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# Characterization of distinctive materials with which to generate nuclear transmutation*

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A Non-Technical Summary of this paper included in Appendix is said "*The summary and abstract of your presentation will be included in national meeting press materials that the Office of Communications distributes to hundreds of journalists*." The abstract of this paper published by ACS as an official material has been revised by organizers of the Symposium and differs somewhat from original one as appears below.

**Abstract**

Present status of researches of the cold fusion phenomenon (CFP) with a lot of curious experimental facts inexplicable by conventional knowledge of nuclear physics could be characterized by a phenomenology. There are three kinds of CF materials where occurs the CFP; (1) transition-metal hydrides/deuterides, (2) some hydrocarbons, and (3) some biological bodies. In this paper, we present an extensive phenomenological investigation of the CFP occurring in these three kinds of materials from the point of view that the phenomenon is induced by essentially the same common causes to them. The most interesting common factor is the periodic array of the host nuclei interlaced with another periodic array of protons or deuterons. Using the TNCF and ND models, we investigate essential factors of the CFP common to the three kinds of CF materials thus giving keys to understand the nature of the curious and perplexing CFP.

## 1. Introduction

Present status of researches of the cold fusion phenomenon (CFP) with a lot of curious experimental facts inexplicable by conventional knowledge of nuclear physics could be characterized by a phenomenology but not by a microscopic theory based on the firmly established principles. Before explanation of this statement, it is better to define the key concept of our treatment here: **The CFP (Cold Fusion Phenomenon**) stands for "nuclear reactions and accompanying events occurring in solids with high densities of hydrogen isotopes (protium H or/and deuterium D) in ambient radiations especially background neutrons" belonging to Solid-State Nuclear Physics (SSNP) or Condensed Matter Nuclear Science (CMNS). **CF materials** stand for materials in which the CFP occurs.

The CFP, first announced its existence by Fleischman et al. [1] in 1989 as "Electrochemically induced Nuclear Fusion" and later called "Cold Fusion," includes various events from emission of such light nuclides as neutrons, protons, alpha particles, to nuclear transmutations generating almost all nuclides of elements on the periodic table accompanying enormous excess energy inexplicable by chemical or physical atomic processes. It is emphasized that these events occur in various materials (CF materials) explained below at around room temperature without emission of detectable gamma rays. Therefore, the CFP should naturally include nucleochemical processes and seems to be induced by some new mechanisms in materials without specific acceleration mechanisms.

There are three kinds of CF materials where occurs the CFP; (i) transition-metal hydrides/deuterides with hydrogen occluding metals ($PdD_x$, $NiH_x$, $TiD_x$, - -) [2, 3] and non-occluding metals (Pt, Au, W, - - -) [4] (ii) hydrocarbons with periodic array of host nuclei (cross-linked polyethylene (XLPE) and phenanthrene) [5, 6] and (iii) some biological bodies (chicken, watercress, bacteria, yeast, - -) [7, 8]. If we take a point of view that the CFP occurring in these CF materials as a phenomenon caused by the same (unknown) microscopic mechanisms, it is natural to investigate the CFP phenomenologically as the chemistry has similarly investigated properties of materials successfully for more than two hundred years from the $17^{th}$ and $18^{th}$ centuries, the days of R. Boyle (1627 – 1691) and A. Lavoisier (1743 – 1794).

Although some progress in this direction has been made by our investigation with models (the trapped neutron catalyzed fusion (TNCF) model and later the neutron drop (ND) model), the new discovery of the CFP in hydrocarbons in recent several years in addition to that in the traditional materials, transition-metal hydrides/deuterides and biological bodies, has given a necessity to investigate the CFP from a new point of view including our works presented in the past.

In this paper, we present an extensive phenomenological investigation of the CFP occurring in the three kinds of materials referred above as a whole from the point of view that the phenomenon is induced by essentially the same common causes to three kinds of CF materials. The treatment necessarily is chemical or nucleochemical as given in a previous paper "Nuclear Chemistry in the Cold Fusion Phenomenon" *Reports of CFRL (Cold Fusion Research Laboratory)* **6-1**, 1 – 18 (October, 2007) posted at http://www.geocities.jp/hjrfq930/Papers/paperr/paperr.html

The most interesting common factor in the above referred three kinds of CF materials is the periodic array of the host nuclei interlaced with another periodic array of protons or deuterons. Using the TNCF and ND models which were successful to give qualitative and sometimes semi-quantitative explanation of the CFP in transition-metal hydrides/deuterides, we investigate essential factors of the CFP common to the three kinds of CF materials thus giving keys to understand the nature of the curious and perplexing cold fusion phenomenon (CFP).

