Reports of CFRL (Cold Fusion Research Laboratory), 7-1, pp. 1 – 7 (December, 2007)

The Cold Fusion Phenomenon as a Complexity (1)
– Complexity in the Cold Fusion Phenomenon –*

Hideo Kozima
Cold Fusion Research Laboratory,
597-16, Yatsu, Aoi, Shizuoka 421-1202, Japan
E-mail; cf-lab.kozima@nifty.com, Website; http://www.geocities.jp/hjrfq930/

* This paper was published in Proc. JCF6 (April 27 – 28, 2005, Tokyo, Japan), pp. 72 – 77 (2005) and published as a paper in Reports of CFRL (Cold Fusion Research Laboratory) for readers' convenience.

Abstract

The science of complex systems treats such problems as **why** simple particles organize themselves spontaneously complex structures like stars, galaxies, hurricanes, and Coulomb lattices of neutron and proton clusters surrounded by a dilute neutron gas in the neutron star matter, as **what** is the cause of *1/f* – fluctuation, and as **what** means the edge of chaos.

The cold fusion phenomenon (CFP) has revealed such nature of many-particle effects as a complexity as shown by various experimental results as the "**stability effect**" in the nuclear transmutation and the "**inverse-power law**" in the excess power generation. The complexity of the cold fusion phenomenon originates in the non-linear interactions between millions of agents (component particles in the cold fusion materials) and is magnified by enormous energy difference (about an order of 10^8) of the cause (atomic) and the effect (nuclear). Existence of complexity in the cold fusion phenomenon is explained in this paper.

1. Introduction

The cold fusion phenomenon (CFP) was explicitly announced its discovery in 1989 by Fleischmann and Pons [1] as huge excess heat accompanying tritium and neutron productions in an electrolytic system with Pd metal anodes and Pt wire cathodes in the electrolytic solution D_2O + LiOD. The motivation of their experiments was the Fleischmann's hypothesis that the Pd lattice gives enormous effect on the *d-d* fusion reactions in the transition-metal deuteride PdDx (x ≃ 1), [2] which the name "cold fusion" originates from.

The history of CFP research in the past 16 years revealed, however, that the Fleischmann's hypothesis should not be essential to CFP as a whole due to following facts; CFP occurs not only in deuterium systems but also in protium systems, there are too various events [4] and too various nuclear products to be explained by simple *d-d* fusion reactions. Furthermore, numerical relations between amounts of products [4] contradict with those expected from the *d-d* fusion reactions known in nuclear physics. It has been known that existence of the ambient thermal neutrons is one of necessary conditions for CFP. Therefore, the name "cold fusion phenomenon" (CFP) should be used as one to signify a phenomenon including nuclear reactions and accompanying events occurring in solids with high densities of hydrogen isotopes (H and/or D) in ambient radiation when dynamical conditions are imposed on them.

Fields and products of CFP observed by now are tabulated in Table 1. [3] In this table, matrix substances and agent nuclei comprise the field where occurs CFP. It is not designated in the table but should be emphasized that CFP occurs more frequently in dynamical, stationary, or non-static conditions than in the static one.

Table 1. Matrix Substances, Agent nuclei, Direct and Indirect Evidence of nuclear reactions in cold fusion phenomenon (CFP). Q is for the excess heat and NT for the nuclear transmutation. Dependences of products on energy ε and position $\boldsymbol{r}$, decay time shortening of radioactive nuclides, and fission-barrier lowering of compound nuclides give direct information of nuclear reactions in CFP.

