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REVIEW ARTICLE

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Nuclear fusion inside condense matters

Abstract This article describes in detail the nuclear fusion inside condense matters—the Fleischmann-Pons effect, the reproducibility of cold fusions, self-consistentcy of cold fusions and the possible applications.

Keywords Fleischmann-Pons effect, reproducibility of cold fusions, self-consistent of cold fusions and the possible applications

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1 Introduction

In March 23, 1989, Martin Fleischmann and Stanley Pons, in the process of electrolysing heavy water using Pd as the cathode and Pt as anode, got more energy output than they had put into the system. The excess energy could not be explained by chemical processes, so they announced the discovery of cold fusion.

In the Autumn of 1989, the DoE (Department of Energy) of the US organized a review headed by science skeptics Huizenga, who recognized that the phenomenon of cold fusion is conflict with the well known nuclear theory, so that cold fusion was impossible, and concluded that the federal funding of the US should not support cold fusion research [1].

Fifteen years later, in December of 2004, the US DoE organized another review of cold fusion, a lot of laboratories around the world have been able to repeat the Fleischmann-Pons effect. The new review recognized that cold fusion did not get great progress after more then 10 years, but the new review “identified areas of research that ‘could be helpful in resolving some of the controversies in the field’—specifically, characterization of deuterated metals and the search for fusion in thin deuterated films—and recommends that agencies consider funding individual proposals in those areas” [1].

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2 Reproducibility of cold fusion

In the process of electrolysis of heavy water using Pd as the cathode and Pt as the anode, if the following two conditions are satisfied spontaneously, excess energy will be produced [2].

2.1 D/Pd ratio larger than 0.88

Figure 1 is the relation of the excess heat and the D (Deuterium) atom introduced into the Pd (Palladium) metal using the process of electrolysis of heavy water by using Pd as the cathode and Pt as the anode. One can see that after D/Pd ratio becomes larger than 0.88, excess heat occurred.

2.2 The current density of the electrolysis is larger than 280 mA/cm^2

Figure 2 is the relation of the excess heat and the current density of the electrolysis. One can see that after the current density of the electrolysis becomes larger than 280 mA/cm^2, excess heat will occur. The horizontal line is the result of a control experiment of the electrolysis of light water (H_2O). One can see that there is no excess heat occurring.

Above experiments were done by Michael C.H. McKubre in Stanford Research Institute (SRI).

Table 1 shows the statistics of the cold fusion experiments around the world, one can see that recently the reproducibility of the cold fusion experiments in some countries have reached 100 percent [3].

The cold fusion experiments show that the excess heat comes from the reaction:

$$D + D \rightarrow {}^4He + \Delta E\ (23.8\ MeV) \quad (1)$$

Figure 3 is the relation of the excess heat and the ^4He produced in the cold fusion experiments. One can see that the excess heat is proportional to the ^4He productions.

At present, the well known nuclear theory cannot explain the phenomenon of the cold fusion. According to the well known nuclear theory, D-D fusion should have the following reactions:

$$D + D \rightarrow {}^3He\ (0.87\ MeV) + n\ (2.45\ MeV) \quad (2)$$

$$D + D \rightarrow t\ (1.008\ MeV) + p\ (3.02\ MeV) \quad (3)$$

$$D + D \rightarrow {}^4He\ (7.6\ keV) + \gamma\ (23.7\ MeV) \quad (4)$$

Reactions (2) and (3) are strong reactions, they are charge independent: the reaction ratio of (2) to (3) should be equal to 1. Reaction (4) is an electromagnetic reaction, reaction ratio of (4) to (2) equals to 10^{-7}. But, in cold fusion, only the reaction: $D + D \rightarrow {}^4He + \Delta E$ (23.8 MeV).

