGD Universe [L3]. The Pollack effect as transformation -OH→ -O^- + dark proton. If this occurs at the first electrode E_1 it becomes negatively charged and one obtains a capacitor like system. Its capacitance could be made large by multi-folding of CNTs.

2. If the electrolyte consists of CNTs, there is a problem. How to get the negative charge of $-(C-O^-)-C$ produced in the Pollack effect to the E_1? Could one imagine that the reaction $-(C-O^-)-C \rightarrow -C=C+O^-$ removing the defect takes place first and after that O^- is transferred to E_1 in the electric field? Or can one think that O^- is transformed to $O+e^-$ (this however requires energy) and dark electron e^- is transferred to E_1. Could also this process occur by quantum tunnelling in the same way as the transfer of the proton.

   If this problem cannot be overcome, only the electrode E_1 can consist of CNTs with -OH side groups. The electrolyte could consist of some organic polymers able to provide dark protons by Pollack effect and allowing the negative ion to donate the electron. Clearly, a fine tuning of the voltage would be required to make the charging maximally effective.

2.3.3 What about the second electrode and what happens when the battery is used?

The discharging of the battery must occur slowly, unlike charging. The battery must behave classically during its use (Ohmic currents) and quantally during its charging.

1. Assume that electrodes E1 and E2 are in the initial state nanotubes prepared making different modifications of double bonds =C

   E1 : =C → -(C-OH) : addition of OH

   E2: =C → -(C=O) : addition of O

   The open question is whether the oxygenation is possible energetically without energy feed.

2. What happens in charging?

   (a) Pollack effect for E1 ocurrs and inducing the modification
   -(C-OH) → -(C-O^-) + dark proton at flux tube

   (b) Dark proton is transferred to E2 and suffers reverse Pollack effect. At E2 one has
   -(C=O) +p, where p is ordinary proton.

3. What happens when the battery is used?

   (a) Pollack effect at E2 is not possible (no -OH groups)! The battery voltage generated in charging induces an ohmic electron current from E1 to E2. The Ohmic current is not quantal and the discharging is slow.

   (b) Electron leaves E1 and the transition -(C-O^-)-C→-(C=O)-C occurs and e^- is transferred to E2 ohmically.

   (c) At E2 e^- combines with a proton to form H. After that the H combines with C=O to give
   -(C=0)-C +H -→ -(C-OH)-C
   The roles of E1 and E2 are changed!

   The next charging must use an opposite charging voltage inducing Pollack effect at E2.

The model is very general. What is essential is that one has a lattice type structure in =X-type units are replaced with -(X-OH)- and -(X=O)- type units for the two electrodes. For instance, carbon nanotubes could be replaced with silicon nanotubes (SiNT), which indeed do exist. Silicon nanotubes, the tubes are not smooth but wrinkled: this would increase the capacity to load charge.

The objection against the proposal is that the energy difference between states -C-(C=O)-C + e^- and -(C-O^-)-C is large and of wrong sign so that e^- is tightly bound to -(C-O^-)-C and Ohmic current cannot be generated. I am not a chemist but I am able to use Google, which answers as follows.

"The energy difference between a neutral carbonyl group plus a free electron $(-C-(C=O)-C+e^-)$ *and the resulting radical anion* $(-C-(C-O^{\bullet -})-C)$ *is characterized by the electron affinity (EA) of the carbonyl compound. For simple aliphatic ketones like acetone, the energy difference is* ≈ 0.0 *to* $-0.5\ eV$ *(approximately* 0 *to* 12 *kcal/mol). This indicates that the formation of the radical anion is typically isothermic or slightly endothermic in the gas phase."*

This would suggest that the liberation of e^- to become a carrier of ohmic current does not require energy or occurs even spontaneously and is made possible so that the electric field of the battery generates ohmic current.

2.3.4 Objections

The basic counter-arguments against the notion of Pollack battery relate to dynamics.

1. The number of dark protons matters. According to the findings of Pollack, every fourth proton in the water in the EZ region is transferred to the magnetic body. This is quite a large number. This provides an order of magnitude estimate of the maximum amount of charge transferred via quantum tunnelling followed by the reverse Pollack effect. If the electrodes are wrinkled, as would happen for the ase of SiNT, the area of the electrodes increases and so does the maximal number of dark protons.

2. The time scale for the lifetime of $(H_3O_2)^-$ phase is attosecond in water. The large fraction of dark protons would give reason for optimism. In the case of DNA, RNA, and cell membrane the region with negative charge is stable and formation of dark nuclei from dark protons should imply the stability against the reverse Pollack effect.

3. At what speed does the transfer to the opposite electrode by quantum tunnelling occur? The tunneling probability could be estimated based on the existing formula for quantum tunnelling by simply replacing Planck constant h with h_{eff}. The tunnelling rate is an exponent $exp(-X)$ of a term X proportional to $1/\hbar$.

   The intuitive expectation is that for ordinary Planck constant X is very large in the scales considered so that tunnelling probability is essentially zero. However, the replacement $\hbar \rightarrow \hbar_{gr,E} = GM_e m_p/\beta_0 \sim 10^{13}$ for a proton could make $X \propto 1/\hbar_{gr}$ small enough. An additional parameter possibly needed as a multiplicative factor is the amplitude for OH → O$^-$ + dark proton decay. The optimistic first guess is that this parameter is of order 1.

