# COLD FUSION EXPERIMENTS WITH ORDINARY WATER AND THIN NICKEL FOIL

COLD FUSION
TECHNICAL NOTE

**KEYWORDS:** *cold fusion, ordinary water, nickel foil*

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*Cold fusion experiments with ordinary water and thin nickel foils are described. The temperature variation and the surface condition of the foils are examined. It has been proven that ordinary water can produce excess heat. Furthermore, reaction products are recorded on nuclear emulsions. Charged particles, electrons, protons, and deuterons, are observed. Micro-explosions caused by gravity decay of neutron nuclei are also recorded. Many traces indicating tiny black holes and white holes are clearly observed. The mechanisms of cold fusion with ordinary water are discussed in terms of the Nattoh model.*

## INTRODUCTION

Cold fusion experiments are currently carried out with heavy water because Fleischmann and Pons[1] and Jones et al.[2] stated that cold fusion occurred only with heavy water. However, the Nattoh model predicts that cold fusion can take place by the same mechanisms as the hydrogen-catalyzed fusion reaction with both heavy and ordinary water.[3] Extraordinary signals indicating the occurrence of cold fusion with ordinary water have been measured.[4] Recently, Mills and Kneizys[5] reported that excess heat could be produced as soon as electrolysis with ordinary water starts when a thin nickel foil is used for the cathode. They proposed a new chemical reaction, the shrunken molecule model. Noninski[6] and Bush[7] followed with further experiments with ordinary water. Bush proposed the mechanisms of nuclear transmutation from potassium to calcium. That explanation is now controversial.

The Nattoh model is based on only one hypothesis—that hydrogen clusters, consisting of more than two hydrogen atoms, that are trapped in tiny cavities, such as grain boundaries, defects, and interfaces in metal, compress themselves to induce hydrogen-catalyzed fusion reactions when the hydrogen pressure exceeds some critical value under electrical current flow. Previous cold fusion experiments with heavy water and palladium foil showed that three quad-neutrons and a higher multiple-neutron combined with each other and simultaneously decayed.[8] This observation clearly indicates that a self-compression effect of the hydrogen clusters does exist in the palladium metal.

When a metal with lower hydrogen permeability, such as nickel, is used for cold fusion experiments, hydrogen clusters might be formed on the surface of the metal to induce cold fusion by the overpotential of the electrolysis. This technical note describes cold fusion experiments with ordinary water and thin nickel foils. The temperature variation and the surface condition of the foils are examined. Also, reaction products are measured by nuclear emulsions. The cold fusion mechanisms for the system are also discussed.

## EXPERIMENTS

Cold fusion experiments with ordinary water were carried out by the electrolysis method. Thin foils of nickel metal were used as the cathode.

The experimental arrangement was analogous to that used in a previous experiment.[9] The hydrogen atoms were charged into a thin nickel foil (50- × 50-$mm^2$ cross section, 40-mm effective diameter, 0.10-mm thickness). A solution of ordinary water mixed with 0.50 mol/ℓ potassium carbonate was mainly used. The 50 ml of solution was contained in a glassy cell. A helical 0.5-mm-diam platinum wire was used as the anode. An anode of three parallel 0.5-mm-diam platinum pins was also tested. The current was changed stepwise from ~0.3 to 3.0 A and the corresponding bias from ~3.7 to 7.6 V. Temperature variations in the nickel foil, solution, and atmosphere were measured by thermocouples. The reference temperature was measured by locating a resistance heater in the cell. After the charging, all the foils were examined by an optical microscope. To directly measure the reaction products, 30 nuclear emulsion plates (50- × 50-mm, 100-μm-thick MA-7B provided by Fuji Film) were located under the nickel foil. As a reference, three nuclear emulsion plates were located ~5 m away from the electrolyzing cell in the same room. After they were developed, the nuclear emulsions were examined by an optical microscope (×50).

## RESULTS

### Temperature

Figure 1 shows the temperature deviations of the potassium carbonate solution and the nickel foil for three experiments.

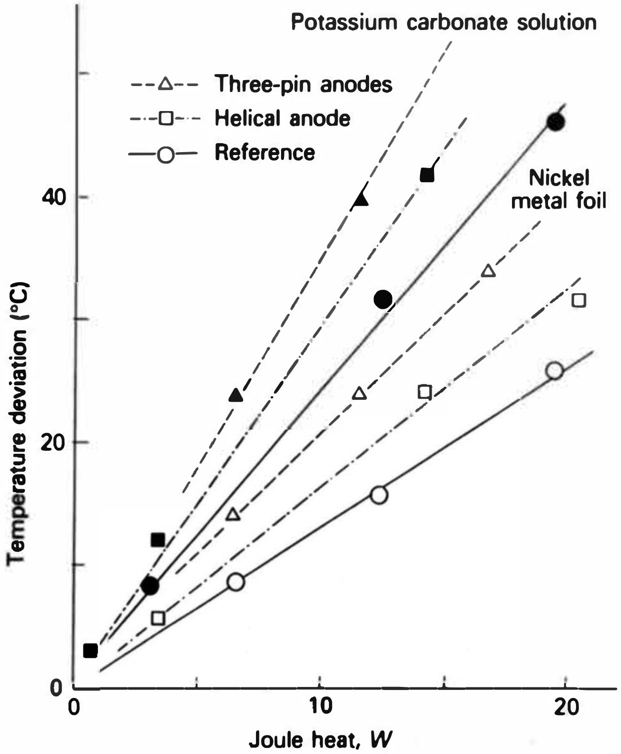



Fig. 1. Temperature variation for nickel foil and ordinary water.

Since the nickel foil was conducted with the atmosphere, the two temperatures were different. The temperatures were subtracted from room temperature, which remained <2°C for 7 h. The Joule heat was calculated from the equation $W = I(V - 1.48)$, where 1.48 V is consumed for decomposing water. By comparing the temperature with the reference, the excess heat was obtained, ~40%. In Fig. 1, the temperature increase is also shown for the three-pin platinum anode. The anode consisted of three parallel 0.5-mm-diam × 15-mm-long pins that were separated by ~9 mm from each other. The excess heat with the pin anode is higher than that with the helical wire anode.

### Optical Microscope Observations

The surface condition of the foils was examined with an optical microscope after the charging. For the potassium carbonate solution, the front surface of the foils was covered by deposited materials, but the back surfaces were hardly changed. Many circular spots with various colors were observed on the deposited layers of the front surface, as shown in Fig. 2. These circular spots were distributed over the front surface and suggested a local and rapid temperature increase. To prove that the circular spots were caused by local discharging, a platinum pin anode was tested; however, there were no similar spots. It is reasonable to consider that these spots might have been produced by the local burning of cold fusion.