The phenomenological approach also has made possible to find out some laws between observables in the CFP (the inverse-power law and the stability effect of nuclear transmutation) and to give explanations of some temporal characteristics of events of the CFP (the bifurcation and the chaos of excess energy generation and of neutron emission) thus explaining the essential sporadic and qualitative reproducibility of the CFP and therefore the lack of quantitative reproducibility,

Finally, we discuss microscopic bases of the premises of the models successful for qualitative and semi-quantitative explanations of the CFP. This is a stage corresponding to the establishment of atomic physics in the first half of the 20$^{th}$ century based on chemical knowledge of atoms and molecules obtained in preceding two centuries. Taking into consideration the common factors to the three kinds of CF materials and the knowledge of under-developing areas of nuclear and solid-state physics, we could put a few steps to understand a possible new state of neutrons in the CF materials in interdisciplinary field between nuclear physics and solid-state physics.

## 2. Cold Fusion Materials (CF Materials) where occurs the Cold Fusion Phenomenon (CFP)

As pointed out in the previous Section, CF materials are classified into three types:

(i) Transition-metal hydrides/deuterides with

(i-a) hydrogen occluding metals (Ti, Ni, Pd, - -) [2, 3]

and

(i-b) hydrogen non-occluding metals (Pt, Au, W, - - -) [4]

(ii) Hydrocarbons (cross-linked polyethylene (XLPE), phenanthrene) [5, 6]

(iii) Biological bodies (chicken, watercress, bacteria, yeast, - - -) [7, 8]

Systems and obtained evidences of the CFP are given in Table 2.1.

Table 2.1 System and Obtained Evidences of CFP. Mother solids, agents, experimental methods, direct and indirect evidences of the cold fusion phenomenon. Q and NT express excess heat and the nuclear transmutation, respectively. Direct evidences of nuclear reactions in CFP are Energy (*E*) and position (r) dependences of reaction products, decrease of decay constants of radiative nuclides, decrease of fission threshold energy of compound nuclei (such as $^4He$) [2].

| | |
|---|---|
| **Host solids** | Pd, Ti, Ni, Pt, Au, W, KCl + LiCl, $ReBa_2Cu_3O_7$, $Na_xWO_3$, $KD_2PO_4$, TGS, $SrCe_aY_bNB_cO_d$, Hydrocarbons (XLPE, phenanthrene), Biological bodies (chicken, Cresson, bacteria, yeast, - - ) |
| **Agents** | *n, d*, *p*, $^6{}_3Li$, $^{10}{}_3B$, S, $^{39}{}_{19}K$, $^{85}{}_{37}Rb$, $^{87}{}_{37}Rb$、(ion beam) |
| **Experimental methods** | Electrolysis, gas discharge, gas contact, (ion beam irradiation) |
| **Direct evidences** | Gamma ray spectrum γ(ε), neutron energy spectrum *n*(ε), space distribution of NT products NT(***r***), decrease of decay constants, lowering of fission threshold energy |
| **Indirect evidences** | Excess energy *Q*, number of neutrons $N_n$, amount of tritium atom $N_t$, helium-4 atom $N_{He4}$, NT ($NT_D$, $NT_F$, $NT_A$), X-ray spectrum X(ε), explosion |
| **Cumulative observables** | NT(***r***), **N**T products, amount of tritium atom $N_t$ and helium-4 $N_{He4}$ in appropriate systems, |
| **Dissipative observables** | Excess energy *Q*, number of neutrons $N_n$, neutron energy spectrum *n*(ε), gamma ray spectrum γ(ε), X-ray spectrum X(ε), |

## 3. Characteristics of CF Materials from the Phenomenological Viewpoint

It is an orthodox mean to use a phenomenological method to investigate an entirely new field of research [2, 3, 9]. After 20 years from the first announcement of the discovery of the CFP, we have too many experimental data sets impossible to explain from conventional points of view established in modern chemistry and physics. So, we are tempted to return to the orthodox road of science.