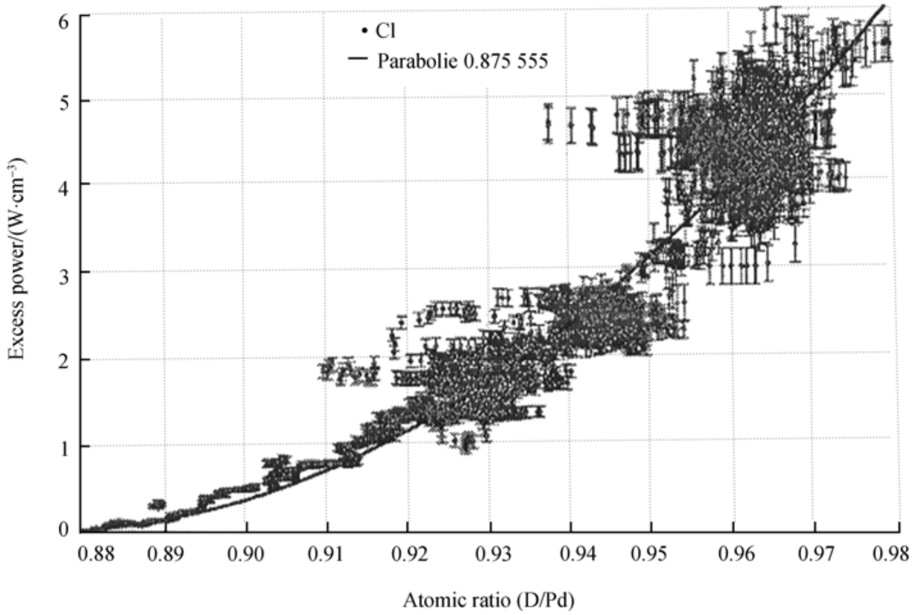

Fig. 1 The relation of the excess heat and the atomic D/Pd ratio.

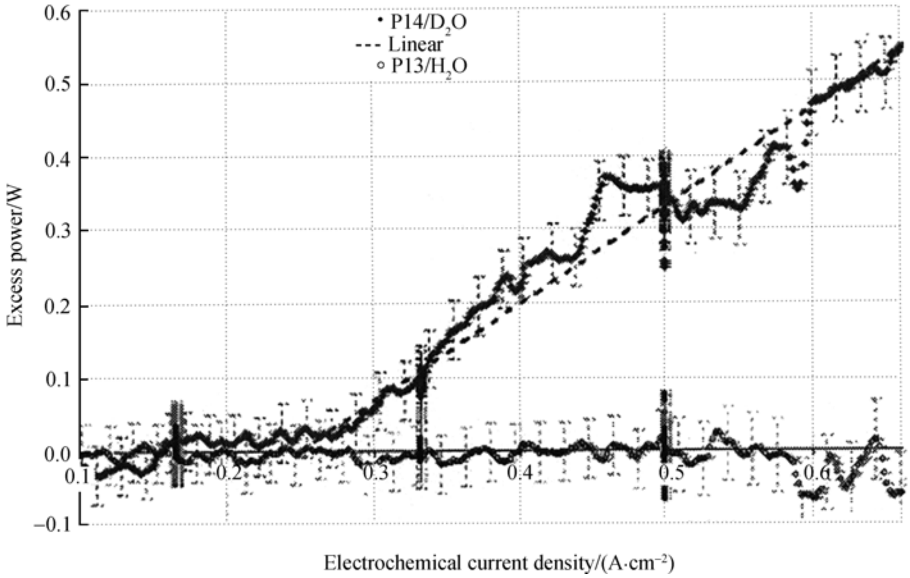

Fig. 2 The relation of the excess heat and current density of the electrolysis.

Table 1 The Statistics of the cold fusion experiments around the world.

Researcher's nationality	Field or degree obtained	Years of cold fusion research	Years of hot fusion research	Estimated number of experiments performed	Reproducibility rate 5years ago	Reproducibility rate last 12 months	Do you conclude that nuclear activity is occurring?
Italy	Chemical engineering	Na*	Yes	Na	Na	50	Na
Russia	Condensed matter physics	18	na	1 000	na	60	Yes
Italy	Physics	14	16	300	40	75	Yes
United States	Mass communications	13	no	6 000	25	75	Yes
United States	Physical chemistry	14	no	200	10	80	Yes
United States	Metallurgy	14	no	3 000	50	90	Na
Japan	Nuclear engineering	14	20	20	70	100	Yes
Romania	Atomic physics	10	no	40	70	100	Yes
United States	Radiochemistry	14	no	700	50	100	Yes
Russia	Nuclear rocket engineering	13	2	3 500	Na	100	Yes
Total estimated experiments				14 720			
Average reported reproducibility					45 %	83 %	

* Na = Not available.

