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Short Communication

The "anomalous heat effect" is a normal event in the cold fusion phenomenon – On the paper "excess heat evolution from nanocomposite samples under exposure to hydrogen isotope gases" by Kitamura et al. Published in the *int. J. Hydrogen Energy* 43, pp. 16,187–16,200 (2018) –

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HIGHLIGHTS

- Cold fusion phenomenon means the nuclear reactions in solids with hydrogen isotopes.
- Nuclear reactions occur in solids without any acceleration mechanism.
- Excess energy accompanied to the nuclear reaction is useful for an energy source.

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ABSTRACT

The anomalous heat effect reported in the paper, "Excess heat evolution from nano-composite samples under exposure to hydrogen isotope gases" by Kitamura et al. published in the *Int. J. Hydrogen Energy* **43**, pp. 16,187–16,200 (2018), is investigated in the science of the cold fusion phenomenon (CFP) established in these 30 years. It is concluded that the effect is a normal event in the CFP consistent with many events observed in materials with various components and compositions composed of host elements and hydrogen isotopes.

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Glossary

CFP cold fusion phenomenon
CF material cold fusion material
NT nuclear transmutation

Introduction

In the paper [1] on the cold fusion phenomenon (CFP), Kitamura et al. reported the "anomalous heat effect" in the excess energy generation in the cold fusion materials (CF materials) of metal nanocomposites supported by zirconia or by silica.

The *Cold Fusion Phenomenon* (*CFP*) is a phenomenon including nuclear reactions observed in such materials (CF materials) composed of host elements and hydrogen isotopes as transition-metal hydrides and deuterides, hydrogen graphite, XLPE (cross-linked polyethylene) and (possibly) microbial cultures. The CFP has been investigated in these 30 years since its discovery in 1989 by Fleischmann et al. [2]. Even if the science of the CFP has not completely established yet, there are a pile of knowledge and understanding of common facts observed in various CF materials (e.g. Ref. [3–5]). It is very important to remember that the events in the CFP are characterize by the qualitative (or statistical) reproducibility not by the quantitative one that is a characteristic of systems with only linear interactions [4,5].

In addition to the above notice on a characteristic of the CFP, we have to recognize the nature of the investigation in this field characterized by the inductive logic explained in our recent paper [6]. The events in the CFP realized by nonlinear interactions in the CF materials have characteristics destined by the complexity and are not pursued by the deductive logic popular in the system composed of component interacting only with linear interactions.

We can classify facts observed hitherto with variety of their aspects into several genres depending on their characteristics to understand their nature. We investigate the experimental facts reported by Kitamura et al. [1] with our point of view in relation to the abundant data obtained in the CFP by now. It is concluded that the "anomalous heat effect" [1] is a normal event in the CFP even if there are several new features in the paper [1] showing novel knowledge about nuclear reactions in the CF materials.

Experiments

The CF materials investigated in the paper [1] have several characteristics remarkable from the scientific point of view to develop the physics of the cold fusion phenomenon (CFP). The characteristics are listed up as follows; (1) composition of the host metal, (2) size effect, (3) temperature effect, (4) compound CF materials.

We pick up several examples having the same characteristics from experiments published in past 30 years in the history of the researches on the CFP with comments on the novel features in the CF materials used in the paper [1]. The physical meaning of these effects listed up above will be discussed in the next section, Theoretical Consideration.

(1) Composite materials as the CF material.

In the experiments reported in the paper [1], the CF material is the $Pd_xNi_{0.35-x}Zr_{0.65}$, $CuNi_y$, and others. The composite materials had been used in the CFP widely in the early stages of researches in this field such as high-temperature superconductor ($Y_1Ba_2Cu_3O_7$), tungsten bronze (Na_1WO3), ferroelectrics (KD_2PO_4 and triglycine sulphate (TGS)), and proton conductors (e.g. $SrCeO_3$) [3]. The alloys similar to the CF materials used in Ref. [1] are stainless steel [7] and constantan [8].

(2) Size effect

The dimension of the CF material is supposed to be essential for the realization of the nuclear reactions in the CFP and many experiments were performed in past. We can cite two examples used by Arata [9] and Reifenschweiler [10] where observed the CFP.