For reference, a 0.55 mol/ℓ sodium chloride solution was also tested. Thin hydrided layers were partly formed on the front surface of the nickel. Many colorful rings were recorded on the back surface of the nickel foil that can be classified into the two groups shown in Figs. 3a and 3b. The rings shown in Fig. 3a might be micro-explosions caused by the gravity decay of the neutron nucleus, while the ring shown in Fig. 3b might be an erosion pit. This is discussed later.

### Observation of Nuclear Emulsions

Several kinds of traces were recorded on the nuclear emulsions. First, three kinds of charged particles, protons, deuterons, and electrons, were observed. Protons and electrons were also observed on the reference emulsions. However, the number densities of these particles were much higher for the irradiated emulsions than that for the background, and they decreased as the thickness of the nuclear emulsions increased. Thus, it was obvious that the particles were produced during cold fusion and penetrated through the nickel foil. Figure 4 shows traces of deuterons. Deuterons were mainly recorded on the front surface of the first nuclear emulsion, but a few traces were observed at a greater depth. Figure 4b shows a trace of a scattered deuteron. The emission of these

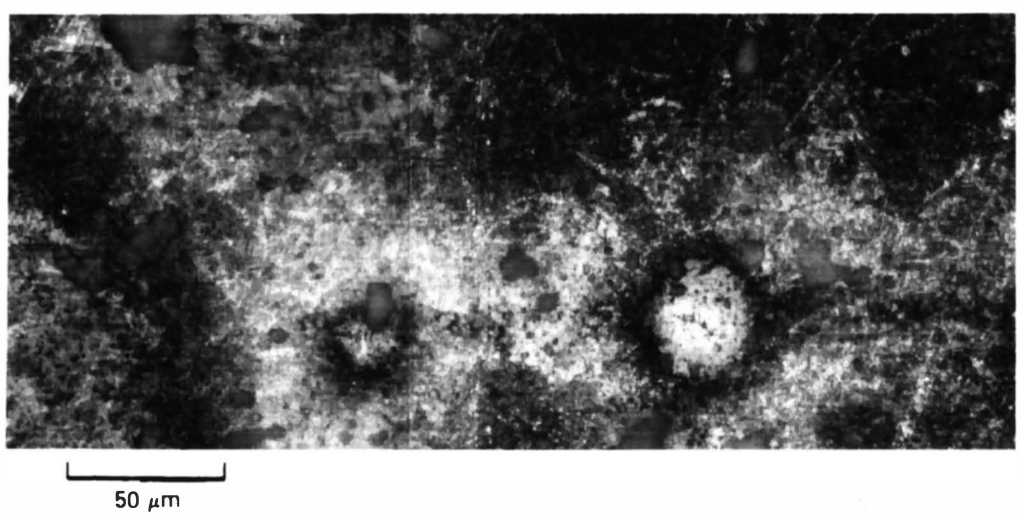



Fig. 2. Circular spots on the front surface of nickel foil with potassium carbonate solution.

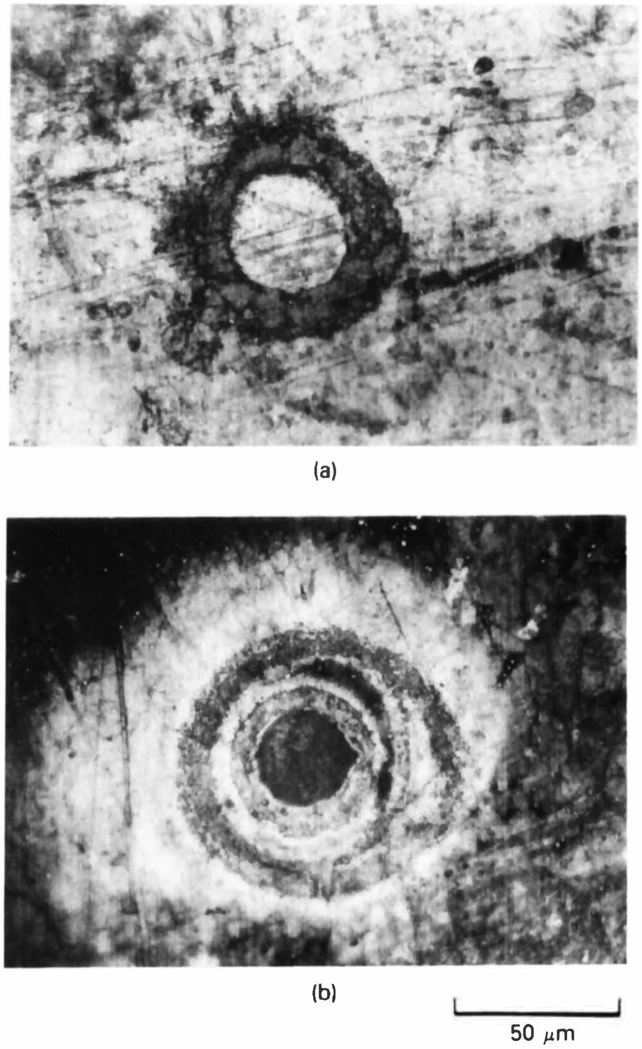



Fig. 3. Rings on the back surface of nickel foil with a sodium chloride solution: (a) micro-explosion ring and (b) erosion ring.