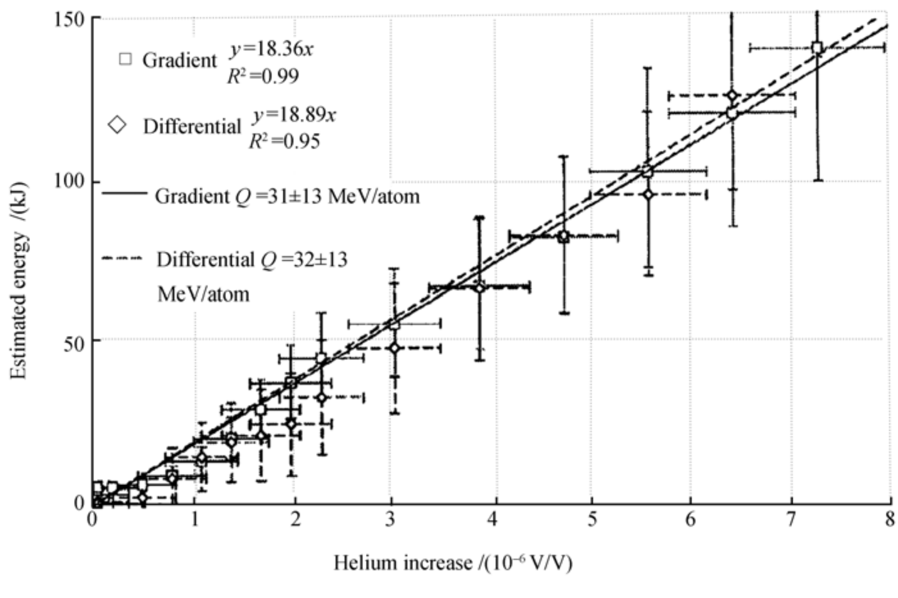

Fig. 3 The relation of the excess heat and the ^{4}He produced in the cold fusion experiments.

3 Self-consistent of cold fusions

Since the Deuterium has a positive charge, it has about keV of energy to overcome the Coulomb barrier before it achieves fusions. At room temperature, the D-D cannot fuse to make a ^{4}He.

In the US, Jones made two experiments at room temperature: after the D (Deuterium) atom is introduced into the Pd (Palladium) metal thin film, Jones found the following D-D fusions:

$$D + D \rightarrow {}^3He\ (0.87\ MeV) + n\ (2.45\ MeV)$$

$$D + D \rightarrow t\ (1.008\ MeV) + p\ (3.02\ MeV)$$

It means that at room temperature, after the D (Deuterium) atom is introduced into the Pd (Palladium) thin metal film, the D-D can fuse [4, 5].

In Japan, Kasagi *et al.* [6] bombarded a TiD thin metal film with 150 keV Deuterium, which is a typical hot fusion arrangement. Besides the two body fusion, Kasagi *et al.* have found a three-body fusion:

$D + D + D \rightarrow {}^4He + p + n$

In this reaction, the products: ^4He, p, and n have characteristics of continues energy spectrum: the maximal energy of α is 6.5 MeV; the maximal energy of the proton (or neutron) is 17 MeV. Indeed, Kasagi *et al*. have detected α particle with a maximal energy of 6.5 MeV and proton with a maximal energy of 17 MeV.

Another three-body fusion was found by Takahashi *et al.* [7]. They bombarded a TiD thin metal film with 150 keV Deuterium, which is also a typical hot fusion arrangement. Besides two-body fusions, Takahashi *et al*. found three-body fusion:

$D + D + D \rightarrow {}^3He\ (4.75\ MeV) + t\ (4.75\ MeV)$

These two experiments are important, because in hot fusion, the Deuterium is free and it cannot make three-body fusions. The ratio of the three-body fusion to two-body fusion of free Deuterium is about 10^{-30}. However, Kasagi *et al.* and Takahashi *et al*. have found the ratio of the three-body fusion to the two-body fusion to be about 10^{-4}; the difference is about 10^{26}. It means that after the D (Deuterium) atom is introduced into the Ti (Titanium) metal or the Pd (Palladium) metal, there may be DD pairs inside Titanium metal or Pd (Palladium) metal. Thus, when D bombards the TiD metal thin film, the D reacts with DD pairs, and a three-body fusion occurred.