Looking into atomic structure of the CF materials classified above, we notice there are periodic array of host nuclei and another periodic array of hydrogen isotopes interlaced to the former array. The transition-metal hydrides/deuterides, group (i), have this characteristic obviously ([2] Section 2.2). The cross-linked polyethylene (XLPE) in group (ii) has clearly this property [5, 6]. About the biological bodies, the problem is a little ambiguous due to the too complicated situation in this case; we do not know where the nuclear transmutations occur in biological bodies while as a result we obtain transmuted nuclei. Despite the ambiguity of the nature of nuclear reactions, we can anticipate that the regularity of cells in biological bodies will play a role of periodic array of carbon nuclei in XLPE or nuclei of host metals in transition-metal hydrides/deuterides.

If these characteristics of the structure of the CF materials are essential for the CFP, they have also close connection to the phenomenological explanation of the CFP occurring in them.

The TNCF (trapped neutron catalyzed fusion) and the ND (neutron drop) models, or the TNCF-ND model as a whole, have explained several experimental data sets qualitatively and sometimes semi- quantitatively; ratios of numbers of events in an experimental system (quantitative) [3], the inverse-power law for the frequency of occurrence and intensity of an event, and the stability effect in generation of NT (nuclear transmutation products) [2, 3]. Further more, the similarity of some dynamical behaviors of the CFP to the complexity investigated in dynamical systems has been qualitatively explained by the TNCF model using the parameter $n_n$ of the model as the parameter of the logistic difference equation (l.d.e) [10, 11].

Next problem is what is necessary to realize the CFP in the situation where are periodic arrays of host nuclei and of hydrogen isotopes. To make clear this point, it is advisable to consider transition-metal hydrides/deuterides where occurs no CFP, i.e. *bcc* transition metals, vanadium V, niobium Nb and tantalum Ta. This problem has been discussed in our works ([2] Section 3.5.4, [12]) showing that non-localized wavefunction of hydrogen isotopes is necessary to realize the CFP. This point will be discussed in the next section.

It should be noticed here that the peculiar state of hydrogen on the surface of metal catalysts is investigated in these more than 30 years [13, 14]. It is not necessary to mention here that all transition metals classified in the type (i) CF materials are used also as catalysts in chemical (atomic) reactions. Following fact has been noticed by researchers in catalysis that hydrogen atoms (protons) on the surface of metal catalysts have nonlocal wavefunctions along the surface and also enter into the metal a few (one or two) atomic layers. This nature of the proton wavefunctions in the (i-b) type CF material is favorable for the formation of the neutron band through the indirect neutron-neutron interaction mediated by protons/deuterons [2, 15, 16]. The reason why the CF materials of the type (i-b) give sometimes positive results for the CFP is explained by this characteristic of the proton/deuteron wavefunctions at the metal surface.

There arises next question that what kind of nucleus is responsible to the CFP if the above condition of the periodic array of host nuclei and a hydrogen isotope is realized and the latter has nonlocal wavefunctions. Here we remember a characterization of lattice nuclei by a concept “neutron affinity” given before [2, 3]. This quantity may have close relation to the neutron levels at neutron evaporation energy [2, 15] and discussed in the next section.

## 4. Microscopic Verification of Premises in the Phenomenological Models

The success of the phenomenological model to explain events in the CFP invites us to give microscopic verification of premises assumed in the models.

In relation to our knowledge about states of atoms and nuclei having possible relation to the CFP, we remind existence of under-developing frontiers of nuclear physics, solid-state physics, and surface chemistry.

In the nuclear physics, there is a new field of exotic nuclei (especially neutron-rich nuclei) with larger excess number of neutrons than that of well-known stable nuclides [17]. In these neutron-rich nuclei, we can expect extension of neutron wavefunctions outsides the nuclear surface. This extended neutron wavefunction in a nucleus at a lattice point (lattice nucleus) will make a direct nuclear interaction (*n-p* or *n-d* interaction) with protons/deuterons in interstices surrounding the nucleus if the protons/deuterons have wavefunctions extending to the lattice point from the interstitial sites.

On the other hand, there are many evidences to show that proton/deuteron wavefunctions in and on transition-metal hydrides/deuterides are not localized at interstices but extended out by several lattice constants [18]. In addition to this fact, we know the existence of exotic nuclei as discussed above [17], we are tempted to investigate a possible realization of a direct nuclear interaction between a lattice nucleus (more directly a neutron in a lattice nucleus) and a proton/deuteron at an adjacent interstice. A preliminary calculation of this interaction ([2] Section 3.7) has shown a possibility of this interaction and accordingly the super-nuclear interaction (or indirect-nuclear interaction) mediated by protons/deuterons at interstices.

