FORGOTTEN INVENTIONS OF LENR

Part 4: Appendix

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Introduction

This four-part review covered a heretical, preposterous allegation: LENR-based inventions (electric cars) were driven well before the concept of the first (hot) fusion device—H bomb—was even born. Sustainable "renewable" energy was produced well before we started to worry about climate change, resource wars, or petrodollars. Further, once in each decade LENR-driven electricity/oxigas-producing devices were created by lucky inventors before LENR as a diffuse concept started to emerge slowly by the 1990s as a result of work by Pons, Fleischmann and Johnson.

It is a tragedy that science as institution never paid attention to these, neither the well-funded hot fusion community nor later the struggling "cold" fusion community.

The signs were on the wall in due course. Pseudo-particles of F. Ehrenhaft, transmutations in gas discharges by Collie *et al.*, and the reversal of an electric field in an interrupted dusty arc discharge was discovered as early as 1905. Science excelled as an experimental method. Science failed as an institution because instead of nourishing these ideas, it crushed each of them. The year 1905 was a turning point in physics. Einstein's legacy has been nourished, but the names of Collie, Moray and Ehrenhaft are not even footnotes.

What makes nature tick at these modest energy levels? The very same trick we see everywhere in biology (like the ATP synthetizing Crebs-Szentgyörgyi cycle): a series of interlocked autocatalytic phenomena, preferably in a resonant mode. This makes possible the synthesis of neutrons from protons and electrons. This is the first bottleneck event. However, on the surface of charged edges and dust particles, this takes place at a modest energy investment as a self-organized phenomena. Other elements of the Edmund Storms chain of fusion events, like the fusion of ${}_2D^1 + {}_1p^1 = {}_3He^2$ may take place with the help of Coulomb charge screening, which is provided by these sites.

In the previous three parts, about ten inventions were scrutinized, finding their common technical/physical foundations. It was clear that surface morphology, hydrogen adsorption and absorption are vital to the economy of the process, both for dust particles and surface edges.

Further, to maintain a reliable process, this surface morphology must be preserved, and most inventions failed here.

Are there additional known unknowns? Yes.

Like technology related unknowns: what is the optimum electrode material? What sort of layers are to be used? What is the best gas mixture? There are a host of other open issues about the layout of discharge tubes, electronic circuits, and operation parameters like frequencies, voltages and interlocked coupled tubes, etc.

Are there further unknown unknowns? My answer is a definite, loud yes. We know enough already to see the worst pitfalls ahead. Why have these inventions/inventors failed?

1) Because of overreacted secrecy. (Every inventor fell into this trap.) As Jed Rothwell put it long ago, about the parallels of early aviation and cold fusion: "Revolutionary devices that are still at the impractical stage must be made public, or they will never attract the critical mass of people necessary to make them practical, commercial products."[1]
2) Wrong theory. Vacuum fluctuation—ether energy as fundamental physics—led nowhere. Nearly everyone fell into this trap.
3) There was no room "down there." Physicist were chasing only "real" particles with an ever bigger accelerator or ever smaller particles with shorter life times. Only semiconductors made a dent in this one-sided approach to nature. However, quasi-particles are more useful and more interesting members of the micro-nano world than tau or sigma hyperons. Inventors had to struggle by themselves to map the weird behavior of quasi-particles.

The "physics of dirt" (as Wolfgang Pauli sniffed at quasi-particles) never attracted enough interest, funding and brainpower as needed. This is more than a mistake, it is a crime.

General Conclusions

After a review of more than ten forgotten inventions and physical effects, there can be several different outcomes.

The *pessimistic* reader will conclude that it is not worth working here, because the lucky and diligent inventors with working prototypes get nowhere, due to lack of social support, *i.e.* research funding, and cooperation.

The *hostile* reader (if he reads this paper at all) will be reassured that during one hundred odd years all these inventions perished, not because there is no physical reality behind these devices, but because the inventors never disclosed all the necessary know-how, and so they got what they deserved.

The *optimistic reader* (I wrote this review for them) will realize that there is a vast, unlimited opportunity—provided the LENR community will cooperate. That has never happened in the past, but it may happen in the future—if there is a future.