Consider now an estimate for the tunnelling amplitude A, whose modulus squared gives the tunnelling probability.

1. Apart from the numerical factor of order one, the amplitude A can be written as an exponent and represents the value of a wave function at point L at E_2. In the classically forbidden region $0 < x < L$ the wave function is an exponentially decreasing function. $\int_0^y k(x)dx$ is analogous to a plane wave $exp(iky)$ with imaginary momentum. By using the relationship $k(x) = p(x)/\hbar$ and $p(x) = \sqrt{2m(E - V(x))}$ between wave vector and momentum, one obtains

$$\begin{array}{ll} A = exp(-X) & X = \frac{1}{h_{eff}} \int_0^L p(x)dx \ . \\ p(x) = \sqrt{2m(E-V(x))} \ , & \end{array}$$

   In the recent case, $V(x)$ is Coulomb energy $V(x) = eE_0x$ for the proton and m is proton mass. In the Earth's gravitational field one has $h_{eff} = \hbar_{gr,E} = GM_E m_p/\beta_0 = r_s(E)m_p/2\beta_0$, $r_s(E) \simeq 1$ cm. The velocity parameter $\beta_0 = v_0/c \leq 1$ has a spectrum of values but there are arguments supporting $\beta_0 \simeq 1$ as the most plausible value for the Earth. For the Sun the value $\beta_0 \simeq 2^{-11}$ is favored.

2. The boundary condition is that the proton, kicked by Pollack effect from the electrode E_1, arrives at rest to the electrode E_2. This gives

$$E = V(L) = eE_0L = eV_0$$

   where E_0 is a constant electric field of the battery and V_0 the voltage between E_1 and E_2. This gives

$$p(x) = \sqrt{2m_p(V(L) - V(x))} = \sqrt{2m_pV_0}\sqrt{1 - x/L}$$

   The integral appearing in the definition of X can be calculated analytically and one obtains

$$X = \frac{4\sqrt{2}}{3}\sqrt{\frac{eV_0}{m_p}}\frac{L}{r_s(E)} \ .$$

3. An order of magnitude estimate is obtained by assuming $eV_0 = 1$ eV implying $eV_0/m_p \simeq 10^{-9}$, $L = 10$ cm. For $\beta_0 = 1$, this gives

$$X \simeq 6 \times 10^{-4} \ .$$

   The value happens to be quite near to the value of $\beta_0 \simeq 2^{-11}$ for the Sun. The value of X is so small that $exp(-X) \simeq 1$ is true in a good approximation.

The conclusion is that, unless the additional coefficient possibly present is very small, the tunnelling probability can be large enough.

2.4 About the role of water

2.4.1 Pollack battery is not the water battery of Pollack

One should not confuse the water battery (see this) proposed by Pollack to Pollack battery. The water battery of Pollack corresponds to the voltage difference that arises between the EZ and the environment due to irradiation. It is not a battery except in a figurative sense.

1. In the TGD version, the Pollack battery is charged using an external voltage that supplies energy to kick protons into a magnetic body and instead of water there is, for example, a nanotube and the electrodes are connected by -OH and =O insertion into double bonds. In this way, a rechargeable battery is obtained.

2. Another fundamental difference is that Pollack interprets the Pollack effect without assuming a magnetic body and only assumes that by some unknown mechanism the protons end up outside the EZ. Such a mechanism has not been found in standard chemistry. Pollack's water battery is based on the Pollack effect in its basic form.

   Therefore there is no assumption of large h_{eff} phases, which are essential in the TGD model and the associated dissipation-free acceleration by magnetic flux tubes. These phases also explain why cold plasma appears in electrolytes. They also explain cold fusion. As well as the relativistic energies for electrons associated with lightning.

2.4.2 There are indications that Donut battery contains water consistent with the Pollack battery property

The most recent test by VTT studied the Donut battery for which the plastic pouch containing the battery was degraded at temperature near 100 degrees Celsius [L29]. According to the VTT raport, vacuum was lost in the high temperature test test and agglutinations have contained a hole or a hole has appeared during the test.

1. The expansion of the popped battery by 17 percent has been used as a counter argument to the claim that the counterpart of electrolyte is in a solid state.

   The temperature of 100 degrees indicates that water was present and evaporated at this temperature. Water expands dramatically in evaporation. During the preparation of the paste UV drying is applied and if this drying has failed to be complete, the battery could have contained water. In TGD framework one can ask whether water was somehow created by the Pollack effect.

2. Water, which has been traditionally considered a battery poison, was found a few years ago to increase the charge storage capacity by a factor of two. Did the boiling of the water present from the beginning or the water created in the system cause the pop? Could the water give an additional contribution to the Pollack effect and improve the Pollack battery in some aspects, at least at temperatures near the physiological temperature, which could be optimal for the Pollack effect? Or is the effect opposite?

3. How could water have been created if it was not present originally? Let's assume a Pollack battery based on nanotube electrodes. The addition of -OH groups induce the transformations C=C $\rightarrow$ C-(C-OH). This is necessary for the occurrence of the Pollack effect as a transition -OH$\rightarrow$ O^- + dark proton at the flux tube. Did dehydration of the hydrated nanotube, resulting in the formation of H_2O molecules, occur? The water created in this way would have evaporated at 100 degrees and induced the expansion of the battery.