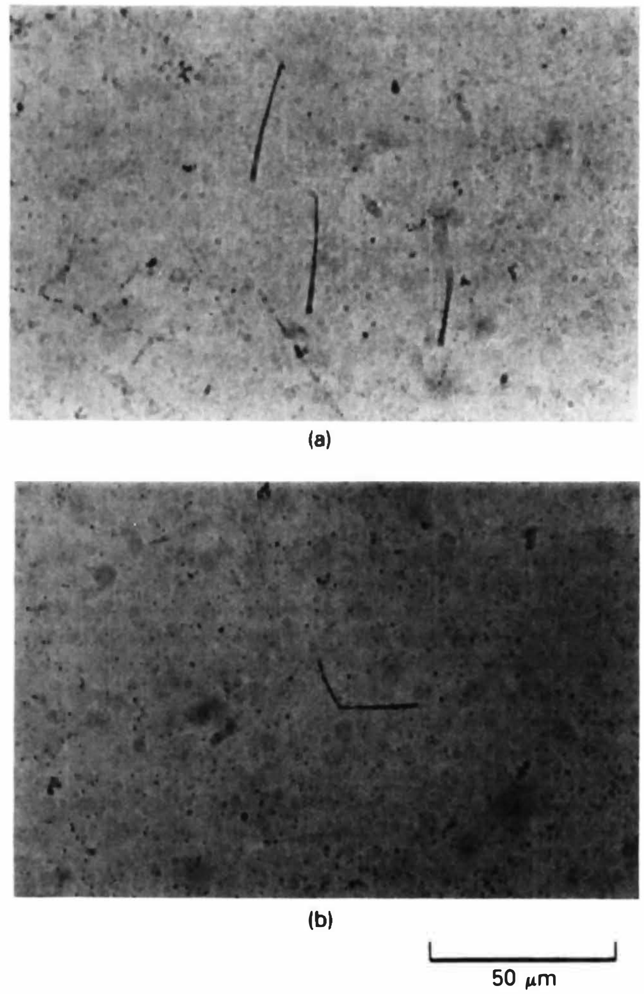
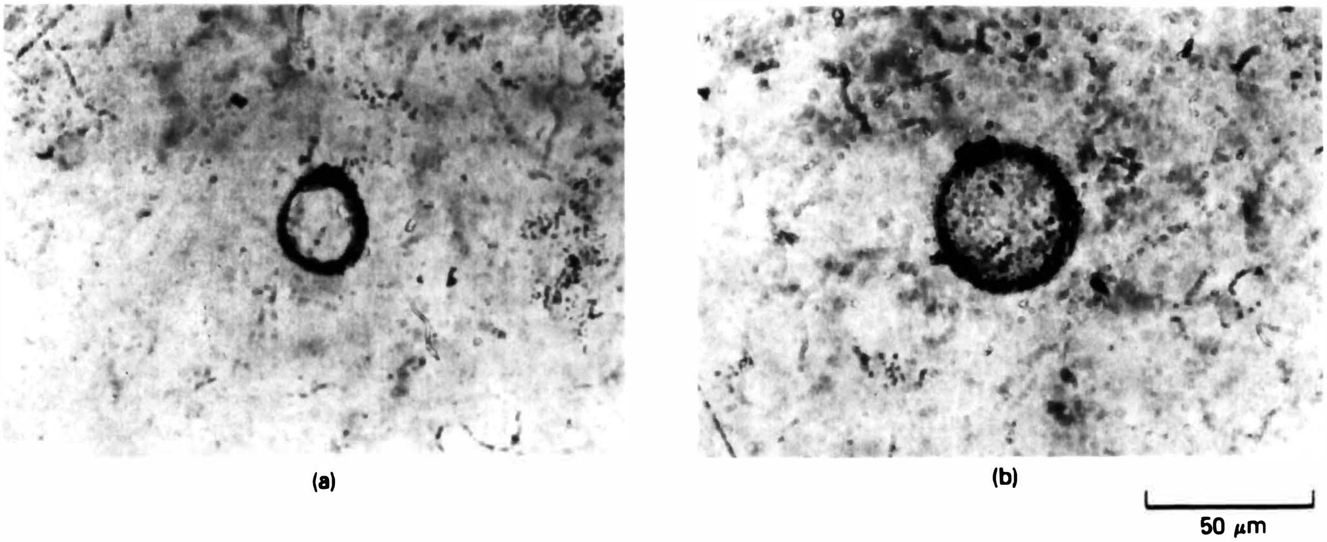



Fig. 4. (a) Deuteron and (b) scattered deuteron.

particles was predicted by the Nattoh model. [See Eqs. (2), (3), (4), and (5) in the next section]. On the other hand, electrons can be released by the breakup of itons.[10] Alternatively, a micro-explosion of a neutron nucleus can emit electrons. In Fig. 4a of Ref. 8, the emission of atomic electrons of the nuclear emulsion was clearly observed on the front surface of the shock wave caused by a micro-explosion.

Second, micro-explosions of neutron nuclei were observed. The single and di-neutrons that are produced by Eqs. (1), (4), and (5) in the next section are "fermented" and collapse by self-gravity like quad-neutrons.[11] Figures 5a and 5b show micro-explosion rings caused by gravity decay of single or di-neutrons. Not all the mass of the collapsed neutrons is necessarily transferred to energy; some is transferred to the unknown gravity decay products. The rings shown in Fig. 5c are associated with widely distributed materials that might have been produced by the gravity decays of a combined single and di-neutron that can be caused by simultaneous fusion reactions.[8] Furthermore, Fig. 5d shows another product, strings, that might be linked to the superstrings that spout from a white hole. Larger micro-explosions have been observed, as shown in Fig. 6. They may have been caused by the gravity decays of multiple-neutrons that can be produced by many-body fusion reactions.[12] Figures 6a and 6b show traces caused by quad-neutrons frequently observed for heavy water[8] that were obtained by transmitted and reflected light, respectively. In Fig. 6b, colorful Newton rings can be observed. Figure 6c shows the gravity decay of multiple-neutrons. These micro-explosions have high energy so that they can be recorded not only on the nuclear emulsions but also on the metal foil. The circular spots on the front surface of the nickel foil shown in Fig. 2 and the ring on the back surface shown in Fig. 3a are caused by micro-explosions of the neutron nuclei.

Third, many traces indicating tiny black and white holes were observed on the front surface of the first emulsion, as shown in Fig. 7. A tiny black hole was expected to be generated from the collapse of multiple-neutrons that might be produced from massive nuclei such as the host metal and the electrolyte. The evaporation of tiny black holes has been successfully observed in heavy water.[8] Figure 7a shows Hawking radiation at the evaporation of a tiny black hole, which is similar to the traces observed in the previous experiment with heavy water.[8] However, the traces shown in Figs. 7b through 7o were first observed in this experiment. The traces




Figs. 5a and 5b. Gravity decay products: micro-explosion of single or di-neutrons.