As I see "mainstream LENR"—the electrochemistry-based, steady state, low temperature, low-current-density line of research—it has no future. The future is only where there is a clear economic return, and that is *reliable electric energy production*. A number of construction principles are worthy for consideration from these inventions. In my opinion they are the following:

- Transient plasma is a must, a non-negotiable demand.
- The plasma is preferably dusty, and at least one electrode must have a surface with cavity cathode construction (higher efficiency).
- The cathode surface must contain edges and have a large surface.
- Discharge tube preferably should be an acoustic resonant cavity.
- Electrode material must store hydrogen isotopes.
- Plasma gas ought to contain H and D and C (CH4).
- Plasma pressure should preferably be atmospheric. Atmospheric pressure is more stable than low pressure.
- The extraction of electric energy should be within a high frequency (KHz-MHz order) resonant electric circuit. The excess electric energy extraction is usually via a metal electrode, but a capacitive coupling may do this task as well.

The "dark horse" is the Coleman construction, with a layered, sand-filled tube, with a constrictive glow. It cannot be made resonant. Electrode quality is not important; the hot part of a resonant electric circuit with an external magnetic field—which influences electrons, but not the ions.

I do have hands-on experience with audio frequency discharge for tubes filled with spherical glass beads. Usually the discharge path is restricted to an ever-changing narrow channel, but at a low pressure (at about 1 kilovolt) the glow is uniform, heating (melting) the glass beads. Our glass beads were between 1 mm-5 mm, so I don't know what would happen at the sub mm range, when there is vapor and carbon dust in the tube. It may have a completely different behavior! This is an unexplored corner of discharges.

1. My Sad Experience

After more than a decade of a fruitless fight with unreliable electrodes in electrochemical cells and gas discharges (Patterson cell, Correa and Chernetzky), I gave up.

In 2006 I chose to explore microwave-driven, pulsating dusty plasmas without electrodes, in embedded acoustic and electromagnetic cavity resonators. It was an instant solution in terms of transmutations. (A hydrogen atmosphere was out of the question due to strict budget limitations.) But the mystery of Tesla's car occasionally came up as the ultimate solution for LENR. Hoping to get funding with a possible research grant, I filed a patent application in 2011. (See WO/2012/153156, "Renewable Energy Production Process with a Device Featuring Resonant Nano-Dust Plasma and an Acoustic Resonator; and WO/2012/164323, "Method to Produce Renewable Heat Energy.") I won research grants five times but the EU R&D funds were always stolen, since the owners of the umbrella company just wanted the money, and could not have cared less about results (Motech, Aqua-Maxima, SKC and Swiss company Femtoscience). So the project is dead, and the patent is abandoned; it is in the public domain now.

2. Transmutations Revisited After 100+ Years

There were about a dozen researchers working on gas discharge-based transmutation. J.N. Collie *et al.* published the most detailed work[2] on hydrogen transmutation on July 23, 1914, just days before World War I. We ask just one question: was their work repeatable? Because that is required for a wider acceptance. The answer, briefly, is "no," but they were not far from it. With some luck and persistence, about ten people working for five to six additional years should have been enough to produce a *reliable recipe for transmutation*. Tesla and the young Moray already had the reliable recipe: a corona discharge around thin, dust-producing electrodes.

Before 1914, they never described their experimental setup, because they kept on improving it. Certainly World War I could not have come at a worse time because young talents were sent to the front, and military needs had priority over academic research. (Sadly, Rutherford's right hand man was shot dead at Gallipoli.)

What were their strong points?

- They used hydrogen in their plasma, which was useful. (They could have used carbon electrodes at atmospheric pressure as well.)
- They used periodic, very high voltage (12 inch sparks) with an inductive coil. Mercury or hammer interrupters yielded very low frequency (1-2 Hz).
- They also used rectifiers, which improves transmutation efficiency.
- They had up-to-date skills in vacuum technology, and spectrum analysis.
- They tried different electrode materials, so the effect of surface quality and electrode erosion was "around the corner" for them.
- They did carefully controlled experiments, to make sure He and Ne were not a result of slow, sneaky diffusion of ambient air into their system.
- They have admitted that their own transmutation results were not reliable and quite often they had null results. They knew there were more unknown parameters influencing the transmutation. They kept on searching for them.
- They realized that a Pd electrode was excellent, but didn't concentrate on it.