4. How would dehydration have occurred?

   (a) Assuming that 2 -OH groups at adjacent hexagonal rings of nanotube (defects in the nanotube) have been transformed by the Pollack effect into the state -O^- + dark proton H^+ on the magnetic body.

(b) Assume that two dark protons drop back from the magnetic body by the reverse Pollack effect and attach to the second O^- so that H_2O^+ ion is formed. Suppose that after this the second O^- donates its electron for H_2O^+ ion so that H_2O and =O are formed so that one -OH defect of the nanotube disappears. The reverse Pollack effect would therefore produce dehydration of the electrode. The rates for the Pollack effect and its reversal by the dropping of two dark protons would determine the fraction of water present in equilibrium state.

2.4.3 Swelling test and the proposal of Marko Manninen for the DONUT battery

Recently a swelling test was carried out for the DONUT battery at VTT (see this). The cell swelling of 4.4 per cent during cycling was detected. This value is considerably lower than typical values ranging up to 20 per cent. The temperature was room temperature during the test.

The evaporation of water near 100 Celsius would lead to a large expansion in the previous test: this could explain the breakdown of the pouch. Now the temperature was room temperature so that this effect is not present.

For the Pollack battery one can consider two options. For the first option charging involves a free acceleration of the dark protons at the monopole flux tubes in the electric field and if the propagation distance is large before transformation to an ordinary proton, they receive a momentum, which can be rather large. The momentum is liberated at the second electrode and tends to push it outwards and could cause damage to it. This force need not have anything to do with the swelling caused by dissipative processes related to the transfer of charge carriers and the estimate discussed later suggests that the force due to momenta of protons is extremely weak. For the second option Pollack effect would take place by quantum tunnelling. In the ideal situation they would be at rest at the second electrode.

2.4.4 The proposal of Marko Manninen for a model of the Donut battery

Marko Manninen has made language model based analysis suggesting models for the Donut battery. There are many models and the following represents one of them.

1. The layered structure would have $N = 4-5$ layers. This is analogous to a series of capacitors for which the voltages and the inverse of capacitance is additive. One layer would contribute about 1.5 eV to the voltage. The figures (see this and this) give some idea about the structure and properties of the two versions V1 and V2 of the Donut battery.

2. The single layer consists of 4 sublayers. The first sublayer is a layer through, which electron and electron currents are transferred between two layers when the battery is used. Note that the electron and proton current need not flow through a separate wire going through the load. The remaining 3 sublayers correspond to anode, electrolyte and anode.

3. Anode (electrode E1) would consist of graphite particles bound in Na_2SiO_3 (sodium silicate/waterglass). The crystal water would be the source of H^+ ions.

4. Electrolyte would be agar-agar hydrogel with polyiodide acting as H^+ shuttle. It would provide a second water network segment. Polyiodide would serve as an internal electron/charge-balance shuttle.

5. Cathode (electrode E2) could consist of H_xTiO_2 particles acting also as H^+ host. Bipolar interlayer is conductive thin-film bipolar collector (carbon, metallic, or conductive polymer) and provides electron path between adjacent thin cells and allows series-stacking without external wiring.

6. The H^+ ions would be transported via Grotthuss hopping through the continuous bound-water network spanning waterglass + agar + waterglass across each thin cell.

There is an objection against the proposal that all 3 layers contain water.

1. Grotthuss hopping should not be possible during the use of the battery since it would make possible very fast transfer of protons making the cycle life very short. Only ordinary conductivity is allowed. If water is present in all electrodes also during the use it is difficult to imagine how the Grotthuss hopping could be avoided. Only anode and electrolyte could contain water and the water at the electrolyte is necessary.

2. This condition poses a constraint also on the Pollack battery option. The anode should contain -OH groups (say water) during charging. For the symmetric option anode would contain -OH groups and cathode =O groups in the beginning of charging. During the use the -O^- ions would be replaced by -OH groups and eventually spontaneous dis-charging would occur. This actually occurs quite generally but might occur much faster now: in spontaneous discharging the battery becomes a closed circuit (there is an interesting analogy with the generation of activation potential in the case of neurons). This suggests an asymmetric option for which -OH groups are not possible at the cathode. Which option is favored, depends on the situation: it might be favorable to have a fast discharging.

It is interesting to see whether this proposal is consistent with a suitable variant of the Pollack battery. In the most general realization of the Pollack battery, anode would be graphene with -OH groups (hydroxylation). Cathode should not contain -OH groups during charging. Also during the use their presence would make possible the Pollack effect implying a rapid de-charging.

1. In the model discussed by Marko Manninen, the cathode consists of H_xTiO_2, so both O_2 and -OH groups are present whereas the anode is graphene plus Natrium-silicate.

   The anode would consist of graphite and sodium silicate, which would contain bound water producing protons. The bound water would be present also at the electrolyte and H_xTiO_2 electrode and make all layers H^+ hosts. An interesting question concerns the mechanism generating H^+ ions in the bound water associated with various parts of the 3-layered system. The protons associated with hydrogen bonds are a natural candidate. The electrolyte would be in a gel phase.