The difference between hot fusion and cold fusion is that in hot fusion, Deuterium is free and must have about keV of energy to overcome the Coulomb barrier before it achieves fusions; in cold fusion, after the D (Deuterium) atom is introduced into the Pd (Palladium) thin metal film, D is in the crystal lattices of the condense matters. Under this environment, D-D achieves fusion.

Based on the DD pairs formed inside the Pd (Palladium) metal or the Ti (Titanium) metal crystal lattices after the D (Deuterium) atom is introduced into the Pd (Palladium) metal or Ti (Titanium) metal, Takahashi proposed the following interaction to explain the cold fusion phenomenon:

$(DD) + (DD) \rightarrow {}^8Be \rightarrow {}^4He\ (23.8\ MeV) + {}^4He\ (23.8\ MeV)$

This is similar to the astrophysics process:

$(DD) + (DD) \rightarrow {}^8Be + \Delta E\ (47.6\ MeV)$

4 New development of cold fusions

In Japan, Arata made a cold fusion experiment by using a high pressure gas Deuterium and nano-Palladium grain [8]. The arrangement of the Arata's cold fusion experiment is shown in Fig. 4.

The outer tube is made from stainless steel; the inner tube is made from Palladium and the nano-Palladium grain was

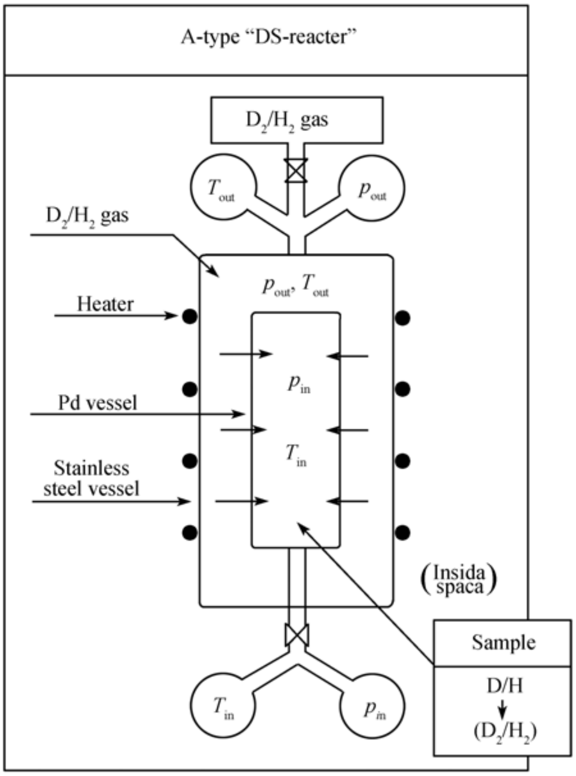

Fig. 4 The arrangement of the Arata's cold fusion experiment.

put inside the inner tube. A heating core is placed outside the outer tube, an independent gas gauge and temperature gauge are connected with the outer tube and the inner tube. When the temperature increases, the Deuterium gas goes into the inner tube through the wall of the inner tube. The arrangement of the Arata's cold fusion experiment are:

(a) There is no Palladium sample in the inner tube and filled with D_2 gas;

(b) There is a black Palladium sample in the inner tube and filled with H_2 gas;

(c) There is black Palladium sample in the inner tube and filled with D_2 gas;

(d) There is a nano-Palladium sample in the inner tube and filled with D_2 gas.

The results of the Arata's cold fusion experiment are shown in Fig. 5.

One can see that:

In the case of (a) and (b), the temperature of the outer tube T_{out} is larger than the temperature of the inner tube T_{in} ($T_{out} > T_{in}$). This is normal. This means that cold fusion did not occur inside the inner tube.

In the case of (c) and (d), the temperature of the outer tube T_{out} is less than the temperature of the inner tube T_{in} ($T_{out} < T_{in}$). This is abnormal. This means that inside the inner tube, cold fusion has occurred.