(3) Temperature effect

In the experiment [1], it was measured the occurrence of the CFP at elevated temperatures between 200 °C and 300 °C. There are several experimental data showing necessity to elevate the temperature of the sample above 100 °C [7,11–14]. Further, it is possible to cite papers where the positive dependence of the excess energy on the temperature was measured in PdD_x system [15].

(4) Effect of the structure of the compound CF materials

It had been used CF materials in contact with substrates having different compositions and dimensions from the host materials. We can see several examples in the works [16–18] where observed the CFP.

The selection of the substrate might be done mainly by consideration of the mechanical strength and chemical usefulness. It should be reconsidered the effect of the boundary layers between the CF material and the substrate from the physics of the CFP as briefly investigated in the next section.

Theoretical Consideration

It is well known that the diffusivity of hydrogen isotopes in transition metal hydrides/deuterides is very large and depends exponentially on the temperature [19,20]. As shown in Figs 1 and 2, the diffusion coefficient of H in Pd increases almost two orders of magnitude in the temperature range 0 and 200 °C and that of H in Ni almost three orders of magnitude in the temperature range 25 and 300 °C [19].

The large diffusivity of protons/deuterons in Ni and Pd is used to explain the formation of neutron energy bands which is the key factor for the CFP in the CF materials such as NiH_x and PdD_x [4]. Elevation of temperature of the CF material means the excitation of protons/deuterons to upper energy

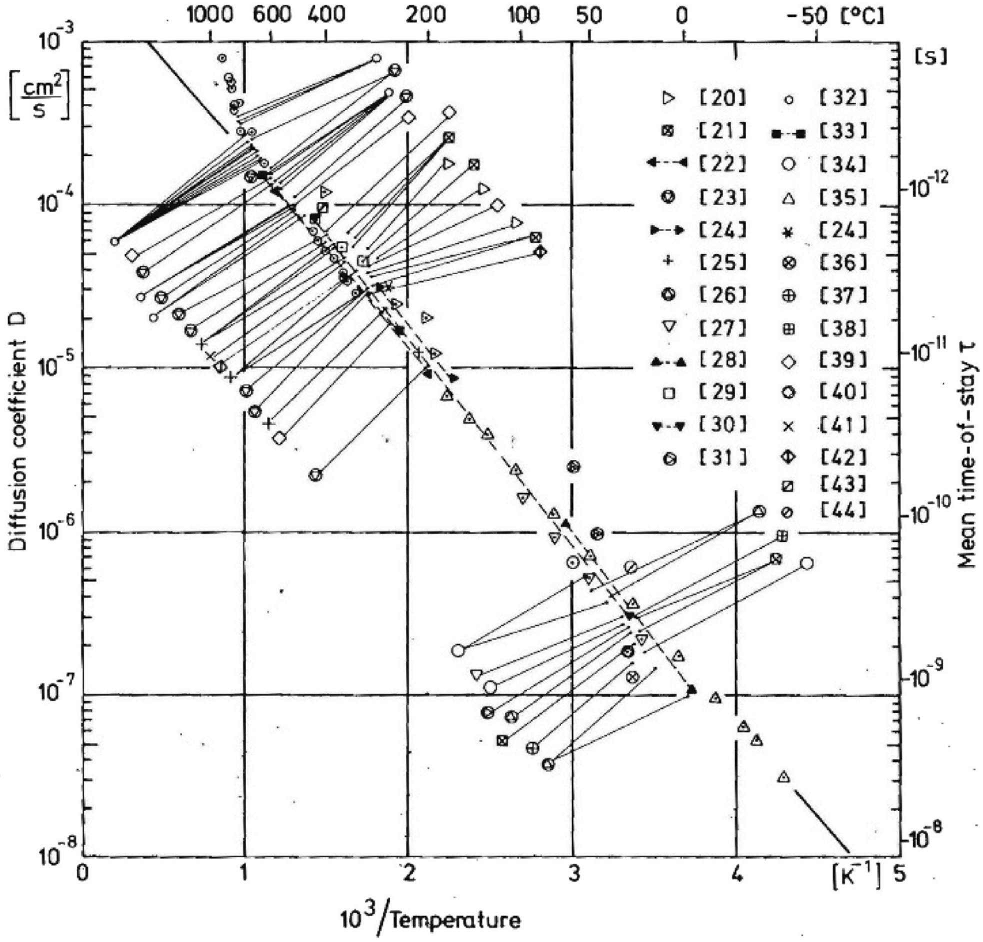

Fig. 1 – Diffusion coefficients of H in Pd. The right-hand scale for the mean time-of-stay tau refers to octahedral-octahedral jumps (Numbers in brackets refer to the paper cite in Ref. [19]) ([19Fig. 12.2]).