2. According to the proposal of Marko Manninen, the conduction mechanism would be Grotthuss hopping: as notice, the cathode cannot contain water. According to Google LLM, Grotthuss hopping, defined as the transfer of protons along a dynamic hydrogen bond network, is central in biology. The formation of the EZ in the Pollack effect is a mystery [L27]. How protons would move so quickly and massively to form the exclusion zone (EZ) and why a gel or hydrophobic biopolymer is needed to catalyze it?

   But why would the catalyst be needed as a separate region rather than being mixed with water as in standard chemistry, where long-range quantum correlations that require long-scale quantum coherence, is not assumed? In the TGD based model, long hydrogen bonds as monopole flux tubes between the catalyst and water would make the catalysis possible as well as the transfer of dark protons. The flux tubes would be identifiable as hydrogen bonds. If only anode contains water long flux bonds are necessary during the charging. If both anode and electrolyte contain water, short flux tubes are enough.

3. The separating layer between layers should be conducting. The question is how much its presence slows down the Grotthuss hopping. For the Pollack option this problem is circumvented if the time spent by the dark proton at the magnetic flux tubes is so long that it can get over the separating layer without dropping.

The model could be seen as a variant of the Pollack battery if Grotthuss hopping relies on the Pollack effect.

1. The presence of water in all layers makes possible the Pollack effect and its inverse. The electrolyte is in gel phase and would act as a catalyst for the Pollack effect in the TGD based model. The discharging Pollack effect could also utilize -OH groups of H_xTiO_2 if present. If bound water is also present in the cathode, Pollack effect takes place for it.

2. In the basic model of the Pollack battery, proton transfer would be by the movement of dark protons along monopole flux tubes in the electric field between electrodes. The problem is that free acceleration gives a large momentum. I have proposed quantum tunneling followed by the reverse Pollack effect at the second electrode as a way to minimize the recoil at the second electrode. In the ideal situation, the dark proton would be at rest at the second electrode and could not "drop" from the magnetic body during the travel. This would minimize dissipative effects and make possible rapid charging and discharging.

3. One can consider the possibility that Grotthuss hopping actually takes place by a transformation -OH of water molecules to O^- + dark proton at the monopole flux tube. If the lifetime of the dark proton state is short enough, this makes possible only hopping instead of propagating even over the distance between anode and cathode. The protons travel in the direction of the electric field as in ohmic conductivity. The presence of -OH groups in water makes possible the Pollack effect generating the hopping current. The dark protons would not get large momentum in hopping and the force at the second electrode would be small.

4. The distance travelled by the dark proton at the flux tube depends on the time spent at the flux tube and the hopping distance could be therefore longer than that between the nearest neighbor water molecules. The length of the shortest possible monopole flux tubes would correspond to the distance between neighboring water molecules. For example, in DNA transcription, the time would be so long for mRNA that it would allow the mRNA containing dark proton associated with the ribose ring to move to the ribosome, where the translation takes place [L27].

To sum up, the model for the Pollack battery is consistent with the proposal if Grotthuss hopping relies on the Pollack effect and its reversal.

3 Developing a model of the Pollack battery

In this section simple estimates for the parameters of the Pollack parameters, such as charge capacity and energy density are carried out. I am not a professional so that the estimates are very naive.

3.1 A classical model for the charging by Pollack effect

The following purely classical model for the charging of the Pollack battery is very simple but might give some idea about the orders of magnitude. Auantum tunnelling might be a more realistic model. For simplicity one can consider a piece of the Pollack battery looking like an ordinary capacitor. The batteries with large values of charges of order 10^5 C involve a multiple folded pair of electrodes.

The transversal dimensions of the batteries used in mobile phones are of order $l \sim 10$ cm and the thickness is $d = 2$ millimeters. The total length of the folded bilayer is of order $L = 1$ m. The thickness of the bilayer varies in the range $h = 20 - 25$ μm. This would allow the bilayer to fold in the vertical dimension $N < d/h \sim 10^2$ times $N \sim 10$ would give a length of 1 meter.

One must solve Newton's equations for the motion of charge in the constant net electric field $\Delta E = E - E_{opp}$ associated with the pair of electrets. One can require that $\Delta E = e\Delta U/h$ is time independent and has the correct sign (for clarity voltage is denoted as U). For proton (mas m_p), the solution can be written as

$$h = \frac{e\Delta U \tau^2}{2hm_p} \quad .$$

Here τ is the time taken to travel the distance h between the electrodes. This gives

$$\frac{\Delta U}{V} \times \frac{eV}{2m_p} = (\frac{h}{c\tau})^2 \quad .$$

Note that ΔU is invariant under the scaling $h \rightarrow h$ and $\tau \rightarrow x\tau$.Using $eV/m_pc^2 \simeq 10^{-9}$ this gives

$$\frac{\Delta U}{V} = 2 \times 10^9 \times (\frac{h}{c\tau})^2 \quad .$$

From this one obtains τ if h and ΔU are given.

$$\tau = \frac{h}{c}\sqrt{\frac{1}{\Delta U/V}} \times \sqrt{2} \times 10^{4+1/2} \quad .$$

$\Delta U = 1$ V and $h = 20$ μm gives

$$\tau = \frac{h}{c}\sqrt{2} \times 10^{4+1/2} = (2\sqrt{2}/3) \times 10^{-1/2}\ ms \simeq .2\ ms \quad .$$

The scaling of $\Delta U/V$ by a factor 10^{-6} would give $\tau \simeq .2$ s. The scaling of $e\Delta U$ to the voltage .04 eV assignable to cell membrane which corresponds roughly to the thermal energy at room temperature gives $\tau \simeq 4\ ms$ which is the time scale assignable to nerve pulses.