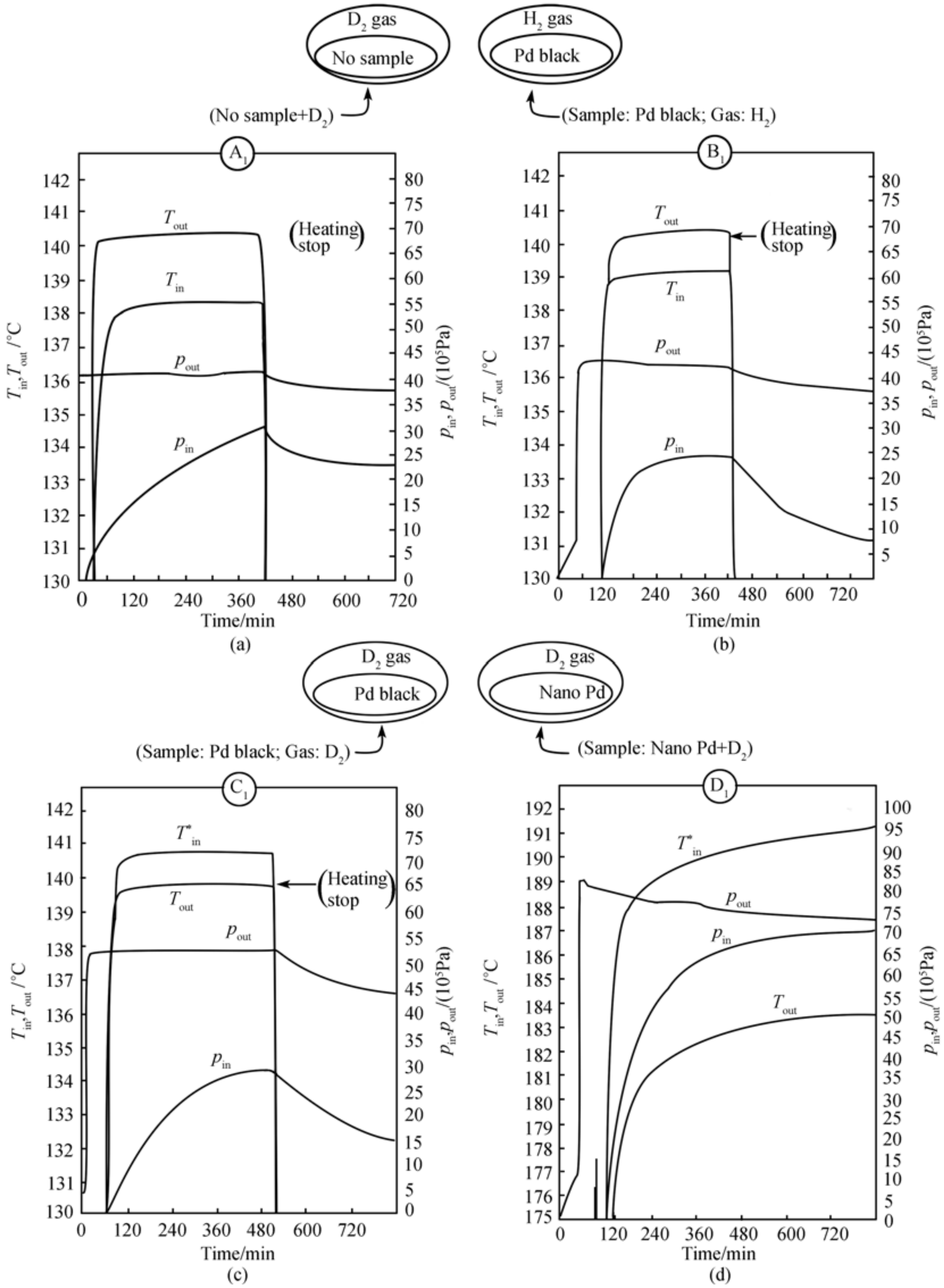

Fig. 5 The results of the Arata's cold fusion experiment.

Arata made other cold fusion experiments by using a high pressure gas Deuterium and different samples of Palladium grain, ZrNiO particles, Pd black and bulk of Pd [9]. The results of these experiments are shown in Fig. 6.

The vertical axis shows the products of ^4He in ppm (10^{-6}). The first bar of 5.2 ppm is the reference of ^4He content in air. One can see that: nano-ZrNiO produced more ^4He than nano-Palladium produced. Bulk Palladium produces no ^4He.

