PRECURSORS TO "COLD FUSION" PHENOMENON AND THE DETECTION OF ENERGETIC CHARGED PARTICLES IN DEUTERIUM/SOLID SYSTEMS

COLD FUSION

TECHNICAL NOTE

KEYWORDS: *precursor, electromagnetic radiation, energetic charged particles*

S. Y. DONG, K. L. WANG, Y. Y. FENG, L. CHANG, C. M. LUO,
R. Y. HU, P. L. ZHOU, D. W. MO, Y. F. ZHU, C. L. SONG,
Y. T. CHEN, M. Y. YAO, C. REN, Q. K. CHEN, and X. Z. LI
Tsinghua University, Beijing 100084, People's Republic of China

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A precursor to the "cold fusion" phenomenon in deuterium/solid systems is sought in order to solve the problem of reproducibility. The results of the first experiments are discussed. Electromagnetic radiation and energetic charged particles have been detected. It is shown that the surface condition has an important effect on this phenomenon.

INTRODUCTION

After the Workshop on Cold Fusion[1] at Santa Fe, New Mexico, in May 1989, the failure to reproduce neutron or excess heat measurements[2] suppressed interest in cold fusion. We asked ourselves a question: If this anomalous phenomenon is not a mistake, how do we identify this phenomenon? Neutron fusion products have been used to identify the nuclear reaction in many cold fusion experiments. However, we suggest that before fusion products can be emitted, there must be some precursors. 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. The precursor might also aid in our understanding of the cold fusion phenomena and help solve the problem of reproducibility.

A PRECURSOR—ELECTROMAGNETIC RADIATION

Among the possible precursors, we selected electromagnetic radiation as our first candidate. We believe that nuclear fusion reactions are possible only if the Coulomb barrier is screened. The experiment in Ref. 3 proved that the muon is not the necessary negative charge that 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 effectively screen the Coulomb barrier in a free atom, there might be some other mechanism in an atom lattice to cause some screening effect. If this is true in a deuterium/solid system, the electrons must change their states before the effective screening occurs. Thus, we may expect 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 to screen the Coulomb barrier effectively. This electromagnetic radiation is ultraviolet or soft X ray; hence, we have to measure it close up to avoid any serious attenuation. The Frascati experiment[4] provided a good chance to detect this electromagnetic radiation.

ENERGETIC CHARGED PARTICLES

To identify the fusion reaction, we thought that the energetic charged particle is a better indicator than the neutron. However, the energetic charged particle cannot penetrate the vessel as the neutron does, and we must detect it inside the vessel as well.

The first step of the experiment was to determine whether there is any electromagnetic radiation or charged-particle emission in a deuterium/solid system. This technical note reports the result of this first step of the experiment.

Thermoluminescent detectors (TLDs) were selected to detect the electromagnetic radiation because they can perform a close-up measurement in a high-pressure vessel, and they have high sensitivity with a low background. The CaF_2 TLD was selected for its high sensitivity in the range of interest. Although the exact sensitivity is not known, it is sensitive even for visible light. The plastic track detector (the CR-39) was selected to detect charged particles for the same reason. Usually, track-etch detectors are not good for lightly ionizing radiation; however, the CR-39 is sensitive to protons and alpha particles with energies as low as 3 and 0.5 MeV, respectively. Pre-etching was used to discriminate the existing background tracks before starting the experiments. Control runs were used to see the effects due to any alpha-particle emitting nuclides in the palladium foils, airborne radon, or cosmic rays. Any particlelike tracks that might be caused by crushing, vibrations, or shocks were eliminated by inspection.

The palladium foil ($0.02 \times 0.5 \times 2$ cm), the CR-39, and the TLD were placed together in a sandwichlike structure after the palladium foil was heated to 500°C for 2 h at 7×10^{-2} Torr. They were sealed in a stainless steel 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 h. Then the valve between the cell and the D_2 source was closed, and the apparatus was heated to 20°C, when the liquid nitrogen vaporized. The cooling and heating cycle was repeated several times. The entire experiment lasted ~2 days, after which we etched the CR-39 film for 6 h (6.25 mol NaOH at 70°C) together with the CR-39 films from the blank run (in air) and the control run (in H_2 + Pd cell).