If we can expect an existence of the super-nuclar interaction, it is also possible to have a neutron band at the energy around the neutron evaporation level of the lattice nucleus [2]. This neutron band makes possible to form a neutron drop, a cluster of neutrons, ptotons and compensating electrons, at surface/boundary regions [2].

The premises of the TNCF/ND model, especially that of existence of neutrons in CF materials with a high density at surface/boundary regions have been supported by the above theoretical explanation of the possible realization of the super-nuclear interaction in and on the transition-metal deuterides/hydrides.

## 5. Conclusion

As far as we investigate the CFP in these three kinds of CF materials defined in Section 2 as a phenomenon caused by fundamentally the same mechanism and accept the common sense about nuclear reactions obtained in nuclear physics, we have to rely on neutrons as a main player in the CFP. Looking into possible mechanisms consistent with the structure of the CF materials and the nature of participating nuclei, we have noticed the periodic structures of both host nuclei and hydrogen isotopes and also nonlocal wavefunctions of protons and deuterons in the CF materials.

In addition to the nonlocal wavefunctions of proton/deuteron in *fcc* transition metals in contrast to their localized wavefunctions in *bcc* ones [2], we found that protons adsorbed on the metal catalysts have nonlocal wavefunctions also [13, 14]. The former characteristics have been used in our quantal investigation [2, 15, 16] to justify the TNCF model successful to explain the CFP in the *fcc* transition-metal deuterides/hydrides.

The similar consideration may be applied to the materials of type (i-b), hydrogen non-occluding metals, W, Pt, and Au, where the CFP had been observed without appropriate explanation in relation to the CFP in the materials of type (i-a), hydrogen occluding metals.

As we have given a common explanation of the CFP both in these metals, types (i-a) and (i-b), based on the same microscopic structure in both materials, we are apt to accept the mechanism suggested by the TNCF model as the model reflecting physics of the CFP correctly.

Furthermore, we have given an explanation of the nuclear transmutation (NT) in the CF materials of the type (ii) with the same model [5, 6]. Thus, we feel the TNCF and ND models for the CFP is applicable to at least two large groups of CF materials belonging to the types (i) and (ii) classified above in Section 2.

This feeling can be extended to the CF materials of the type (iii) where the atomic structures are more complicated than those in other two. Despite of the long history of research of the nuclear transmutation in the materials of type (iii), called sometimes as the biotransmutation [7, 8], it is too difficult to take it into our consideration in accordance to other knowledge of science and accordingly this field has remained in the periphery of the cold fusion research until now.

The scheme given in this paper to treat the CFP's obtained independently in the three kinds of CF materials, types (i), (ii) and (iii) classified in Section 2, on the common basis will give a strong support for the reality of the phenomena which have been looked at with somewhat questionable eyes. We know that there opens a new sight if we have a new intention, as old Buddhist saying expresses.

**Acknowledgement**

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# Appendix.

## Non-Technical Summary of This Paper sent to ACS (January 9, 2009)

**ENVR 021**

(Paper ID 1219079)

### Characterization of distinctive materials with which to generate nuclear transmutation

Low energy nuclear reactions (LENR) as part of condensed matter nuclear science (CMNS) and as one of the most controversial topics in science recently attracted widespread attention when it had come to the decision to re evaluate the almost forgotten experimental data generated over many years starting in 1989 with the Pons-Fleischmann experiment. However, the current status of this research does not allow an unambiguous explanation in giving the reasoning for D-D collisions at room temperature, at least, not on the basis of conventional knowledge. Therefore, in this presentation we attempt to briefly outline a new approach with which to explain the physics of LENR, and here, in discussing this issue, we distinguish between three kinds of materials with which LENR effects may be likely to be observed: 1) transition-metal hydrides/deuterides, 2) hydrocarbons, and 3) biological cells. We present an extensive phenomenological investigation on LENR effects describing, based on TNCF and ND models, the most crucial factors, to our mind, responsible to achieve D-D collisions. The most interesting common factor can be seen in the physical characteristics of the host nuclei that stays in strong interaction with the deuterons absorbed and placed within interstitial sites of the host lattice.