Matrix Substances	Transition metals (Ti, Ni, Mo, Pd, Pt, etc.), Proton Conductors ($SrCeO_3$, $REBa_2Cu_3O_7$, $AlLaO_3$), Ferroelectrics (KD_2PO_4, TGS, etc.), Others (C, Na_xWO_3, Stainless Steel, etc.)
Agents	${}^1_0n$, ${}^1_1H$, ${}^2_1H$, (${}^{16}_8O$), ${}^6_3Li$, ${}^{10}_5B$, ${}^{23}_{11}Na$, ${}^{39}_{19}K$, ${}^{85}_{37}Rb$, ${}^{87}_{37}Rb$, SO_4^{2-}, etc.
Direct Evidences	Neutron energy spectrum $n(\varepsilon)$, Gamma rays $\gamma(\varepsilon)$, Spatial distribution of NT products (${}^{A'}_{Z'}X(\boldsymbol{r})$), Decay time shortening, Fission barrier decrease
Indirect Evidences	Excess Heat Q, Number of neutrons N_n, Number of tritons N_t, Number of ${}^4_2He$ N_{He4}, Number of NT products N_{NT} (for NT_D, NT_F, NT_A, and NT_T), X-ray spectra $X(\varepsilon)$

The TNCF (trapped neutron catalyzed fusion) model proposed by the author in 1994 [4] has been one of successful approaches to qualitative and semi-quantitative explanations of several events in CFP and has given several numerical relations between amounts of products consistent with experiments. Basic assumptions of the model are based on the many-particle nature of the CF system where occurs CFP. Existence of the trapped thermal neutrons in CF materials, one of the basic assumptions in the TCNF model, is clearly a result of many-particle interactions in the solids if the assumption has any reality behind it. [5]

These facts clearly show that CFP is a phenomenon conditioned by multi-component, dynamical and/or stationary properties of systems composed of transition metals and hydrogen isotopes under influence of ambient thermal neutrons.

There are discovered a few characteristics and few laws in CFP. Following characteristics are essential factors in CFP to study its physics; qualitative reproducibility and sporadicity of events, favorable combinations of a cathode, a hydrogen isotope, and an electrolyte (e.g. Pd, D, Li; Ni, H, K). Two laws were recently discovered in CFP; the stability effect in the nuclear transmutation [3,6] and the inverse-power law of excess heat generation. [3,7]

These characteristics and laws in CFP show clearly that the entirety of CFP should be treated as a kind of complexity as explained below.

2. Many-particle Effects in CF Materials Resulting in Complexity

In this section, we explain a general nature of the complex system with non-linear interactions between its agents first and then explain the nature of the cold fusion phenomenon (CFP) in relation with complexity.

2.1 Complex System, Complexity and *1/f* Fluctuation

In a complex system (system composed of many components (agents) interacting with nonlinear forces), there occur various phenomena alien from those in simple systems that have been the main objects of modern science until 20th century. The science of the complex system has developed in recent twenty years and includes several new branches as synergetics, self-organization, fractals, chaos, emergence, complexity and so on named by pioneering scientists according to their points of view.

To make our discussion clear, we will use a terminology defined below referring to the Waldrop's book [8] as follows: the science of complex systems are divided into three classes; A. self-organization, B. chaos and C. complexity. These classes, A, B and C, correspond Wolfram's universality classes, I and II, III and IV, respectively, in relation with the cellular automata rules of S. Wolfram.

The Wolfram's classes are, on the other hand, characterized by the Langton's λ parameter in a von Neumann universe; Wolfram's classes, I and II, III and IV, correspond to λ's in following regions, $0.0 \leq \lambda < \lambda_c$ with a critical value $\lambda_c \simeq 0.275$, $\lambda_c < \lambda < 0.50$, and $\lambda \simeq \lambda_c$, respectively.

There is another interesting phenomenon, *1/f* fluctuations, closely related with CFP. The *1/f* fluctuations of the power spectrum in thermionic tube was discovered in 1925 by J.B. Johnson [9] and now recognized ubiquitous in many different phenomena. [10] It is interesting to notice that there is an attempt (self-organized criticality or SOC) to explain the *1/f* fluctuations in relation with a nonlinear process that had fractal characteristics. [10] If this explanation applies to CFP, characteristics of CFP are explained in the frame of many-particle dynamics with nonlinear interactions among agents as investigated below.