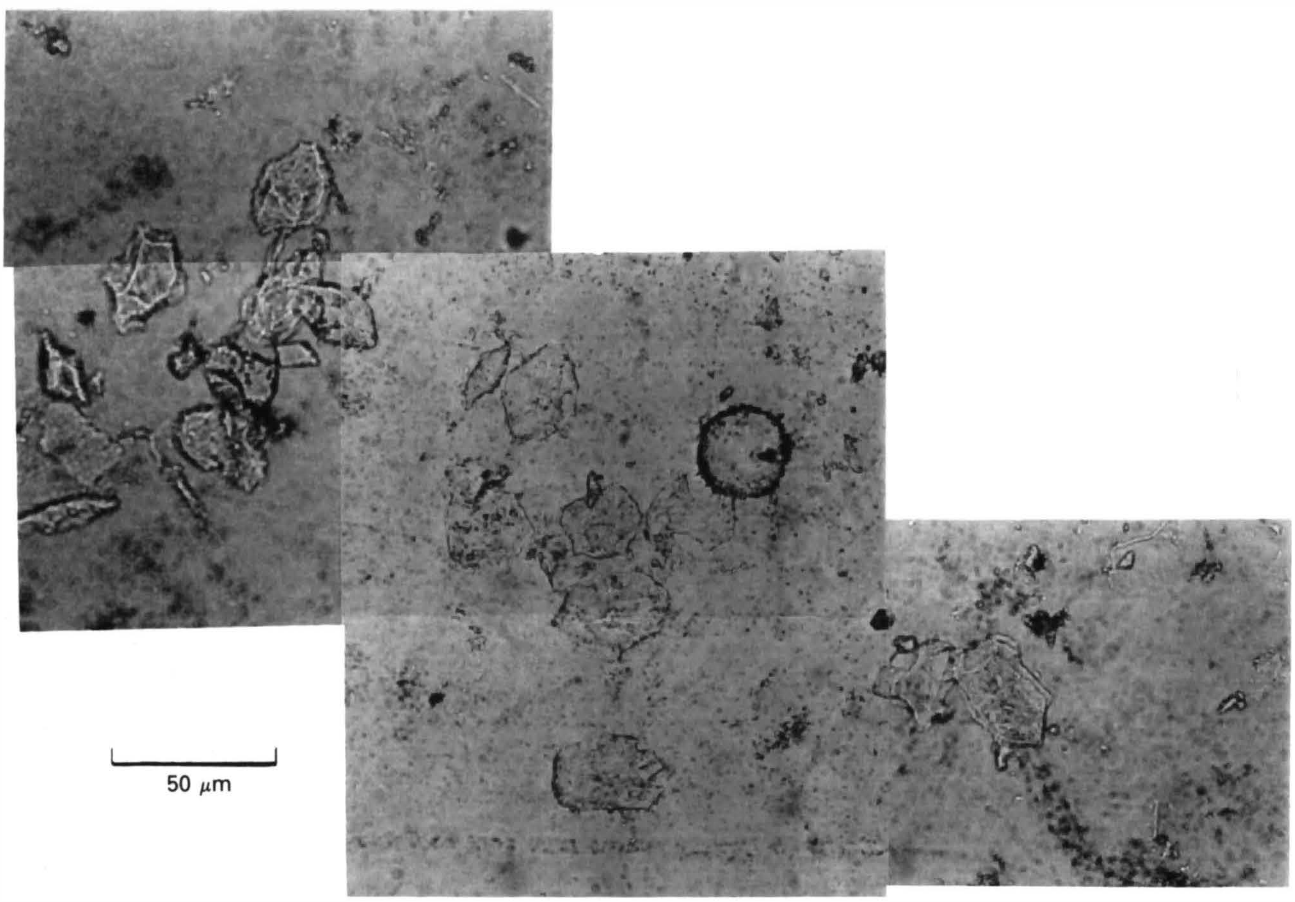



Fig. 5c. Gravity decay products: micro-explosion associated with gravity decay products.

in Figs. 7b through 7f, vertical views, show a typical feature of the black hole, the conic shape. Materials seem to spout energetically from the bottom of the cone. The traces shown in Figs. 7g through 7l have little shape variation, and the traces shown in Figs. 7m, 7n, and 7o are bottom views of the black holes.

It is reasonable to consider that the traces shown in Figs. 7b through 7o were not caused by materials spouting

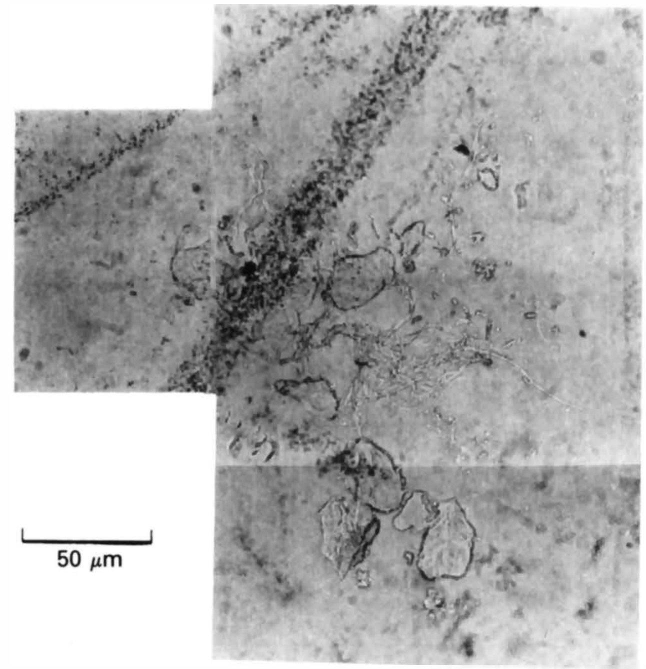



Fig. 5d. Gravity decay products: gravity decay products with strings.

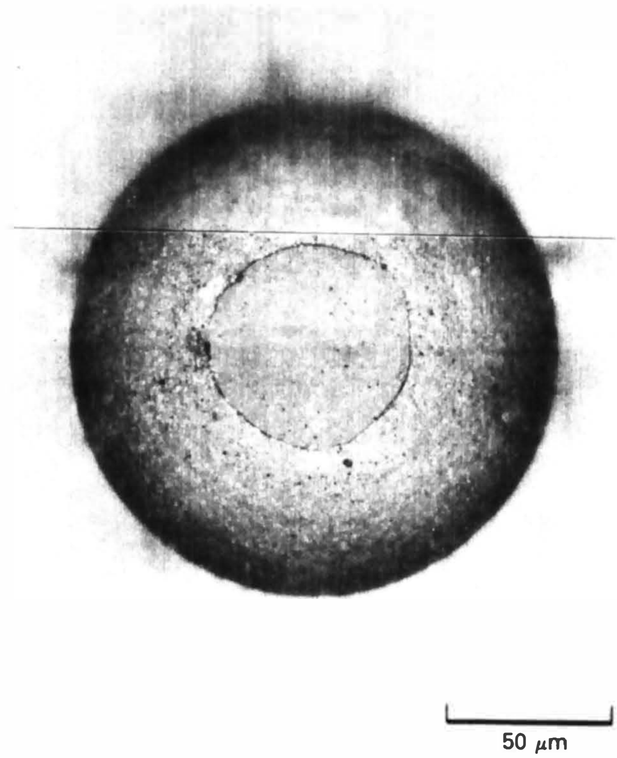



Fig. 6b. Micro-explosions by multiple-neutrons: micro-explosion of quad-neutron (with reflected light).