RESULTS

The results are shown in Table I. The numbers listed are the TLD readings. Although the calibration for the CaF_2 TLD is not available yet, the comparison between the sample runs and the blank runs shows that there is some electromagnetic radiation in the deuterium/palladium and hydrogen/palladium systems. For example, run 5 shows that in the cell filled with D_2, the TLD detected an electromagnetic radiation that is clearly higher than the background or blank level. In the cell filled with H_2, the TLD detected almost the same level of electromagnetic radiation. The interesting point is that although the H_2 cell exhibits electromagnetic radiation signals similar to those of the D_2 cell, it gives no charged-particle tracks on the CR-39 film.

Figure 1 shows a series of CR-39 photos taken by differential interference microscopy. Figure 1a shows a CR-39 photo in the D_2 + Pd cell. It is clear that there are some tracks of energetic charged particles. To estimate the energy and charge of these particles, we show a CR-39 photo irradiated by a particle source (americium source with intensity of 4×10^5/min in 2π solid angle) in Fig. 1b. The sizes of these tracks are comparable. In Fig. 1c, a CR-39 photo in the H_2 cell is shown as a control run. The contrast is apparent, hinting

TABLE I

TLD Measurement

Run	D_2 Cell			H_2 Cell	Blank Cell	Laboratory 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

