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THE PRECURSOR OF "COLD FUSION" PHENOMENON IN DEUTERIUM/ SOLID SYSTEMS

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ABSTRACT

It is suggested that detecting the precursor of the ″cold fusion″ phenomenon in deuterium/solid systems will help solve the problem of reproducibility. The results of first step in this direction are discussed. Electromagnetic radiation and energetic charged particles have been detected. It has been shown that the surface condition has an important impact on this phenomenon.

INTRODUCTION

This work was begun after the Workshop on Cold Fusion at Santa Fe in May, 1989 (1) The failure to reproduce neutrons or "excess heat" (2) suppressed the surge of interest in the "Cold Fusion" effect at that time. We asked ourselves a question: If this anomalous phenomenon is not a mistake, how do we identify the phenomenon? The neutron was selected as a fusion product to identify the nuclear reaction in many cold fusion experiments. But the low level signal of neutrons in a γ-background was one of the difficulties. Sporadic bursts of signals coming in unpredictable times made it even more difficult to measure in a convincing way. This irreproducibility and unpredictability has mired "cold fusion" in a mist of illusion. We suggested that before the emission of the fusion products occurs, there must be some precursor reactions. If we can measure the precursors and find the correlation between the fusion products and the precursors, then the measurement of sporadic bursts would be more convincing. Besides, the precursor might also guide our approach to the cold fusion phenomena and make it easier to solve the problem of reproducibility.

PRECURSOR—ELECTROMAGNETIC RADIATION

Among the possible precursors, we selected electromagnetic radiation as the first target. We believe that a nuclear fusion reaction is possible only if the Coulomb barrier is screened somehow. The experiment (3) proved that the muon is not the necessary a negative charge which screens the positive core of the Coulomb force. The only available candidate is the electron. Although the mass of the electron is too small to screen the Coulomb barrier in an effective way in a free atom, we still hope that there might be some mechanism in an atomic lattice that causes a screening effect. If this is true in a deuterium/solid system, the electrons must change their states before effective screening happens. Thus, we may expect to see certain electromagnetic radiation before the anomalous nuclear effect appears. The photon of this electromagnetic radiation should be in the range from 10 eV to 3 keV, since the electron should approach an orbit similar to that of a muon in order to screen the Coulomb barrier effectively. This electromagnetic radiation is ultra-violet or soft X-ray; hence, we have to measure them close to the source to avoid serious attenuation. The Frascati experiment (4) provided a good chance to detect this electromagnetic radiation.

ENERGETIC CHARGED PARTICLES

In order to identify the fusion reaction, we thought that energetic charged particle is a better identification than the neutron. However, energetic charged particles cannot penetrate the vessel the way the neutron does, so we have to detect it inside the vessel.

The first step of the experiment was to determine whether there is any electromagnetic radiation and emission of the charged particles in a deuterium/solid system. This paper reports the result of this first step of the experiment to search the electromagnetic radiation and charged particle emission.

A thermoluminescence detector (TLD) was selected to detect the electromagnetic radiation, because it is easy to use it to make a close-up measurement in a high pressure vessel, and because it has high sensitivity with low background. The TLD (CaF_2) was selected for its high sensitivity in the range of interest. The plastic-track detector (CR-39) was selected for charged particle detection for the same reason. Pre-etching was used to discriminate the existing background tracks before starting the experiment. A control run was used to see the effects due to any α-emitting nuclides in the palladium foils, or due to airborne radon or cosmic-rays.

Palladium foil (0.02 cm × 0.5 cm × 2 cm), CR-39 and TLD are put together in a sandwich-like structure. The structure was heated to 500°C for 2 hours at 7×10^{-2} torr, and then sealed in a stainless cell attached to a source of D_2 gas. After evacuating the cell using a roughing pump (1.5×10^{-2} torr) we loaded D_2 gas to a pressure of 9 atm, and immersed the cell in liquid nitrogen for 4 hours. Then the valve between cell and the D_2 source was closed, and we let it warm to 20°C when the liquid nitrogen vaporized. The cooling and warming cycle was repeated several times. The entire experiment lasted about 2 days, after which we etched the CR-39 film for 6 hours (6.25 mol NaOH 70°C) together with the CR-39 films from the blank run (in air) and control run (in H_2+Pd cell). The TLD (CaF_2) are measured by Thermoluminescence Dosimetry.