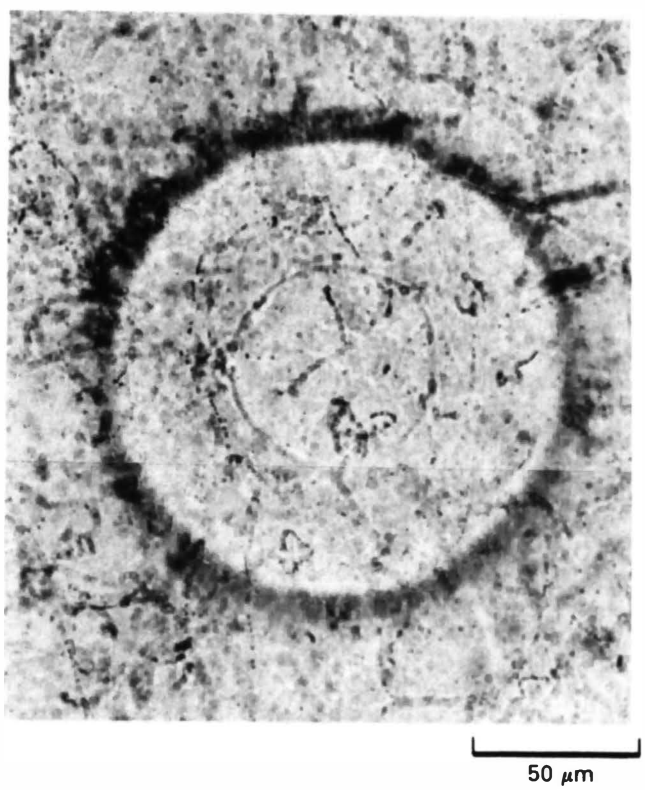



Fig. 6a. Micro-explosions by multiple-neutrons: micro-explosion of quad-neutron (with transmitted light).

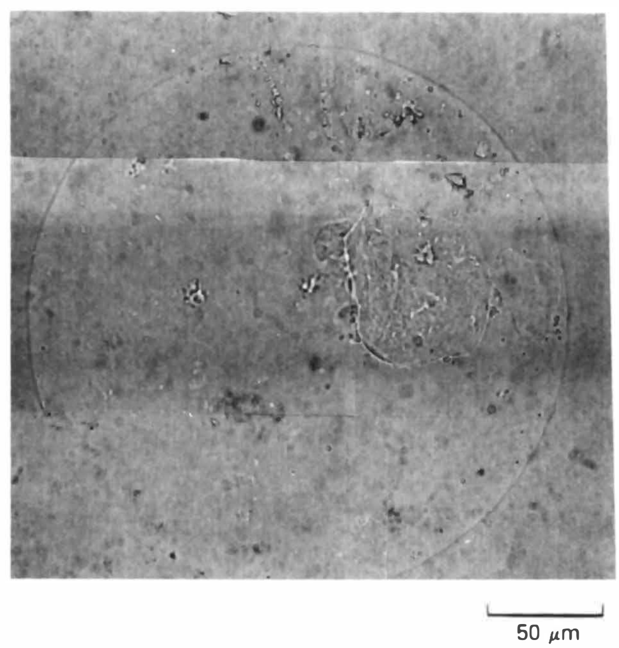



Fig. 6c. Micro-explosions by multiple-neutrons: micro-explosion of multiple-neutron.

from the entrance of the black hole but rather from the exit of the black hole, i.e., the white hole. The situation can clearly be seen in Fig. 7i, in which the evaporation of the black hole and the exhaust from the white hole were simultaneously recorded on the nuclear emulsion. Thus, the tip of the cone shown in Figs. 7b through 7l should be the material-absorbing point. The absorbed materials, after they are broken down, should spout from the bottom of the cone.

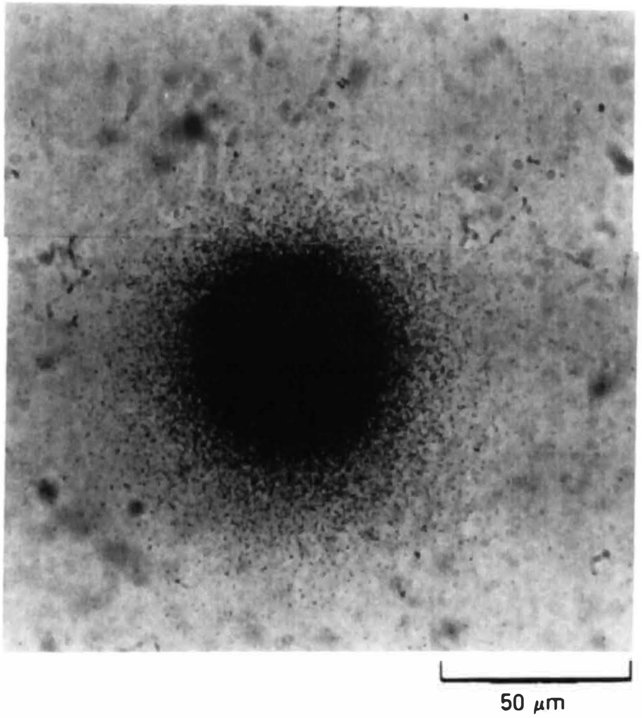



Fig. 7a. Tiny black and white holes: top view of black hole.

Fourth, a star might be produced by a collision between multiple-neutrons and the nuclei of the nuclear emulsion. For heavy water, four stars were successfully observed on nuclear emulsions.[13] For ordinary water, it can be expected that single or di-neutrons or multiple-neutrons can generate stars on the nuclear emulsions. Figure 8 shows a star that was recorded on the front surface of the first emulsion.