What did they miss?

- The discharge tube shape was never suitable for acoustic resonance, and the low frequency sparks were also out of range. Thus transmutation yield was poor.
- They never suspected that the electrode surface morphology was among the important unknown parameters. They did not realize that sputter-induced dust and edges are responsible for the initiation of transmutation.
- They did not pursue pure mercury electrode experiments, but only Hg-Si, which gave indecisive, mixed results.
- They did not realize the importance of pulsed arc discharge.
- They sometimes cooled the plasma by a water jacket for sealing, but it cooled the discharge as well, reducing the free electron density and energy in the discharge, and thus its energy level.

■ They did not use a Brown tube (oscilloscope) and so failed to note the reversal of the tube potential. This potential reversal must have had a correlation with transmutations. No potential reversal, no transmutation. Thus they missed an important diagnostic tool.

My own subjective estimation is that they were quite close to unravelling the important parameters for transmutation. Had they used thin Pd corona discharge tubes, they could have gotten reliable results within weeks. I leave it to the readers: were they far away? History never gave them a fair chance.

The most important, but undeservedly forgotten paper about transmutation was written by J. Norman Collie (Fellow of Royal Society), H.S. Patterson and Irvine Masson. Their paper, "The Production of Neon and Helium by the Electrical Discharge," was published by the Royal Society.[2] This is the most descriptive paper about the transmutation of (ordinary) hydrogen into helium and neon. There might have been other transmutations on the electrode surfaces, but they were not analyzed. In fact, given the crude, insensitive tests of that age, analysis of the transmutations on the surface had no chance.

The long paper has had a chance to start a similar revolution as the papers about radioactivity of the Curie couple. I blame the outbreak of World War I for the oblivion of this important paper. I encourage our readers to read it.[2]

One of the several discharge tubes is shown in Figure 1. Note the double-walled, intricate structure, meant to avoid leakage of ambient air via the glass wall. The electrodes are the ring shaped "A" and the flat, circular shaped "B" are housed inside the inner tube. Transmutation was detected by emission spectroscopy of the residual gas, during a discharge. This structure of spectral lines can be photographed as well.

This made possible careful, reliable observation of transmutation of hydrogen (protium) into helium and neon. Unfortunately, deuterium and tritium cannot be detected by emission spectroscopy, so the chain of fusion events from hydrogen into helium were a sort of mystery.

J.J. Thomson, co-discoverer of the electron, did stumble into tritium—and called it X3 (tritium). However, he thought that it was occluded in the discharge electrode material, thus dismissed transmutation as a possible source of X3.[3] Strange for us now, but transmutation has been a legitimate mainstream idea, bright researchers worked on it and mainstream journals published test results. There were unhindered discussions on the subject!

There was a fair chance to discover deuterium too with the early mass spectrometer, thus indirectly proton and neutrons, but politics (World War I) disrupted this path.

Most transmutation tests were done in a less sophisticated double-walled discharge tube, shown in Figure 2. Electrodes are connected via mercury, but it is used as a sealant as well. The electrodes are straight as well as the discharge tube, with a bottleneck (B).

Several versions of this tube were built, but none of them made possible acoustic plasma resonance, thus transmutation yield was fairly low. Needless to say, electrical transients were not studied, though a simple cathode ray tube (Brown tube) was available at the time.

Most Ne gas was found in case of Pd electrodes, but other metals—like Cu, Pb, Tl, Li, Na, K, Mg—were used as well, with mixed results. Sometimes Ne, sometimes He was in majority, sometimes both of them.

Collie and his co-authors couldn't find the "rules" behind the observations, but did a careful set of control tests to rule out outside leakage and contamination. From this viewpoint their control test withstands the scrutiny of time.

Consequently the appearance of He and Ne can be attributed to fusion of hydrogen within the discharge tube.