levels which accordingly results in the extension of the proton/deuteron wavefunction [21]. Then, the overlapping of the wavefunctions of an interstitial proton/deuteron and a neutron in lattice nuclei increases resulting in the increase of the super-nuclear interaction favorable for the CFP [4]. Therefore, it is natural from our point of view that the third characteristic (temperature effect) of the CFP listed in the previous section is a natural consequence of the supposed mechanism of the CFP where the neutrons in the neutron bands are responsible to the nuclear reactions.

In relation to the explanation of the temperature effect by the increase of the super-nuclear interaction, it is interesting to see the inverse isotope-effect of the diffusion constants of H and D in Pd in the temperature region below about 200 °C. As shown in Fig. 3 [19], the diffusion constant of D in Pd is larger than that of H. This fact is used to explain the preference for PdD_x over PdH_x in the CFP below 200 °C [22].

The size of the CF materials is a decisive factor for the formation of the Ni–H or Pd-D superlattice due to the fact that it is easier to realize a homogeneous distribution of the occluded protons/deuterons in smaller size materials [4,5].

The nuclear reactions between the neutrons in a neutron energy band and the nucleus in the CF material occurs when the nucleus is in a disordered position. This fact is used to explain the surface nature of nuclear transmutations in the CFP shown typically by experiments by Iwamura et al. (e.g. Ref. [18]). Therefore, the boundary regions formed between a CF material and substrates in the compound materials are advantageous for realization of the CFP. The common experience of the surface nature of the nuclear transmutation products is the manifestation of this characteristic.

Concluding remarks

The excess energy in the CFP is a product of the nuclear reactions between the "trapped neutrons" and nuclei at disordered positions in the CF material [3–5]. In addition to the excess energy, there should be the by-products of the nuclear reactions in the CF material. We have to identify the products of the nuclear reactions such as transmuted nuclei and emitted particles to confirm the CFP. Some of such trials were successfully analyzed using our model [23–25]. The next program of the work reported in the paper [1] should be the identification of the nuclear reactions producing the excess

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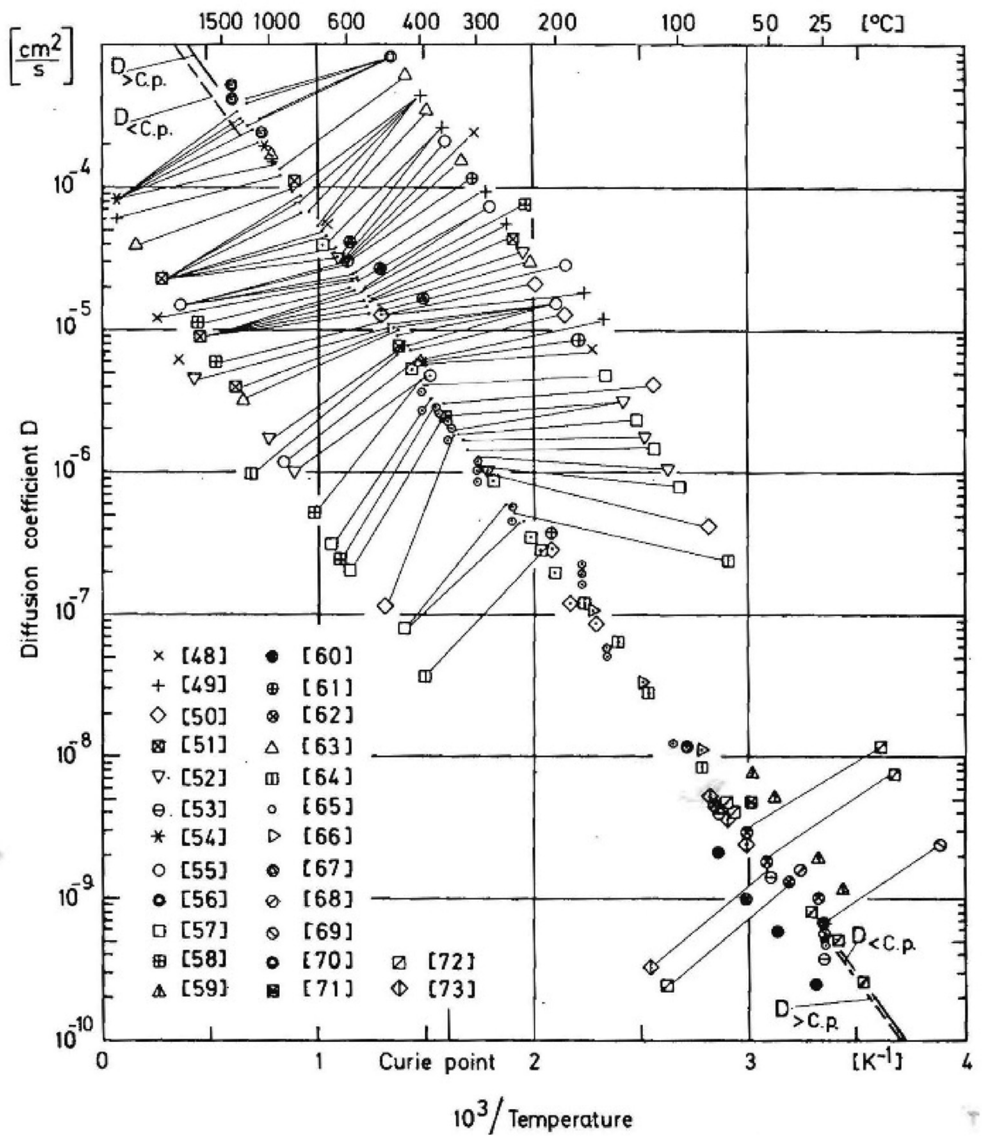