Lastly, strange traces were observed on the front surface of the first emulsion, shown in Fig. 9, that were never observed in the previous experiments with palladium foil.[8,9,13] When a metal foil with lower hydrogen permeability such as nickel is used, the hydrogen cluster is compressed on the metal surface to form an extremely small assembly by the self-compression effect.[14] A single assembly could be of the order of $<10^{-8}$ cm even if millions of hydrogen atoms were compressed because the itonic interaction range might be of the order of $10^{-11}$ cm (Ref. 14). The assembly can easily penetrate through the metal barrier. After penetration, the assembly would rapidly expand to scatter many hydrogen atoms because the itonic cover fades somewhat. The traces shown in Figs. 9a, 9b, and 9c might be caused by those scattered itonic hydrogen atoms. When the hydrogen cluster is so compressed as to be condensed, some structure could be constructed, as water vapor is condensed into frost. Traces like frost can be seen inside an envelope in Figs. 9a and 9b. The "hydrogen frost" could become droplets as it expands; these can be seen among the widely scattered itonic hydrogen atoms, as shown in Fig. 9c.

## EXPLANATIONS BY THE NATTOH MODEL

In this section, the mechanisms for cold fusion with ordinary water and thin metal foil are explained by the Nattoh model. First, the fundamental reactions of cold fusion with ordinary water should be considered. The Nattoh model is based on the hydrogen-catalyzed fusion reaction, which is caused by the self-compression effect of the hydrogen cluster.[14] Thus, cold fusion can take place in ordinary water as well as in heavy water. Since the hydrogen atoms and electrons involved in the reaction are plural, many variations can occur in the hydrogen-catalyzed fusion reactions. The main reactions for ordinary water can be written as follows:

*for the emission of a single iton $i_1$:*

$$2\mathrm{H} + e + \mathrm{H} \rightarrow {}^2\mathrm{He} + i_1 + {}^1n \quad (1)$$

$$\hookrightarrow \mathrm{D} + e^+ + \nu \quad (2)$$

$$\hookrightarrow \mathrm{D} + i_1 + p \ , \quad (3)$$

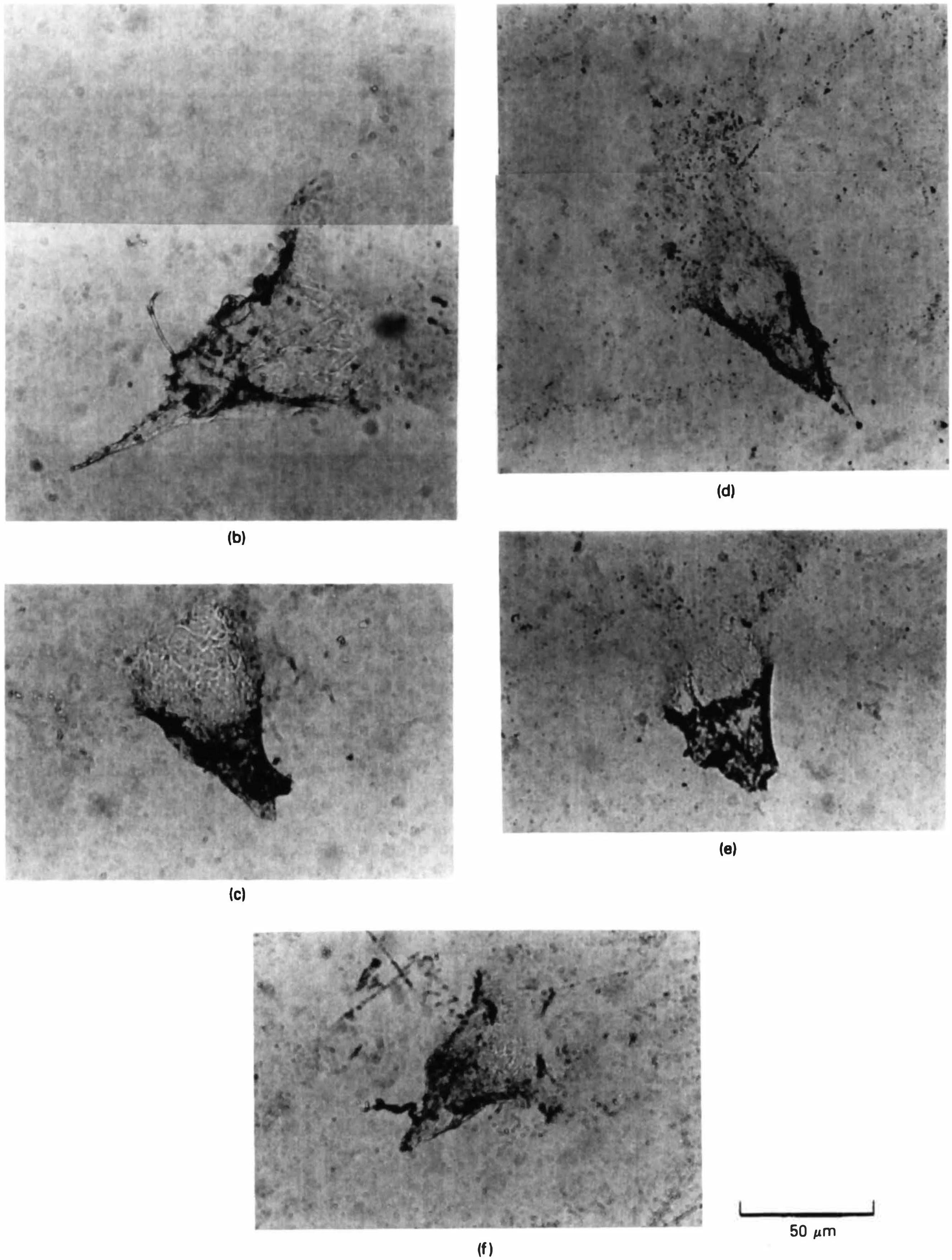
*for the emission of a double iton $i_2$:*