In my opinion this test is worth repeating, and any modestly equipped physics department lab can do it.

The Mitkevich devices

The interrupted arc discharge devices of Mitkevich (1904) are of simple layout. In Figures 3 and 4, the electric and mechanical layouts are shown, taken from the original paper. The arc discharge has been interrupted by mechanical means, that is the discharge volume was increased, rapidly.

This diminished the effect of voltage reversal; nevertheless, it was noticeable, detectable.

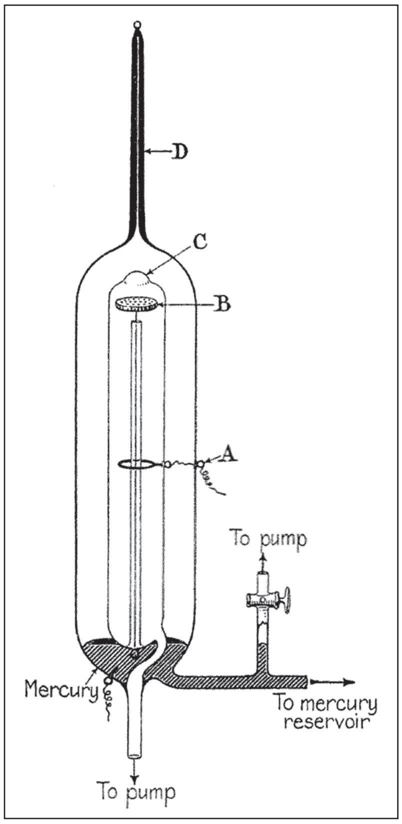

Figure 1. Collie's sophisticated double-walled discharge tube to study transmutations. The double wall prevented the diffusion of He into the inner tube from the ambient air. There was no He without transient discharge.

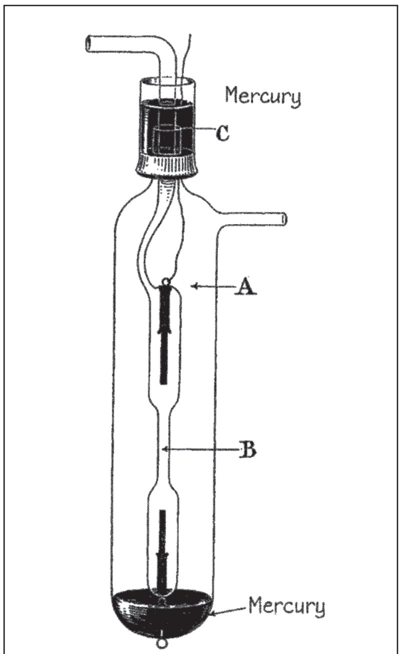

Figure 2. A simple double-walled discharge tube for transmutation experiments in hydrogen atmosphere. He and Ne appeared after awhile, depending on the cathode material. There were sophisticated control steps to exclude the possibility of external contamination.

In fact, this was the first published paper when the electricity generating capability of a transient dusty plasma was noticed. But this work was instantly forgotten.

3. The Intriguing Features of Dusty Plasma

Dusty plasma—in some context colloid suspensions—has different features from usual homogenous plasma and liquids. This modest looking inhomogeneity gives rise to some of the most useful and richest classes of self-organized structures in physics.

"Ordinary" plasma is well known in the absence of outside magnetic fields (magnetohydrodynamics). Even combustion flames—like in furnaces or diesel engines—are dusty, due to soot. Thus dusty plasma is as old as the first fires, but it was not scrutinized until recently. Its diagnosis is notoriously difficult.

In the zoo of plasma states, transient dusty plasma waves are the strangest beasts.

In dusty plasma waves, extreme electric fields may arise along with extreme accelerations for charged particles. These extreme local non-equilibria can't be generated by other technical means even at large expense. The "table top" transient dusty plasma devices are more powerful accelerators than, for instance, the Large Hadron Collider in Geneva (but do not give homogenous beams). It has much higher local instant temperatures than inertial fusion plants or tokamak devices.