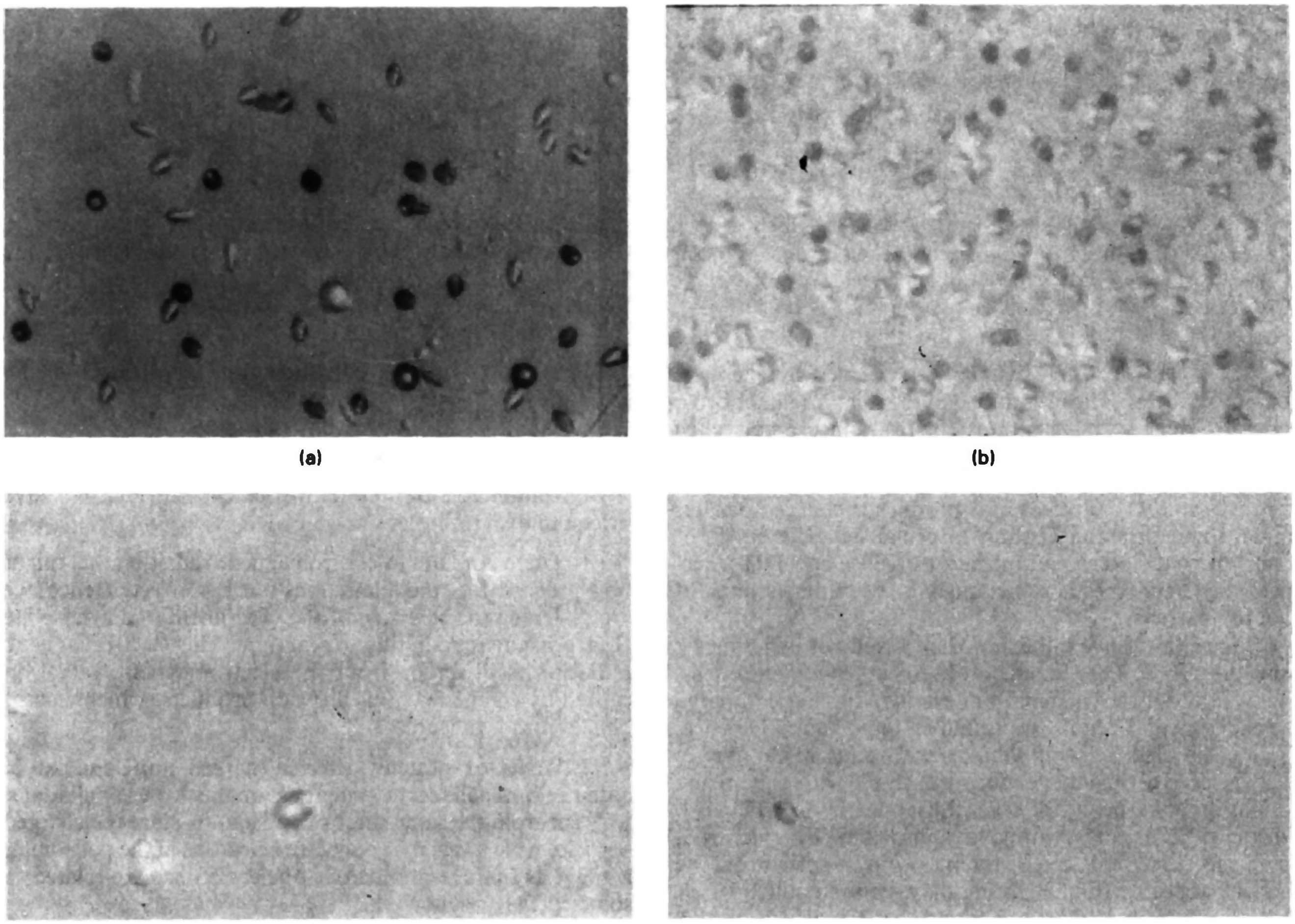
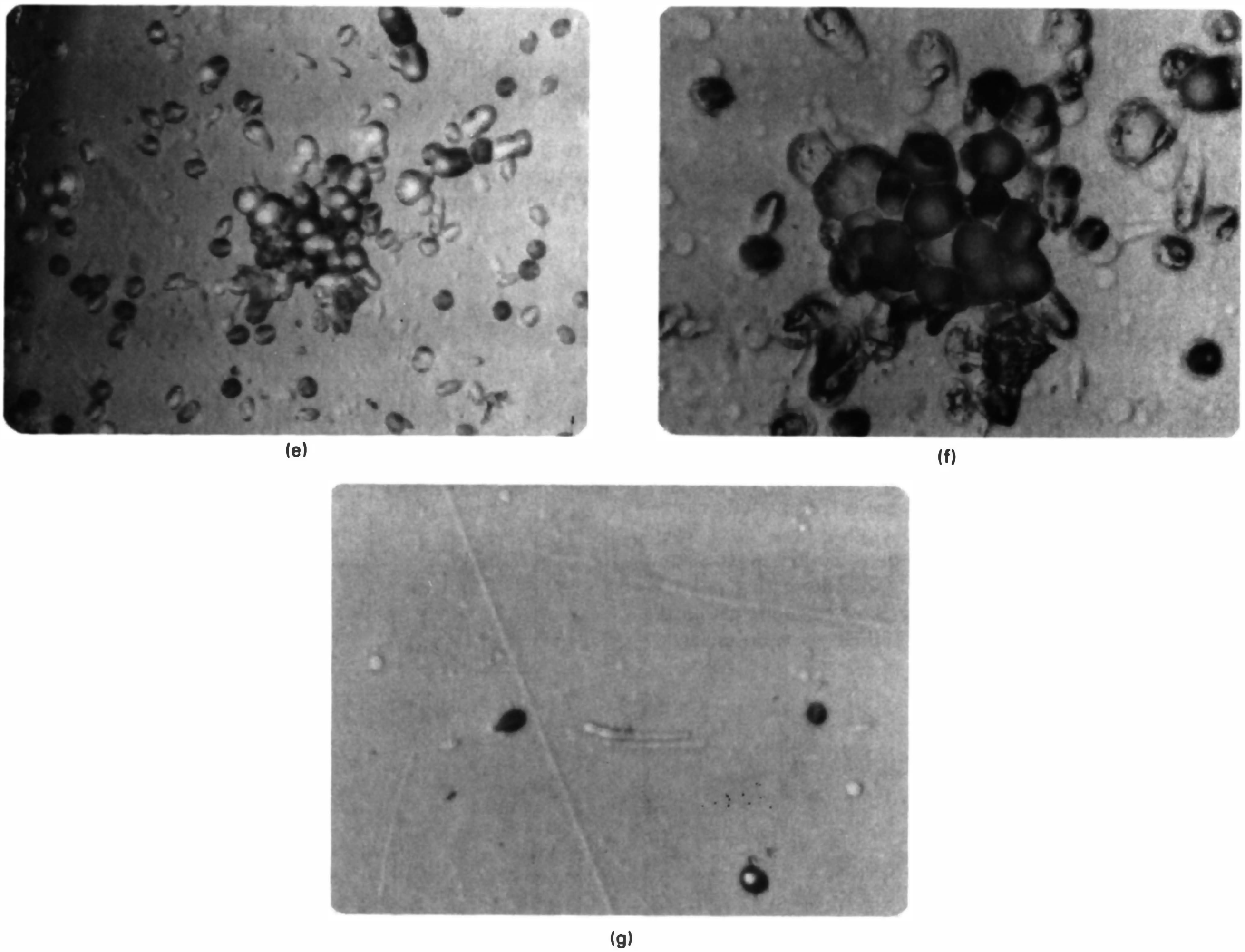