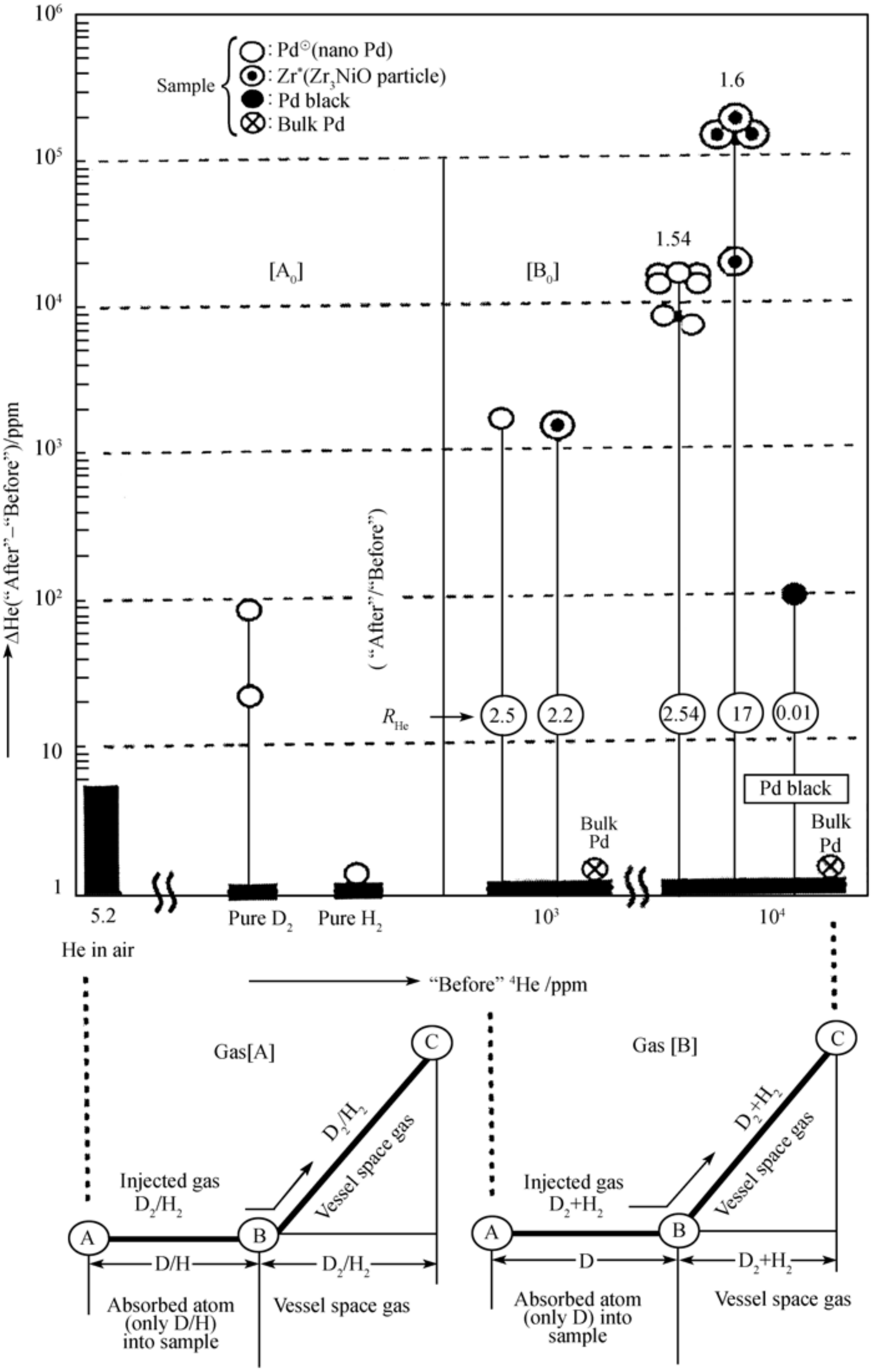

Fig. 6 The results of Arata's other cold fusion experiments.

5 Conclusion and prospect

Since cold fusion experiments are reproducible and can be self-consistent, it is therefore a real science. One should put more efforts to achieve both theoretical and experimental progress.

The nano scale of the Pd or ZrNiO with high pressure Deuterium gas loading may have bright application prospects if the excess heat and the products of ^4He of the process can be further increased.

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