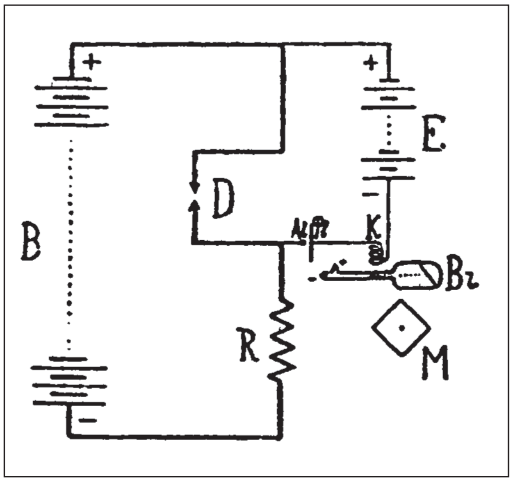

Figure 3. The electrical layout of the Mitkevich test to study the reversal of voltage in transient arc discharge. B: 110 V battery, E: compensating battery for voltage, D: arc gap, B_2: Brown tube to measure voltage transients, M: revolving mirror, R: resistance.

Yet they are rightly sorted into the "low energy device" category, as their energy input seldom exceeds the kW order.

Interesting self-organized, resonant structures may arise even if there are negative ions in an oscillating, driven plasma among positive ions. Ion and electron oscillations take place at quite different lengths and frequency scales at low (m bar) pressure.

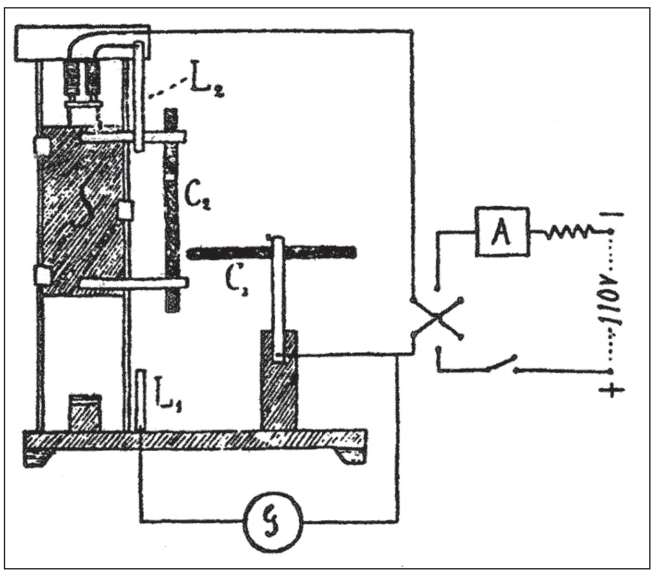

Figure 4. The mechanical layout of arc discharge disruptor. C_2: electrodes, L_1: electromagnetic switch.

In the usual plasma, the Debye scale is the main factor; outside of it there is no net electric field between ions and electrons. Any outside disturbance will be immediately smoothed out, counterbalanced by the fast moving electron fields. In ordinary plasma—and in metal lattices as well—there is no high intensity internal electric field which may act as Coulomb shielding, despite good efforts.

Dusty plasma—and colloidal suspensions to a smaller degree—does offer this at a modest external energy expense. All plasma must be sustained by input energy (unlike permanent magnets, which maintain their field after magnetization).

Plasma can be generated by several means, but chemical or electric energy are the usual methods to maintain them.

When dust particles float in a plasma, they become charged automatically, since the electron speed is always higher than the much bulkier dust grains, even if the latter is in the nanometer range.

When the dust particles are electrically conductive, only a small amount of charge is accumulated on the surface. When they are non-conductive they penetrate and stick for awhile under the surface, giving rise to some "electret"-like features. The particle charge and its sign may vary due to temperature (thermal emissions), grain size, ambient electrons and ion temperature, modes of external excitation, shape of the dust particles, distribution function of the dust particles—just to name the most important parameters.

Grain particles cannot accumulate all the electrons, because the accumulated electrons already repulse slow electrons, and thus only the high speed electrons may get through. Further, positive ions are attracted into the huge accelerating field of charged grain particles.