It seems that the time scale is much faster than the charging time scale so one can ask whether the Donut battery could be modelled as a Pollack capacitor. In fact, the TGD view of dielecrets quite generally involves dark ions travelling at monopole flux tubes and also the generalized Pollack effect.

3.2 The geometric description of dielectrics in terms of warping

TGD provides a first level description for dielectrics in terms of the warping of the space-time surfaces [L26, L28] which defines a basic distinction between TGD and General Relativity noticed already during the first year of TGD. Also quantum criticality and phase transitions could have a space-time correlate the notion of warped Hamilton-Jacobi structure.

3.2.1 The notion of warping

Consider first the notion of warping.

1. TGD allows solutions of field equations, which are gravitational vacua in the sense of GRT and also gauge theory vacua for induced gauge fields. The solutions however allow warping possible only for surfaces. A thin metal plate or a sheet of paper are good examples of a system unstable against warping and therefore critical systems.

2. TGD indeed allows minimal surface solutions with a 1-D CP_2 projection belonging to geodesic circle $S^1 \subset CP_2$ for which M^4 time coordinate in the rest system of the causal diamond CD is of form $m^0 = t - \Phi/\omega$. The induced metric of X^4 given by $ds^2 = (1 - R^2\omega^2) - dz^2 - dwd\overline{w}$ is flat and has a deformation of the Poinca group as isometries. The interpretation $c_\# = \sqrt{1 - R^2\omega^2}$ as a reduced light velocity is natural: the path around a warped space-time surface is longer than along a non-warped one. There would be no gravitational force but the vacuum would be warped. This warping makes sense also for monopole flux tubes obtained as deformations of the Cartesian product $M^2 \subset Y^2 \subset M^4 \times CP_2$. M^2 would be completely analogous to a metal plate and could be warped.

3. The warping can occur also at the level of the embedding space $H = M^4 \times CP_2$ for the Hamilton-Jacobi structure [L14]. Now $M^2 \subset M^2$ and CP_2 degrees would mix. An analogy is provided by a cylinder surface for which the coordinates (z, Φ) are replaced with coordinates $z - k\phi, z + k\phi$ for which coordinate lines are dual helices.

   The hypercomplex coordinates $(u, v) \rightarrow (t - z, t + z)$ would be replaced with $(u = T - z, v = T + z)$ where T is defined as $T = t - \phi/\omega$. The canonical embedding of $M^2 \subset M^4$ with constant CP_2 coordinates would be tilted towards the direction of $S^1 \subset CP_2$. CP_2 complex coordinates would suffer a time dependent $U(1)$ rotation $\Phi \rightarrow \Phi - \omega t$, which is holomorphic transformation and gives rise to a twisted Hamilton-Jacobi structure.

4. Even more general twisted Hamilton-Jacobi structures can be imagined [L14]. The TGD based model for the honeybee dance [K1] led to the proposal that there are preferred extremals as sphere bundles, which assign to a given point of the space-time surface a geodesic sphere, whose position in CP_2 depends on 2 M^4 coordinates so that one speak of local $SU(3)$ rotation of the geodesic sphere depending on two M^4 coordinates. Could also these kinds of twistings

define exotic Hamilton-Jacobi structures? Could also twistings depending on time coordinate and complex coordinate w define exotic exotic Hamilton-Jacobi structures?

5. The twisted Hamilton-Jacobi structures could be associated with monopole flux tubes serving as body parts of field bodies. This would give connection with $\hbar_{gr}$. Also space-time surfaces representable as graps $M^4 \times CP_2$ could have a twisted Hamilton-Jacobi structure and the Hubble tension [L27] could be understood if the Hamilton structures differ by a small twist in long and short cosmological scales. .

3.2.2 Warping and dielectrics

The flat warped space-time surfaces are characterized by the reduced light-velocity $\beta_0 = c_\#/c \leq 1$. There is a criticality with respect to the variations of $c_\#$ (instability of metal plates illustrates this). Also the twisted Hamilton-Jacobi structures would be characterized by $c_\#$.

The criticality of the warping could induce or accompany various kinds of quantum criticalities. In the case of the Allais effect, this kind of quantum criticality would explain the variation of the pendulum frequency that cannot be explained in terms of gravitation.

Quite generally, one can write $f_\# = c_\#/\lambda = f/n$, where $n = c/c_\#$ is analogous to the refractive index appearing in electrodynamics in presence of matter. In Maxwellian electrodynamics, refractive index relates to the relative dielectric constant ϵ_r via the formula $n = c/c_\# = \sqrt{\epsilon_r}$. Could reflective index n have a geometric description in terms of the warping of the space-time surface? If so, the warping of the space-time surface could be seen directly via the reflection of light!

Refractive index depends on frequency. This can be understood in terms of quantum criticality implying the value of $c_\#$ associated with the massless extremal assignable to the photons depends on frequency. At resonance, at which ϵ_r diverges, the value $c_\#$ would in the ideal case vanish: there would be no propagation of signals. The standard interpretation would be in terms of absorption of the signal by atoms, which contribute to the resonance frequencies.