RESULTS

The results are shown in Table 1. Although the calibration for TLD (CaF_2) is not available yet, the comparison between the sample runs and blank runs has shown that there is some electromagnetic radiation in the deuterium/palladium and hydrogen/palladium system. The interesting point is that although the H_2 cell exhibits similar signal of electromagnetic radiation as D_2 cell, it gives no charged particle tracks in CR-39 film. Fig. 1 shows a series of photos of CR-39, taken by differential interference microscopy.

Table 1 Thermoluminescence Dosimeter Measurement

No. of runs	D_2 cell			H_2 cell	Blank cell	Lab background
	cell A	cell B	cell C			
1	102.6	194		158		
2	69.8	52	48.8		26.5	36.3
3	58				24.7	20.8
4	58.6				25.2	30.6
5	61.3			62.4	26.5	17.3

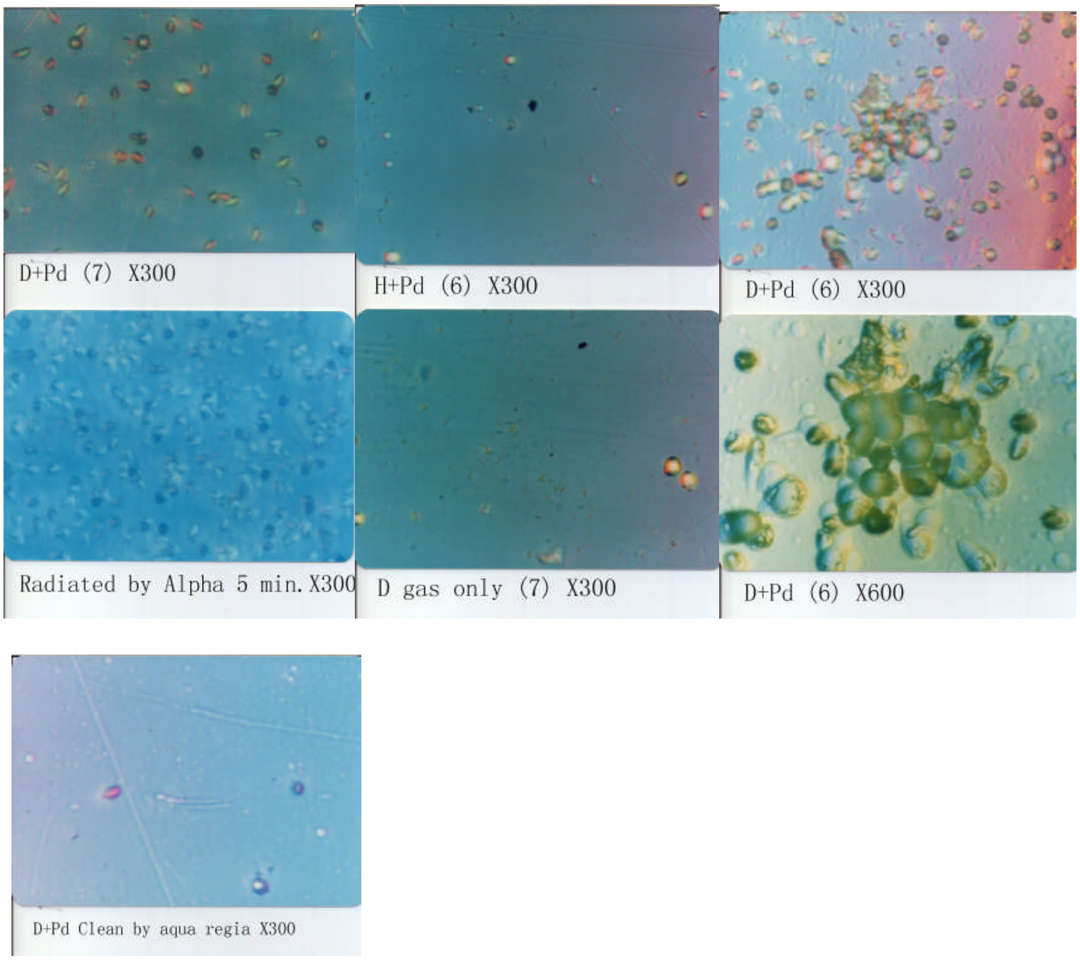

Fig.1 a, D_2+Pd, ⑦, ×300; b, Radiated by α-particle source(Am) 5 minutes, ×300; c, H_2+Pd, ⑥, ×300; d, D_2 gas only, ⑦, ×300;e, D_2+Pd, ⑥, ×300;f, D_2+Pd, ⑥, ×300