$$2\mathrm{H} + 2e + \mathrm{H} \rightarrow {}^2n + i_2 + p \quad (4)$$

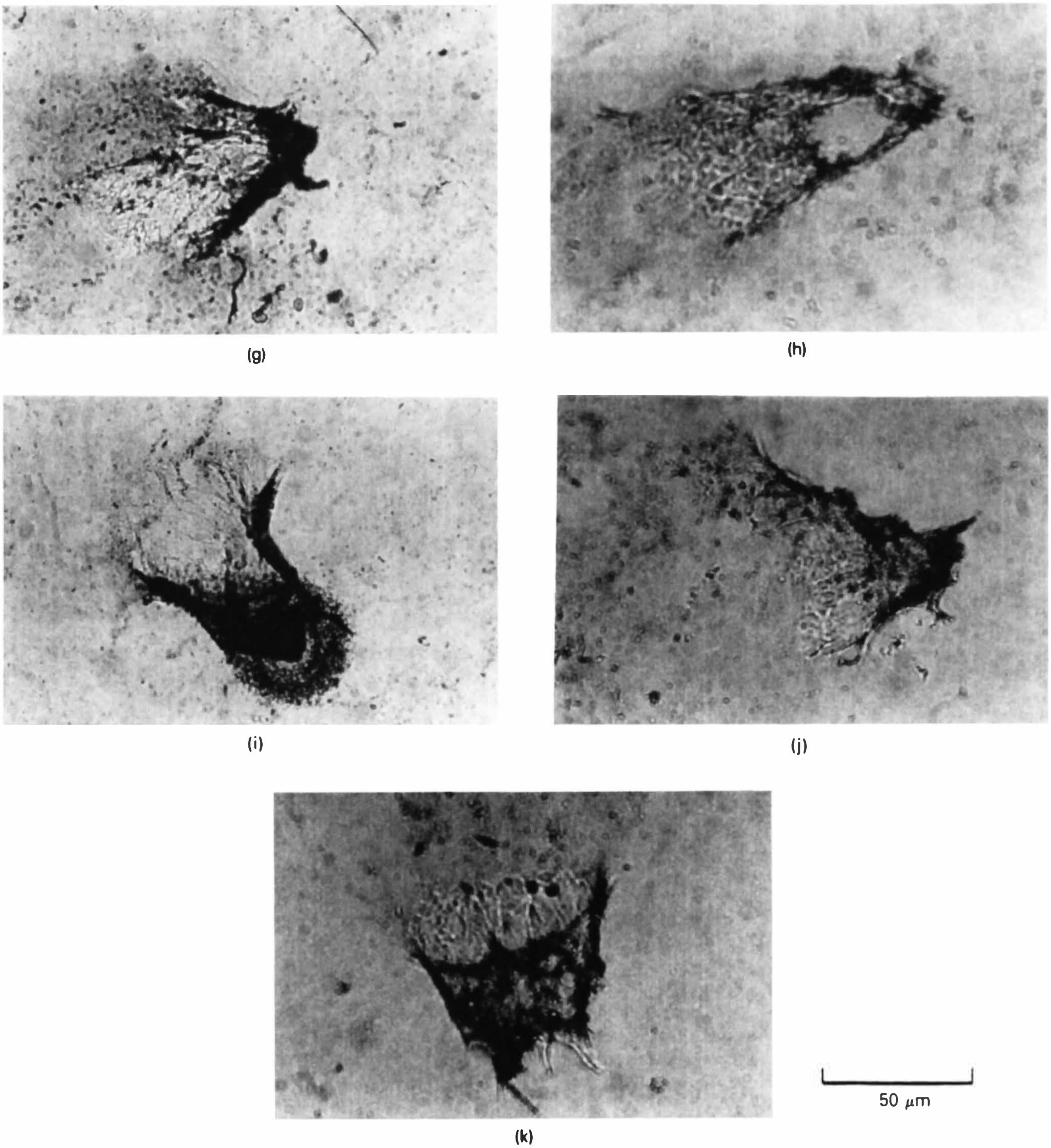
$$\hookrightarrow \mathrm{D} + i_2 + {}^1n \ , \quad (5)$$

where the strange products ${}^1n$ and ${}^2n$ are fermented single and di-neutrons, respectively. The itons are found to cover up the fusion products in the previous experiment.[9] The prediction of ${}^2$He might be contradicted by Pauli's selection rule, but here the itonic cover might allow it to exist for a moment. Furthermore, the fermented neutrons shrink and finally undergo gravity decay. Gravity decays of the fermented neutrons have been observed in the second traces in the preceding sections. When the nuclei of the metal or solution are surrounded by a hydrogen cluster, multiple-neutrons might be produced[12] that can be collapsed into a tiny black hole. The tiny black hole instantaneously evaporates with the Hawking radiation or changes into a white hole and contributes to heat production; these traces have also been observed on the nuclear emulsions of the third traces.

Second, let us consider regions in which these reactions can be maintained. For a metal with lower hydrogen permeability, such as nickel, thin layers of hydrogen clusters a few atoms thick are formed on the surface, where the hydrogen concentration is high enough to induce self-compression of the hydrogen clusters. For a metal rod, high-energy hydrogens produced in Eqs. (2), (3), (4), and (5) can cause additional hydrogen-catalyzed fusion reactions so that the chain reactions of the hydrogen atoms can be maintained under certain conditions.[15] For a thin metal foil, on the other hand, the chain reactions might be somewhat limited by the leakage of the high-energy hydrogen atoms from the foil. The range of the hydrogen atoms is hundreds of microns in the metal hydride, so that the thickness of the foil is an important factor. Fortunately, the hydrogen chain reactions have a very high multiplicity, unlike the neutron chain reactions in a fission reactor, so that they could well be maintained two-dimensionally on the surface. Alternatively, cold fusion might be maintained even without the chain reactions. It was found that nickel atoms can be picked up by the hydrogen atoms, and this leaves pits on the surface.[16] Hydrogen clusters can probably be formed in the pits and surround the heavy nuclei of the nickel metal and electrolyte. Here, the hydrogen-catalyzed fusion reactions can be maintained by the supply of hydrogen atoms externally from the electrolyte solution. This is why cold fusion is ignited as soon as the charging starts, unlike in palladium.




Figs. 7b through 7f. Tiny black and white holes: vertical view, conic shape.