Incoming positive ions are neutralized, and thus leave the dust particle, or just remain stuck to the surface. This is the situation for the practically non-existent steady state.

When pressure waves are generated—usually by external acoustic pressure or by alternating power excitation—electric fields are further enhanced, as shown in Figure 5.

In the absence of pressure waves, there is still an electric field around the charged dust particles, which facilitate LENR at a slow rate.

Figure 5 shows a schematic distribution and buildup of an internal strong electric field, as a result of an acoustic standing wave. Only a half period is shown. In the other half period, the positive ion density is higher at the same place where now negative dust particles are in the majority.

Now we focus exclusively on economic cases where the rate of nuclear reaction is the highest. (There are some fusion reactions for light nuclei in the positive column of DC discharge dusty plasma, but the yield is low.)

Higher fusion rates and higher mass nuclei may appear in the dusty plasma of arc discharges. Arc discharge is a natural site of oscillating dusty plasma, and as early as 1907 it was

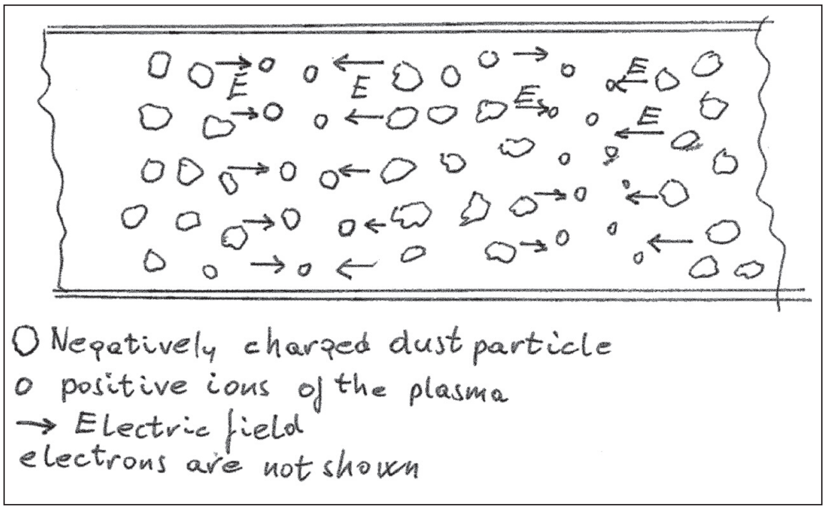

Figure 5. Distribution of ions and electrons in a dusty plasma distributed by outside acoustic excitation. Note the pressure peaks, where charged dust particles are accumulated, thus creating an intense internal electric field.

discovered by accident that transmutation takes place there.

Arc plasma (even if created by a DC power supply) is always unstable. The electron emission, necessary for maintaining a plasma, is provided by the thermionic emission of the cathode but it is not stable and it fluctuates in time. Atmospheric dusty arc discharge has a characteristic 1/f noise; that is, the higher the frequency of a component, the lower its amplitude.

It is worth looking for fusion with boundless (open air) atmospheric arc discharge—like George Oshawa's carbon-air reaction chain.

Bounded arc discharge is better, because some of the frequencies of the hissing 1/f noise will be amplified by the discharge tube as an acoustic cavity.

This is the reason why early investigators found transmutation in cylindrical discharge tubes. They were not aware that a gas discharge automatically provides dust by the erosion of electrodes, and that the glass discharge tube may be an acoustic resonator at the same time.

The fusion rate is further improved if fine dust is provided in the arc discharge volume, as done by E. Esko and A. Jack in Quantum Rabbit tests.[4]

From a scientific point of view, this setup is better for transmutation studies than electrolysis using palladium cathodes, but it is still far from being economic. Each part of the process must be as economic as possible, and an arc discharge is simply wrong for this purpose.

Microwave or inductively or capacitance driven plasma is far more economic. Only resonant power supplies are economic to generate plasma.

A high voltage, oscillating corona discharge might be a suitable area for economic plasma generation, provided it is coupled to an acoustic resonant cavity.

The published Correa and Chernetzky discharge tubes are acoustically non-resonant, thus they cannot yield high fusion rates.