These interesting features of the complex system may appear in the cold fusion phenomenon (CFP) if CFP is characterized by many-particle effects in the CF materials where observed various events, which will be classified similarly as phenomena in the complex system.

2.2 Cold Fusion Phenomenon (CFP) and Complexity

There are several evidences showing that CFP should be treated in the science of complex systems.

First of all, the irreproducibility and sporadicity of CP events suggest chaotic nature of the process realizing CFP.

Second, there is an evidence of possible existence of self-organization in CFP. Negele and Vautherin [11] had shown that there appears a lattice of neutron-proton cluster, the Coulomb lattice, in a thin neutron star matter. In boundary and surface regions of CF materials, there occurs a situation where neutrons in a neutron band accumulate to form a high-density state due to the local coherence realized by a dispersion relation of the band. [12,13] The density of neutrons approaches to the lower limit of the density used in the simulation by Negele and Vautherin [11] showing possible self-organization of the Coulomb lattice in CF materials even if there are crystal lattices of the host elements (e.g. Pd) that does not exist in the neutron star matter. Existence of the crystal lattice may intensify the self-organization process.

Third, in addition to this theoretical analogy of CF material to the neutron star matter where many-particle effect plays essential role, there is experimental evidence showing many-particle effect of nucleons in CF materials; the stability effect in products of the nuclear transmutation in CFP, the first statistical law in CFP, discovered in 2003. [5,3] Counting a number of observations $N_{ob}(Z)$ of an element with an atomic number Z, from papers published in over ten years, we compared $N_{ob}(Z)$ with the logarithmic abundance of the element log $H(Z)$. [14] Even if the numerical values of $N_{ob}(Z)$ are small and the comparison is between $N_{ob}(Z)$ (not log $N_{ob}(Z)$) and log $H(Z)$, there is an excellent coincidence between them except few cases at several values of Zs with such reasonable explanations for discrepancies as follows; a large value of $N_{ob}(Z)$ at $Z = 47$ (Ag) next to Pd (a major element in the system) in the periodic table and absence of $N_{ob}(Z)$ for noble gases $Z = 10$, 18, 36 (Ne, Ar, Kr) which were not tried to detect intentionally without expectation. [5]

This coincidence of $N_{ob}(Z)$ and log $H(Z)$ clearly shows existence of a state where nucleons interact together to form stable groups as if they are in the process realized in the evolution of stars to produce elements in the universe from the lightest component, proton, up to the heaviest, uranium. Possible cause of this coincidence could be given by the above-mentioned self-organization in the cf materials with high-density neutrons.

Fourth, the inverse power law of the power spectrum of the excess heat generation, the second law in CFP, discovered in 2004, shows another evidence of the complex nature of CFP if SOC mechanism applies. [6,3] Referring to the explanation of *1/f* fluctuations in terms of the fractal, the inverse power law may also relate CFP with self-organization.

Fifth, the success of the TNCF model shows complex nature of CFP on which the model based. There are numerical relations between numbers N_X of events X in CFP:

$N_t = N_Q$, $N_{NT} = N_Q$, $N_{He4} = N_Q$,

$N_n / N_t \simeq 10^{-6}$, $N_Q \equiv$ Q (MeV)/5 MeV,

where N_Q is defined as above. These relations were semi-quantitatively explained by the TNCF model that assumes thermal neutrons in CF materials based on many-particle nature.

3. Conclusion

From explanations of the complex system in general in subsection 2.1 and of the cold fusion phenomenon (CFP) in 2.2, we can guess that essential features of CFP may have close relation with the science of the complex system. These experimental facts explained in 2.2 (varieties of fields and products of CFP, numerical relations of numbers of events and two laws relating complex nature of CFP) clearly show that many-particle effects cause the cold fusion phenomenon in complex systems composed of transition metals, hydrogen isotopes, some minor elements appropriate for the transition metals, and/or hydrogen isotopes, and the background thermal neutrons.