(a) (b) (c) (d)

Fig. 1a-1d. Series of CR-39 photographs taken by differential interference microscopy: (a) D_2 + Pd (700×), (b) alpha-particle source radiation (700×), (c) H_2 + Pd (700×), and (d) D_2 only (700×).


(e)

(f)

(g)

Fig. 1e–1g. Series of CR-39 photographs taken by differential interference microscopy: (e) D_2 + Pd (700×), (f) D_2 + Pd (1400×), and (g) D_2 + Pd cleaned with aqua regia (700×).

that the signals in CaF_2 TLD are not caused by energetic charged particles. The electromagnetic radiation might originate from electrons that are transiting from state to state when palladium is filled with hydrogen or deuterium. Figure 1d shows a CR-39 photo in a cell with D_2 only (no palladium). It proves that D_2 alone cannot produce a charged-particle signal. Figures 1e and 1f show a special signal, a bunch of tracks, with different multiplications (700× and 1400×, respectively). This special signal might be caused by a burst of charged particles.

Price et al.[5] have published their results of experiments using the CR-39. They found only two charged-particle tracks. This is quite different from our results. Having compared the experimental details, we found an important difference: Price et al. cleaned their samples with aqua regia. We repeated our experiment, cleaning the sample with aqua regia. To our great surprise, the tracks disappeared (see Fig. 1g). 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 (sputtering rate of ~200 Å/min), we found that the chlorine penetrated into the palladium to a few hundred angstroms (Fig. 3). When we used chlorine gas to intentionally contaminate the palladium surface, we found that the tracks in CR-39 again disappeared. (All these palladium foils were cut from the same sheet.)

SUMMARY

To summarize the results of our experiments, we have three points:

1. There is a kind of electromagnetic radiation that might be a precursor of the anomalous nuclear effect. Hence, we are designing the next step of the experiment to diagnose the electromagnetic radiation in real time. This electromagnetic radiation is different from the electromagnetic radiation caused by energetic charged fusion products, which cannot be taken as a precursor.