Fig. 2 — Diffusion coefficients of H in Ni. ($D_{<\,C.p.}$ and $D_{>\,C.p.}$ are best values below and above the Curie points) (Numbers in brackets refer to the paper cited in Ref. [19]) ([19Fig. 12.3]).

energy by determination of the nuclear products in the experimental system.

It should be noted the occurrence of the exothermic reactions accompanied with the crystallization of component elements in Pd–Ni alloys well-known in metallurgy of Pd alloys (cf [26]. and Appendix). It is probable to occur similar exothermic reaction in the hydrides/deuterides used in the experiments reported in the paper [1]. Then, it is possible that there occurs a mutual acceleration of the positive feedback of the energy to the nuclear reactions in the CFP [27] and also of the energy to the exothermic crystallization of component elements. The exothermic crystallization depends definitively on the composition of the CF material and therefore the process should be very complicated. If this mutual acceleration occurs, the CFP in the CF materials composed of Pd–Ni alloys works very effective to realize nuclear reactions between neutrons and nuclei at disordered position and then the structure of the CF material deteriorates rapidly to terminate the reactions by destruction of the optimum structure for the CFP [27]. So, it is desirable to check the occurrence of the crystallization in the sample after the experiments.

In this paper, we did not take into our account any negative data with the same reason expressed already in the *DOE Report* published in 1989 [28] by the following words applicable to any discussion related to the evaluation of negative data.

“- - - *As a result, it is difficult convincingly to resolve all cold fusion claims since, for example, any good experiment that fails to find cold fusion can be discounted as merely not working for unknown reasons. Likewise, the failure of a theory to account for cold fusion can be discounted on the grounds that the correct explanation*