The nature of complexity will give an explanation of the large value of the excess heat Q in CFP showing $1/f$ fluctuation. Usually, fluctuations of a physical quantity in a system composed of a large number of particles (agents) are negligibly small. The relative fluctuations of a quantity G will usually given by an equation of the type

$$(<G^2> - <G>^2)/ <G>^2 = 1/<G>$$

where the < > indicate average values and will usually be very small due to a large value of $<G>$ in the many-particle system.

However, it becomes very large near a critical point where $<G>$ becomes very small as at the second-order phase transition. The Langton's critical parameter λ_c is another example to specify a point where fluctuations become very large. This is one cause of large Q if CFP is a complexity.

It should be pointed out another cause to make the excess heat Q very large. There is a tremendous difference in energy of the cause (atomic) and the effect (nuclear); nuclear energy output is 10^8 times larger than atomic energy input. The small fluctuation in atomic processes that ignite nuclear reactions may induce a huge effect due to this difference. This is the second possible cause of the large Q that together with peculiar nuclear products troubled people to understand its nature for such a long period.

The nature of the complexity of CFP will be the main theme of the forthcoming investigation.

References

[1] M. Fleischmann, S. Pons and M. Hawkins, "Electrochemically induced Nuclear Fusion of Deuterium", *J. Electroanal. Chem.*, **261**, 301 (1989).

[2] M. Fleischmann, "Cold Fusion: Past, Present and Future", *Proc. ICCF7* pp. 119 – 127 (1998).

[3] H. Kozima, "Cold Fusion Phenomenon" *Rep. Fac. Science, Shizuoka University* **39,** 21 – 90 (2005).

[4] H. Kozima, *Discovery of the Cold Fusion Phenomenon - Evolution of the Solid State-Nuclear Physics and the Energy Crisis in 21st Century*, Ohtake Shuppan KK. Tokyo, Japan, 1998. ISBN 4-87186-044-2.

[5] H. Kozima, "Quantum Physics of the Cold Fusion Phenomenon" in *Developments in Quantum Physics,* ed. F. Columbus and V. Krasnoholovets, Nova Science, New York, 2005. ISBN 1-59454-003-9.

[6] H. Kozima, "CF-Matter and the Cold Fusion Phenomenon" *Proc. ICCF10* (Aug. 24 – 29, 2003, Cambridge, MA, USA) (to be published).

[7] H. Kozima, "Cold Fusion Phenomenon and Solid State-Nuclear Physics" *Proc. ICCF11* (Oct. 31 – Nov. 5, 2004, Marseille, France) (to be published).

[8] M.M. Waldrop, "Complexity – The Emerging Science at the Edge of Order and Chaos," Simon and Shuster, New York, 1992. ISBN 0-671-76789-5.

[9] J.B. Johnson, Phys. Rev. 26, 71 (1925).

[10] E. Milotti, "*1/f* noise: a pedagogical review"
http://arxiv.org/ftp/physics/papers/0204/0204033.pdf

[11] J.W. Negele and D. Vautherin, "Neutron Star Matter at Sub-nuclear Densities" *Nuclear Physics*, **A207**, 298 – 320 (1973).

[12] H. Kozima, "Neutron Drop; Condensation of Neutrons in Metal Hydrides and Deuterides", *Fusion Technol.* **37**, 253 – 258 (2000).

[13] H. Kozima, "Excited States of Nucleons in a Nucleus and Cold Fusion Phenomenon in

Transition-Metal Hydrides and Deuterides" *Proc. ICCF9* (May 19-24, 2002, Beijing, China), pp. 186 – 191 (2002).
[14] H.E. Suess and H.C. Urey, "Abundances of the Elements" *Rev. Mod. Phys.* 28, 53 – 74 (1956).