*Briefly explain in lay language what you have done, why it is significant and what are its implications (particularly to the general public)*

**What I have done**: I have given a new phenomenological explanation for various events of the cold fusion phenomenon (CFP), or LENR, in both light (protium, H) and heavy (deuterium, D) hydrogen systems using models based on experimental results. Building on new knowledge in both nuclear and solid-state physics, I have been developing a theory to explain the premises used to construct these models. Furthermore, I have discovered laws governing the occurrence of two previously unexplained phenomena—the generation of excess energy and also the generation of new elements in CFP—by looking at them from the phenomenological point of view. These laws are similar to those which appear in the science of complexity, suggesting that the origin of CFP is closely related to complexity. Thus, I have shown that the theory of CFP is part of the science of complexity. Additionally, through this research, I have indirectly shown the value of the phenomenological approach in the research process.

**Why it is significant**: This work has shown that CFP may be a new science in an interdisciplinary field combining nuclear physics and solid-state physics closely related to surface chemistry and also that it is closely related to complexity. This work have shown that CFP is not a phantom but a real phenomenon in the field of science especially related with complexity. This means also that complexity observed in various fields of science is playing an essential role in CFP. This fact resolves the controversial question of lack of quantitative reproducibility and controllability of the events in CFP as matters of course.

Additionally, this work demonstrates the significance of the phenomenological approach, which, though recently apt to be neglected, has long been one of fundamental approaches to investigate new fields of science.

**What are its implications (particularly to the general public)**: Establishing the validity of CFP as a new science lays the groundwork for its continued development. The development of CFP has exciting potential applications for energy production and the generation of new elements. As opposed to the current method of controlled nuclear fusion which requires large expensive machines working in extreme conditions to produce energy, CFP requires only simple equipment and utilizes widely available materials such as nickel and water. If CFP is understood, the far simpler requirements needed to use CFP will greatly facilitate the production of energy for daily use. In addition, this work contributes to the general understanding of the scientific method by demonstrating the importance of the phenomenological approach in research because it was only through using the phenomenological approach that this research could be accomplished.

*How new is this work and how does it differ from that of others who may be doing similar research?*

**How new is this work?** : This work is relatively new. The research began 15 years ago and continues to this time. I have established the first model which explaining successfully many experimental data sets and developed it to the second model to explain more complicated data sets. The foundation of the models and the relation of our theoretical investigation with complexity have been worked out in these about 5 years.

**How does it differ from that of others**: There are many trials to explain some phases of the CFP especially in the deuterium systems but none to explain the CFP as a whole. The reason why I have come up with an explanation for CFP as a whole whereas other explanations only address isolated parts may have its basis in differing understanding of how to approach CFP; if we think that CFP should be explained along a line extended from those in nuclear physics modified by the solid-body environment, we are apt to stick to several specific favorable facts and thus discard abundant experimental facts which can be viewed as a whole. In contrast, by not skipping the phenomenological approach and jumping directly into the microscopic approach and by utilizing the orthodox principles of scientific research, I have been able to interpret these abundant experimental facts in a way which provides an encompassing explanation of CFP.

Would you or another member of the research group be available in Salt Lake City to talk with the news media to elaborate on your research and answer questions?

*(The session would include several other researchers, last about 30 minutes, and be held at the Salt Palace Convention Center. It would be held the day of your presentation*

*or the day before the presentation. If a discussion session is scheduled, you will be notified of the time and other details at a later date.)*

**Yes.**

*Please include any additional comments you may have:*

**Additional comments**: Science is an endeavor of human minds guided by curiosity—this curiosity being our inheritance from the course of evolution—about phenomena experienced by a society as a whole to establish a system of our concepts about objects surrounding us. Current scientific research appears to suffer from a lack of curiosity. Recent research seems driven by the desire for profit rather than a true desire for understanding. This trend in research corresponds to the contemporary short-cutting of the scientific method in which in the haste to achieve results, researchers leap to the microscopic approach, bypassing the more robust phenomenological approach. We should not forget fundamental principles of science expressed as follows;

"*From this natural phenomenon which previously seemed impossible to you, you should realize that there may be others which you do not yet know. Do not conclude from your apprenticeship that there is nothing left for you to learn, but that you still have an infinite amount to learn.*" B. Pascal, **Pensées**, 231 (Translated by A.J. Krailsheimer).

"*Facts which at first seem improbable will, even on scant explanation, drop the cloak which has hidden them and stand forth in naked and simple beauty.*" Galileo Galilei, **Dialogues Concerning Two New Sciences**, Day 1 (Translated by Henry Crew and Alfonso De Salvio).

"*The man of science must work with method. Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house. Most important of all, the man of science must exhibit foresight.*" Henri Poincaré, **Science and Hypothesis**, p. 141. (Translated by W.J.G.).

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