Could dielectrics be understood in terms of warping? If the density of electric energy for the space-time surfaces obtained as small deformations of warped vacuum extremals and idealizable using the flat metric for a warped vacuum extremal equals to the energy density assigned to the electric displacement D satisfying $D = \epsilon_r E$, $\epsilon_r = (c/c_\#)^2$, the description of dielectrics could be d geometrized.

To see whether this can occur, one one can consider the density of conserved energy density associated with time translations given by Kähler action. Note that the induced Kähler field reduces in a special case to the electric field.

1. Let us consider a deformation of warped vacuum $X^4 \subset M^4 \times S^1$ for which S^1 angle coordinate is given by $\Phi = \omega m^0$, where $m^0 = t$ is standard M^4 time coordinate.The induced metric is $g_{tt} = 1 - R^2\omega^2 = c_\#^2$. If one takes $u = (c_\#/c)t$ as a new time coordinate the induced metric reduces to the standard Minkowski metric when gravitation is neglected. u has interpretation as proper time and is therefore a natural choice.

2. The induced Kähler form $J_{ti} = sin^2(\Theta)\omega$ becomes in the new coordinates $J_{ui} = sin^2(\Theta)\omega/c_\#$. The expression for the conserved four momentum density includes a part proportional to the energy momentum tensor and a part which has no analog in standard electrodynamics. It is enough to study the contribution of energy momentum tensor the momentum densities $P^{au} = T^{u\beta}\partial_\beta m^k m_{kl} j^l_a \sqrt{g}$, $j^l_a = \delta^l_A$. This givs $P^{au} = T^{ua}(c/c_\#)$, where $c_\#$ comes from $\partial_u m^0$. The energy momentum tensor density is given by $T^{\alpha\beta} = g^{\alpha\mu}g^{\beta\nu}J_{\alpha\mu}J_{\beta\nu} - (1/4)g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}\sqrt{g_4}$. Neglecting gravitation, the induced metric is the standard Minkowski metric, which effectively disappears from the expression from the energy momentum tensor. The resulting expression for energy density differs from that for empty Minkowski space by the factor $(c/c_\#)^3$. This differs from the relative dielectric constant $\epsilon_r = (c/c_\#)^4$ associated with $D \cdot D = \epsilon_r^2 E^2$. For time translations this gives for the density of conserved energy $T^{uu}(c/c_\#)^3\sqrt{g_4} = T^{uu}(c/c_\#)^3$. Same result is obtained also by using t as a coordinate which is not surprising since the expressions are general coordinate invariant.

3. What about the volume action $\sqrt{g}$ associated with the cosmological constant. For the metric determinant one obtains using the time coordinate $u = (c_{\#}/c)t$, the energy current $T^{u0} = (c/c_{\#})\sqrt{g} \simeq (c/c_{\#}$ so that the energy density is scaled up also now.

4. It would seem that one should get rid of the factor $c/c_{\#}$ in both cases. If one considers only the energy momentum tensor rather than the conserved energy proportional to $\partial_u m^0 = c/c_{\#}$, one indeed obtains the expected result in both cases.

One can consider also the Schrödinger equation $\partial_t \Psi = H\Psi$ Taking the proper time coordinate $u = c_{\#}/c$ as coordinate, would give $\partial_u \Psi = c_{\#} H\Psi$. The energy eigenvalues would be scaled. Also the scaling of charges for the dielectric would affect the eigenvalues in the standard way. General coordinate invariance requires the scaling of Hamiltonian by $c/c_{\#}$.

For dielectrics, the charges are effectively screened by $1/\epsilon_r$ so that the Coulombic interaction energies of atoms, proportional to the product of charges, are scaled down by $1/\epsilon_r^2 = (c_{\#}/c)^4$ which reflects the screening. Voltages are scaled by factor $1/\epsilon_r = (c_{\#}/c)^2$.

3.3 Energy storage in the case of the Pollack battery

I have not considered the energy storage in the case of the Pollack battery earlier. Most batteries store energy chemically and also in terms of polarization energy. So one can consider first ordinary batteries.

1. Chemical energy storage has an alog in biology: the valence bonds of proteins store energy. That is why polymers as electrolytes are natural. Something chemical could happen to the electrolyte or electrodes during the charging. Chemical changes can also occur at the electrolyte-electrode interfaces. Covalent bonds are energetic. The result is basically an unstable state that will break down before long. Just like in biology.

2. Google says that 95-99 percent of energy is stored as chemical energy for typical capacitors so that practically all energy is stored as chemical energy. Chemical potential characterizes chemical energy and is a thermodynamic quantity. The correct quantity to consider is free energy $F = E - TS$ and is a convenient constant at temperature and constant volume. F increases when "particles" with a positive chemical potential, defining the counterpart of chemical energy, are added.

3. Including the electric field brings in the work done to polarize the substance. For linear dielectrics it can be characterized in terms of the relative dielectric constant ϵ_r. ϵ_r does not tell us about the chemical energy storage in its entirety, although it is important. The values typically satisfy $\epsilon_r < 100$.

   The estimate for the electrostatic energy $E = \epsilon_0 CV^2/2$ of capacitor with area $A = 10^{-2}$ m^2 and distance $d = 1$ mm between plates gives $E = 2.76 \times 10^8$ eV. For $\epsilon_r = 100$ this becomes $E = 2.76 \times 10^{10}$ eV. This value is completely negligible with the value $E \sim 10^{25}$ eV claimed by Donut Lab. There the energy storage must be chemical.