Fig. la shows the photo of CR-39 from the D_2+Pd cell. It is clear that there are some tracks of energetic charged particles. In order to estimate the energy and charge of these particles, we show the photo of CR-39 irradiated by a particle source (Am source with intensity of 4×10^5/min in 2π solid angle) in Fig. lb. The sizes of these tracks are comparable. In Fig. lc, the photo of CR-39 from an H_2 cell is shown as a control run. The contrast between them is apparent. It hints that the signals in TLD (CaF_2) are not caused by energetic charged particles. The electromagnetic radiation might originate from electrons which are transiting from state to state when palladium foils are filled with hydrogen or deuterium. In Fig. 1d, a photo of CR-39 from a cell with D_2 only (no palladium). It proved that D_2 alone cannot produce a charged particle signal. Fig. le and Fig. 1f show a kind of special signal, a group of tracks, at a different magnification (×300 and ×600, respectively). This special signal might be caused by a burst of charged particles.

In October, 1989, P.B. Price *et al.* published their results of experiments using CR-39. (5) They found only two tracks for charged particles in CR-39. This is quite different from our results. Having compared the experimental details we found an important difference: they cleaned the samples with aqua regia. We repeated our experiment with the sample cleaned with aqua regia. To our great surprise, the tracks in CR-39 disappeared (Fig. lg). We analyzed the surface of palladium cleaned by aqua regia, using the auger electron scanning probe. A clear peak of chlorine appeared (Fig. 2). Using the argon ion mill, we found that the chlorine penetrated into the palladium to a depth of a few hundred angstroms (Fig. 3). When we used the chlorine gas to contaminate palladium surface intentionally, we again found that the CR-39 tracks disappeared.

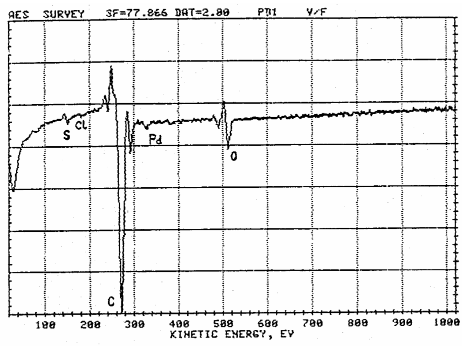

Fig 2. a Pd (before cleaning)

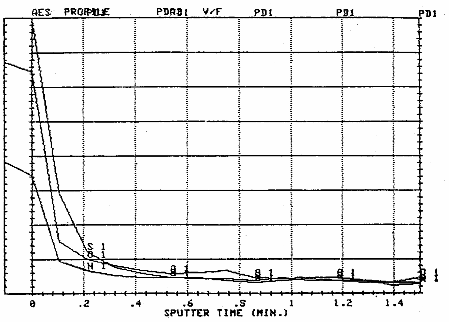

Fig 3. a Pd (before cleaning)

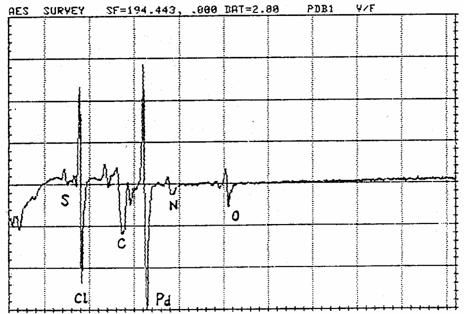

Fig 2. b Pd (cleaned by aqua regia)

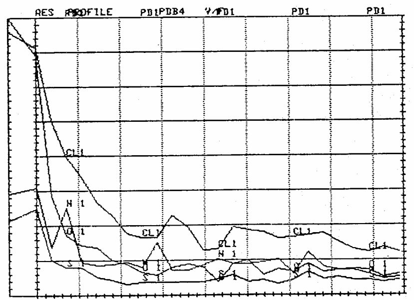

Fig 3. b Pd (cleaned by aqua regia)

SUMMARY

To summarize our experimental results, we have three points:

First, there is some sort of electromagnetic radiation which might be a precursor of the anomalous nuclear effect. Hence, we design the next step of experiment to diagnose the electromagnetic radiation in real time. The electromagnetic radiation is different from the electromagnetic radiation caused by energetic charged fusion products, which can not be taken as a precursor.

Second, we have detected charged particle signals in a deuterium/palladium system repeatedly, as long as we use the palladium foil cut from the same sheet of palladium. Since the charged particles have a range of only a few microns in the palladium, this suggests that the anomalous nuclear effects are related to some surface phenomena.

Third, surface contamination may suppress the anomalous nuclear effects. This may explain why many experiments failed in the past year.

These three points together are consistent with the electron screening model, which has been suggested by the existing nuclear reaction data at low energy (6).

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