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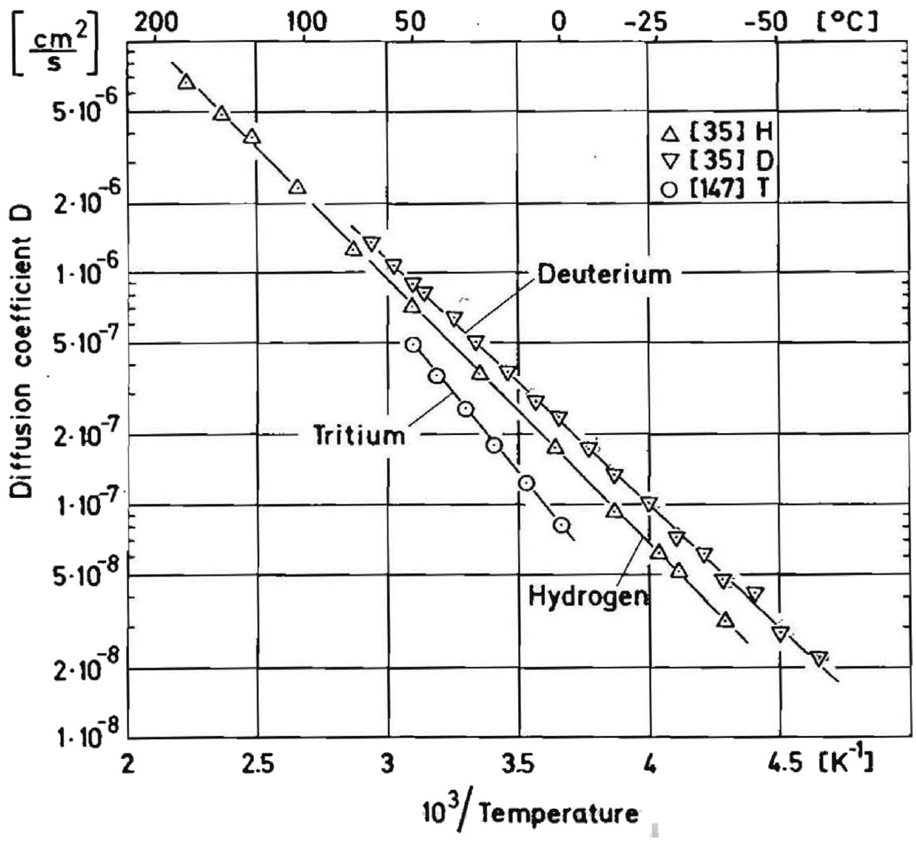

Fig. 3 – Diffusion coefficient of isotopes of hydrogen in Pd (Numbers in brackets refer to the paper cited in Ref. [19]) ([19] Fig. 12.16).

and theory has not been provided. Consequently, with the many contradictory existing claims it is not possible at this time to state categorically that all the claims for cold fusion have been convincingly either proved or disproved - - -." [25 (V. Conclusions and Recommendations, A. Preamble)]

Conclusion

The elaborate experiments reported in the paper [1] have confirmed again several characteristics of the CFP enumerated in Section Introduction. The most interesting feature in the experimental results may be the excess energy production at higher temperature region than 200 °C (up to 300 °C) where it is possible to occur the crystallizations of component elements in the sample. The coexistence of the nuclear reactions and chemical reactions in the sample may result in complex phenomena which are fundamentally explained by our model as the mutual interference of the nuclear reaction and the chemical reaction in the framework of the CFP [5].

Acknowledgement

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Appendix. On the generation of heat due to crystallizations in the Pd–Ni–P deposits [26]

"In the electroless plating of Pd–Ni–P alloys from ethylenediamine complex solutions containing sodium hypophosphite as a reducing agent, the generation of heat due to the crystallizations of palladium and palladium phosphides were observed at around 300 °C. Another generation of heat was observed also at around 400 °C dues to the crystallization of Ni_3P. We found several broad peaks of the heat generation between the two peaks of the heat generations due to the Pd–P deposit and Ni–P deposit. Fig. 5 shows the relation between the phosphor content in the deposit of Pd–Ni–P plating and amount of heat generation (determined by the peak of heat generation in the Dsc curve).” (p. 68, Translated into English by H.K. The Fig. 5 in the above sentence is cited below as Fig. A1).

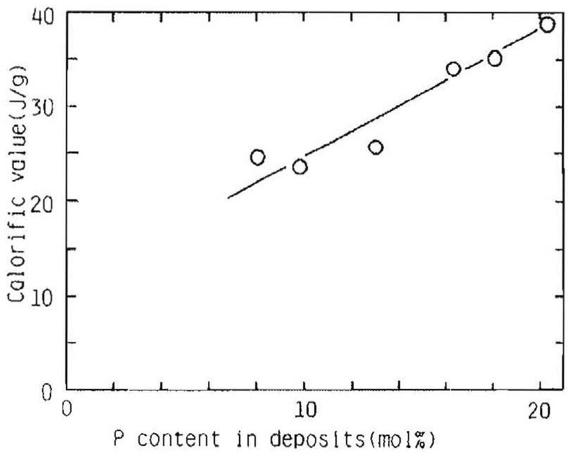

Fig. A1 – Relation between P content in electroless Pd–Ni–P films and calories of exothermic reaction. ([26] Fig. 5).

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