4. If temperature T and volume V are constants, only the change of the chemical potential and the build-up of polarization contribute to the free energy.: $dF = sum_i mu_i dN_i + E \cdot dP$.

Google reveals that chemical energy storage can occur in at least two ways. Vanadium redox battery with liquid electrodes and Lithium ion battery are the basic examples.

1. In Vanadium redox battery the two electrodes and separate by a membrane contains. Vanadium is unique in the sense that it allows several ionization state V^{k+}, $\in \{2, 3, 4, 5\}$ The charge of the vanadium ions increases or decreases in redox reactions (note that oxidation means giving an electron and reduction receiving it).

2. In Lithium ion batteries, the energy is stored to the opposite electrode, where the Li ions flow. In the electrolyte through which Li ions are transferred, a charge cloud of opposite sign accumulates around Li$_+$ and this "shuttle" ends up at the opposite electrode where it knocks the surrounding material and penetrates to the electrode: intercalation is the term used.

Electrostatic energy of the charging electric field is stored in the state of E2 but not in electrolyte. Only E2 stores energy by changing it chemically. This state is a higher energy state and not stable. When the external load is added this state begins to decay.

Also in the charging of the Pollack battery, a process analogous to intercalation occurring in E2 is expected to occur but the total gain is the energy obtained in the acceleration at the monopole flux tubes irrespective of the mechanism of the energy storage.

Since the flux tubes are not thermodynamic systems, the dielectric constant is expected to be $\epsilon_r = 1$ and the above simple model should apply. If the dielectric constant at the flux tubes is larger than one, the potential energy is scaled down by factor $1/\epsilon_r$ so that $\epsilon_r = 1$ is the optimal option.

If the electrostatic energies and atomic binding energies at the electrode E1 are scaled down $1/\epsilon_r^2$ so that the energy needed to kick protons to dark protons is reduced and is favorable for the occurrence of the Pollack effect. For water $\epsilon_r < 1/80$ is true. Irrespective of whether the charge carriers flowing through the load are electrons or protons, the total energy liberated during the use is the energy gained in the charging.

The energy needed by the Pollack effect is estimated to be about .33 eV [L17] as difference of energies -OH and -O$^-$ + proton systems. The value of this energy depends on the interaction with electric fields of the environment. For dielectrics, standard theory predicts a reduction of atomic energies by factor $1/\epsilon_r^2 = (c_\#/c)^4$ following from the screening of charges. For water with $\epsilon_r = 80$ this would give energy of 33 μeV. The large dielectric constant of water could explain why the Pollack effect takes place. Note that the Pollack battery idea might also work for dark Li ions as charge carriers.

3.4 A model for the Pollack battery

There are two cases to be considered: the models with ideal quantum tunnelling for which dark protons arrive at E2 at rest and without quantum tunneling in which case they gain the difference of Pollack energies for E2 and E1, the gain of chemical energy and the polarization energy. As found, the polarization energy $E = \epsilon CV^2/2$ is completely negligible so that the energy storage to E2 should be chemical energy by the analog of intercalation.

1. Dielectric property of E2 reduces the bound state energies of atoms by the factor $1/\epsilon_r^2 \leq 10^4$ so that the dielectric property is expected to be important. The screening of electric charge also helps the intercalation to E2. Solvation of ions to water is an analogous process.

2. One can consider a possibility of a phase transition $\epsilon \simeq 1 \rightarrow \epsilon_r < 100$ at E2. This would help intercalation of the protons at E2 and allow the load of electrostatic energy to E2 during charging.

3.5 Estimates

Let us discuss now estimates for the parameters of the model taking the claims of Donut Lab seriously and using the proposed model for Pollack battery.

3.5.1 Estimates for the charge and energy of the Pollack battery

Consider first the estimates for the change and energy.

1. The value $Q = 26$ Ah= 10^5 C of the charge capacity claimed by Donut [L29] measures the total charge of the electrodes E2 of the battery (analogous to a series of capacitors). The number N_p of protons transferred from E1 to E2 by Pollack effect, followed by its reversal, can be estimated from the claim $Q = N_p e = 10^5$ C $= x \times 10^{23} e$, $x = 6.248$. This gives the estimate $N_p = x \times 10^{23}$. When the number of the layers is N so that one has effectively N capacitors in series, the sum of the transferred protons is $N_p = NN_p$.

2. The total energy of the battery generated in charging is claimed to be $E = 400$ Wh. This energy should be $E = N_p \times e_p$, where e_p is the energy gained per proton loaded to E2 during charging. e_c corresponds to chemical potential per proton in E2. Note that the Pollack

energy does not show up if it is the same for E1 and E2. The estimate for e_p is $e_p = 13.8$ eV. This happens to be very near to binding energy 13.6 eV of a hydrogen atom: is this an accident?

This suggests that there are N layers analogous to capacitors in series so that voltages V/N add to V and energies e_p/N and to e_p. For $N = 8$ layers the voltage of a single layer would be $V/8 \sim 1.75$ V. $N = 4$ layers would give $V/N = 3.5$ V, which seems to be large. This suggests that chemical energy storage is involved. For $V = 1.5$ eV and for $N = 4$ layers the ratio of chemically stored energy would be $r \sim 3.5/1.4$.