Shock waves in plasma are excellent to provide a single shot high density dusty plasma environment, like the Wendt/Irion experiment.

Constricted glow discharge (glow discharge via an open pore medium) is also a locally aperiodic oscillating discharge, but probably hard to maintain in reliable conditions, and no resonance can be maintained at a bulk volume.

It must be repeated that in a dynamic (especially resonant) acoustic condition, the peak energy of electrons are increased due to the temporary separation of charges, as shown in Figure 5. The dust acoustic waves (DAW) provide the necessary high electric field intensity. The potential (and overall charge) of dust particles are at its possible peak volume. Consequently, positive ions rush towards the dust particles, and Coulomb shielding is provided in the presence of a strong negative field.

This mechanism is more economic and more powerful than other methods can provide—like a metal lattice. This is due to the electric field build-up on the particle surfaces.

Even in electrochemical LENR processes, enhanced local charge improves the efficiency of fusion, due to laser excitation or sound excitation.

The Physical Features of Oscillating Dusty Plasma

By now the reader has hopefully grasped the essence of the importance of local charge accumulation. In a way, it is like the build-up of magnetic fields in a soft ferromagnetic material due to a small external field.

Self-organization due to dissipating nonlinear phenomenon is well known in biology. Dusty plasma has the same fundamental features. The complexity of the self-organization, from chaotic to orderly transitions, are the usual features of these phenomena.

In such a brief introduction, I have to warn readers to decrease their expectations for the following reasons:

— Mainstream researchers of dusty plasma have never considered LENR as a possible area for study, simply because the feasibility of such research is not "in the air."
— The electrostatic waves are just a small sub-field within dusty plasma studies. Interested readers will find at first quasi-equilibrium tests because the predictive capability ends there. Electrostatic waves are described in general terms, but no experimental investigation ever reached the necessary sophistication which would be required.
— The usual parameter range of dusty plasma experiments satisfies the need of astronomers, as some of the matter in our Universe is in the form of barely noticeable dust.
— In the corona of our Sun (and other stars), enormous shock waves and eruptions take place. Due to the gravity of stars, incoming dust may participate in LENR reactions in the solar corona. It is a well known and deeply troubling anomaly that the average temperature of the solar corona is in the order of millions of ˚C, while the surface of the Sun is just around 7000˚C. So the solar corona ought to be colder, and not much hotter than the surface. Although this extreme contradiction has been known for decades, no mainstream astronomer had the courage to propose that dusty plasma is a theater for fusion heat release. The available amount of dust can be just another variable influencing our weather, in the long term.
— The constitutive equations of different dust particles are

not known. We do not know the diffusion rate of electrons after impact when they are shot into an electrically non-conducting grain, deep under the surface. Further, there are no test results for temperature effects because it also has an influence on the diffusion rate of electrons. While we have the general equations for electrons, ions and the dust cloud, coupling them via material equations has not been completed. "On site" tests are hopeless, even in the distant future.
— Our parameter range of interest is several orders of magnitude higher pressures and temperatures. Where the studies have been done so far, they have aimed the parameters of extreme cold and low pressure in outer space.
— Last but not least, numerical calculations are at best estimations. The study of dusty plasma is important, since it allows us to understand qualitatively the strange features of dust particles. Thus it is an important tool to understand historical LENR effects. No numerical calculations are to be expected because experimental parameters will not shift to high pressure to satisfy us.

I encourage readers with academic curiosity and at least modest mathematical skills to immerse themselves in the intricate details of the Shukla and Eliasson paper[5] and the Fortov and Morfill book.[6]

Dust grain charging, and the oft-mentioned acoustic-electrostatic waves, are important to us but thermophoretic forces, radiation pressure forces, ion drag forces and absorption forces are also of interest.

As for waves, dust ion acoustic waves in our strongly coupled plasma are also interesting and dust acoustic shock waves (Wendt/Irion exploding wire) or just plain dust lattice waves are of interest.

Dust crystals are interesting and intriguing but do not occur under our range of parameters.

Therefore I omit copying the set of partial differential equations, because they are unsolvable.

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