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

3. Surface contamination may suppress the anomalous nuclear effect. It may explain why many experiments have failed.

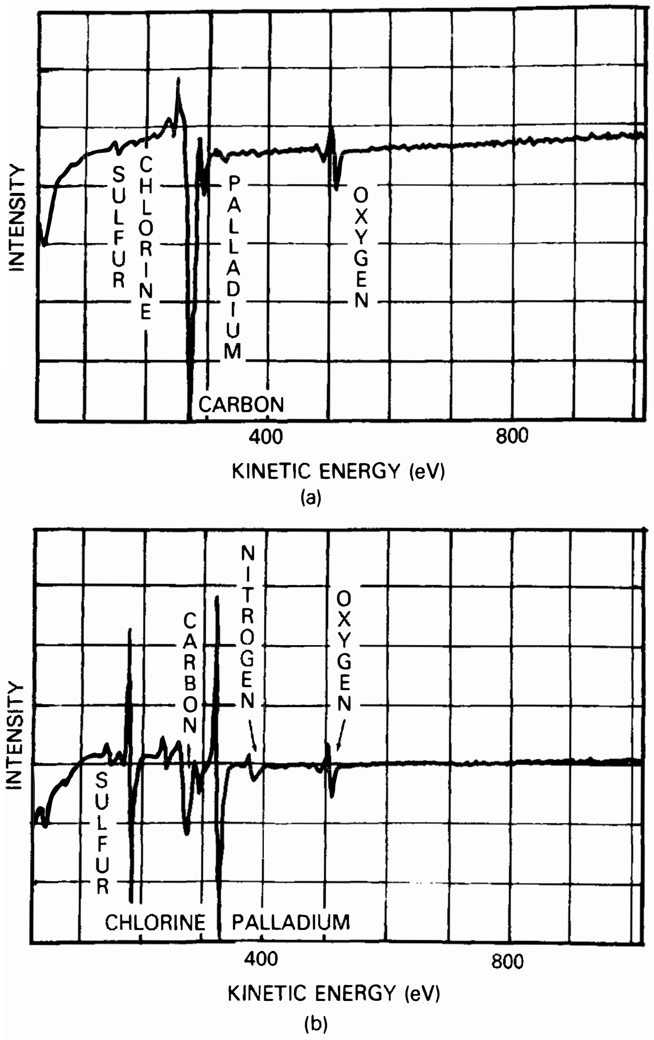


Fig. 2. Auger electron energy spectra (a) before and (b) after cleaning with aqua regia.

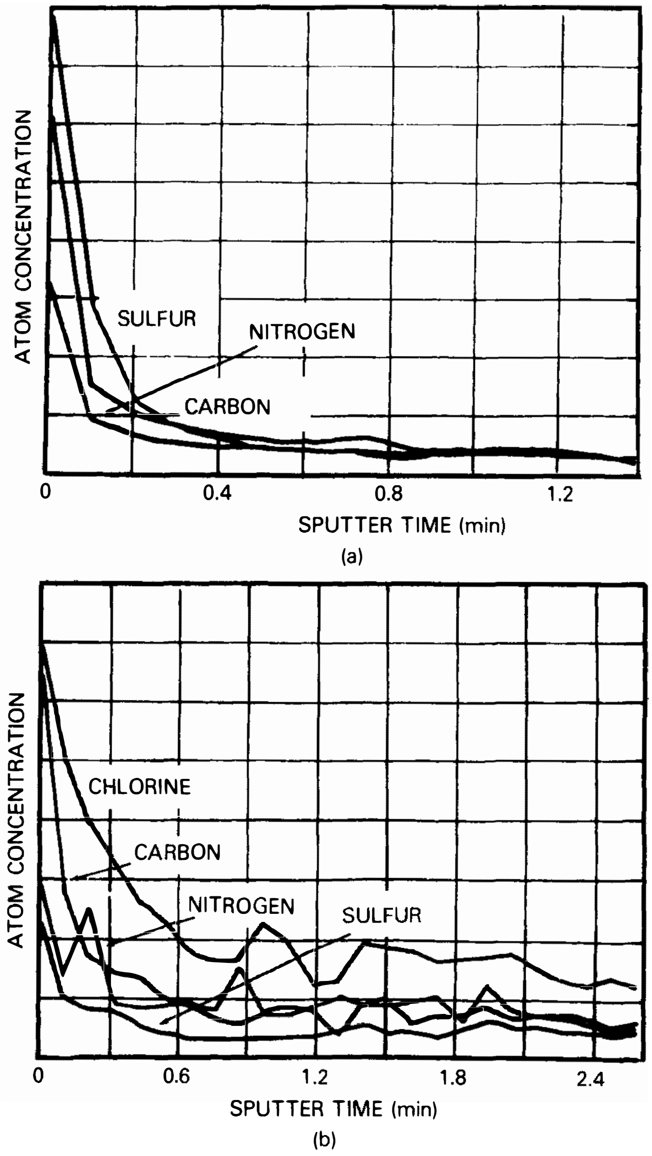


Fig. 3. Profiles of selected elements on the surface of palladium, sputtered by an argon ion beam, (a) before and (b) after cleaning with aqua regia.

These three points 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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