3. What comes to mind is that the dropping of dark protons to E2 induces the feed of electrostatic energy to E2 generating a phase transition increasing the value of ϵ_r from say $\epsilon_r = 1$ to $\epsilon_r \leq 100$. This would reduce bound state energies by a factor $1/\epsilon_r^2$ so that the atoms would be energetically near the ionization. These almost ionized states could correspond to Rydberg atoms with very large size for hydrogen atoms. The phase transition would mean a liberation of ionization energy of almost 13.6 eV, quite near to the 13.8 V suggested by the claim of Donut Lab. The chemical energy of E2 would increase due to the feed of electrostatic energy during charging.

   Could the Pollack protons dropping to E2 induce the phase transition and almost ionize the protons of E2? Why would the number of almost ionized electrons be nearly the same as that of Pollack protons? Could water molecules H_2O be generated in the dropping of the proton inducing the change $\epsilon_r = 1 \rightarrow \epsilon_r \sim 80$. Could hydroxide ion OH^- and the dropping proton combine to form an excited $\mathrm{H_2O}$ molecule in which second hydrogen or both of them are nearly ionized.

Both tunneling and no-tunnelling options for Pollack battery seem to be possible.

1. Consider first the option without quantum tunnelling. In a good approximation e_p should be the energy gain $E = eV$ in the acceleration. If there are 4 layers with voltage 1.5 eV giving a total voltage 6 eV, 7.8 eV would be loaded to the internal degrees of freedom of E2. Chemical storage is therefore necessary and could involve a phase transition changing ϵ_r in the proposed way. For $E = 200$ W, the value $N = 5$ layers with the energy gain for a single layer would be $e_p = 1.37$ eV.

2. What about the quantum tunnelling option? In this case the net energy transfer is very small and vanishing if the Pollack energies e_P for E1 and E2 are identical. If E1 is dielectric, the Pollack energy e_P, to be distinguished from the energy gain e_p, would be rather small, of order $.33eV/\epsilon_r^2$ and about 3 μV for a dielectric with $\epsilon_r = 10^2$. Practically all energy should be loaded to E2 as chemical energy. This is quite possible for the proposal discussed above.

3. For both options, an irreversible change of E2 feeding electrostatic energy to E2 during the loading should take place. This energy would be liberated during the use. E2 would be analogous to a protein in biology liberating its chemical energy as a metabolic energy. A considerable fraction of the surplus energy in E=13.8 eV would be internal energy.

4. A plausible looking option is that a considerable part of the electrostatic energy used to charge the Pollack battery is used to realize the phase transition $\epsilon_r = 1 \rightarrow \epsilon_r \leq 100$ at E_2 induced by the dropping dark protons. These phase transitions are very frequently occurring phenomena in condensed matter physics and even the realization of bit in terms of the two states has been proposed.

3.5.2 An estimate for the momentum transfer

A possible problem of the Pollack battery is that the momentum gained by the dark protons by acceleration at the flux tube is so high that it induces a large recoil effect. Quantum tunnelling for the Pollack effect might cure this effect: in the optimal situation dark protons would arrive at rest to E2.

The momentum transfer to E2 can be estimated. This gives estimates for the average force and acceleration, when the charging time is known. 5 minutes is the shortest time used in VTT tests.

1. Energy conservation $mv^2/2 = e\Delta V$ gives

$$F = \Delta p_{tot} = N_p m_p v = N_p m_p c\sqrt{2e\Delta V/m_p c^2} \ .$$

   Here one has $\Delta V/mp \sim 10^{-9}$.

2. The average acceleration a_2 for $E2$ is

$$a_2 = \frac{F}{M(E2)} = \frac{N_p m_p}{M(E2)}\sqrt{2e\Delta V/m_p c^2}\frac{c}{T},$$

   where T is the charging time.

3. The mass of E2 is $N_2\langle A\rangle m_p$, where N_2 is the number of atoms having an average mass number $|A|$. This gives

$$a_2 = \frac{N_p}{N_2}\sqrt{2\Delta V/V}\langle A\rangle\frac{eV}{m_p}\frac{c}{T} \ .$$

   For $T = 5$ min, the order of magnitude is $a_2 \sim 1$ mm/s^2 to be compared with the acceleration of gravity $g = 10$ m/s^2. The estimates $\Delta V \sim 1$ V, $N_p = 10^{23}$, $N = 5$ and $N_p \sim N_2$ do not change this estimate much. Note that by making E2 massive by using heavy atoms such as Titanium, one can reduce the acceleration. The force caused by the momentum transfer on E2 would be for $M = 10^{-2}$ kg of order 10^{-5} N.

   Could this relate somehow to the 4 per cent swelling reported in the VTT test of the Donut Lab battery(see this)? Google LLM informs that the swelling force for mobile phones with a 4 per cent expansion is about 4×10^5 Newtons. The swelling force, as Google LLM defines it, cannot be identified as that caused by the momentum transfer in the recent case. The charge transfer mechanism is totally different for the Pollack battery for which the transfer would occur at the monopole flux tube outside the battery in the ideal case and without dissipation. Ohmic dissipation and fraction reduce the momentum transfer and the dissipated energy and momentum cause the swelling force.

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