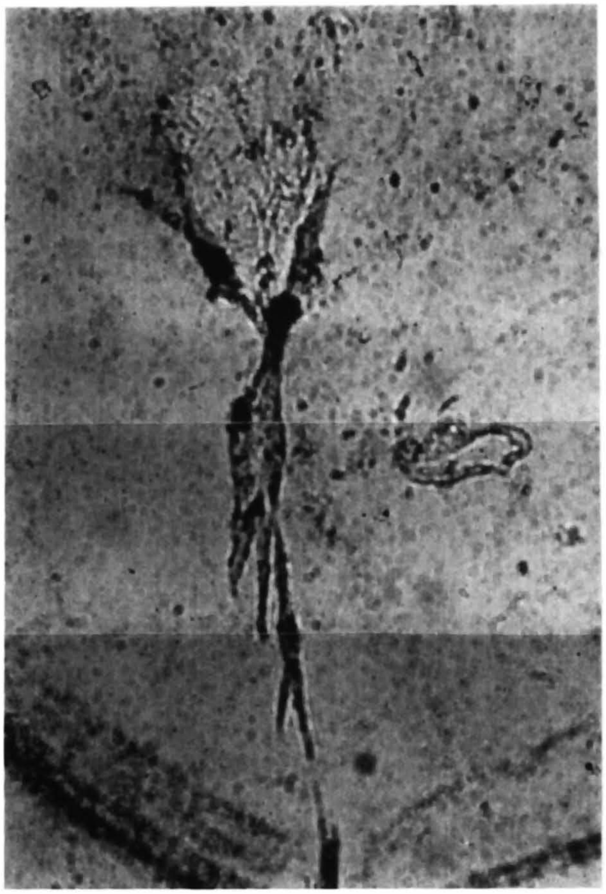



Figs. 7g through 7k. Tiny black and white holes: vertical view, variational shape.

## DISCUSSION

Cold fusion experiments with ordinary water have been described. It has been proven that cold fusion really does occur with ordinary water to produce excess heat, as previously predicted.[4] Measurements with nuclear emulsions have verified that charged particles, such as electrons, protons, and deuterons, and neutron nuclei are produced during cold fusion. The fundamental reaction during cold fusion is neither the conventional fusion that dominates in high-temperature plasma nor the new chemical reaction proposed by Mills et al.[5] It is a new fusion reaction, i.e., the hydrogen-catalyzed fusion reaction that was proposed by the Nattoh model.

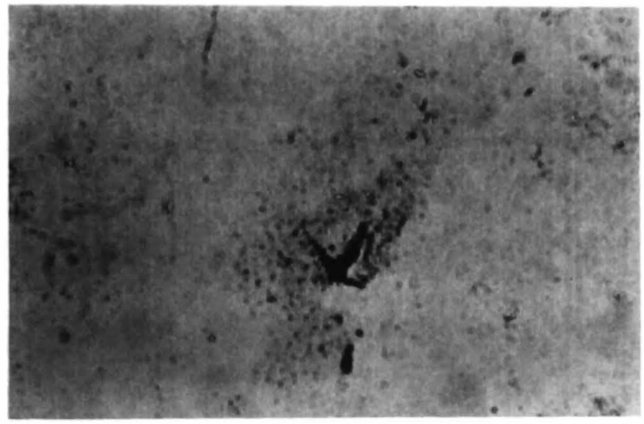
The difference between nickel and palladium foils is remarkable. For the thin palladium foil, hydrogen atoms can easily penetrate through the foil so that cold fusion reactions



(l)

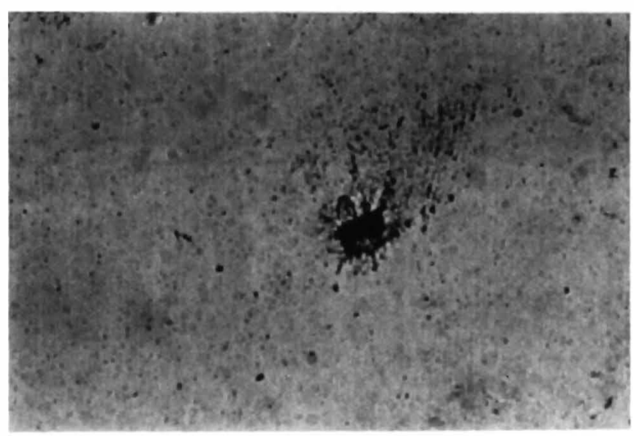
50 μm

Fig. 7l. Tiny black and white holes: vertical view, variational shape.



(m)

(n)



(o)

50 μm

Figs. 7m, 7n, and 7o. Tiny black and white holes: bottom view.

take place all over the foil including near the back surface. However, for nickel, with low hydrogen permeability, the hydrogen atoms are trapped on the front surface of the foil, so that cold fusion predominantly takes place on the surface. Here the reaction products should penetrate through the foil to be recorded on the nuclear emulsions. In particular, the itonic nuclei that are heavily charged might be stopped in the foil. This is why no traces of the breakup of itonic beads and micro-explosions of the itonic nuclei were observed on the nickel foil, unlike palladium. On the other hand, hydrogen frosts were found for the first time during this experiment. They were not observed in the previous experiment with palladium.[9] This inconsistency might be caused by thin protection sheets that were usually located on each nuclear emulsion. In this experiment, no sheet was placed on the front surface of the first nuclear emulsion so that the particles could directly be detected.

Gravity decays of neutron nuclei and the production of stars were observed as associated reactions during cold fusion. It is especially remarkable that many tiny white holes were discovered. The tiny white hole has spouting and conic zones. The nucleons that are absorbed in the black hole are violently destroyed so that unknown tiny materials such as superstrings might spout from the white hole. White strings can be seen in the spouting region of the white hole, for example, in Fig. 7c, and they might be something linked to superstrings. On the other hand, the conic zone of the white hole seems highly reactive, so that it is recorded on the surface of the emulsion. The tiny black hole might have a reactive filmlike zone around the horizontal zone of the event.

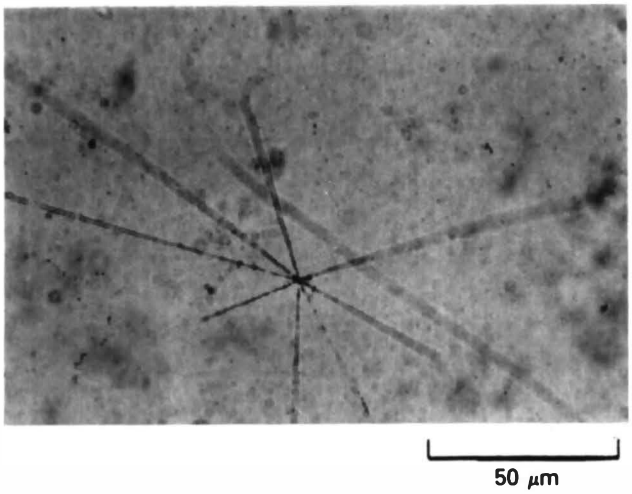
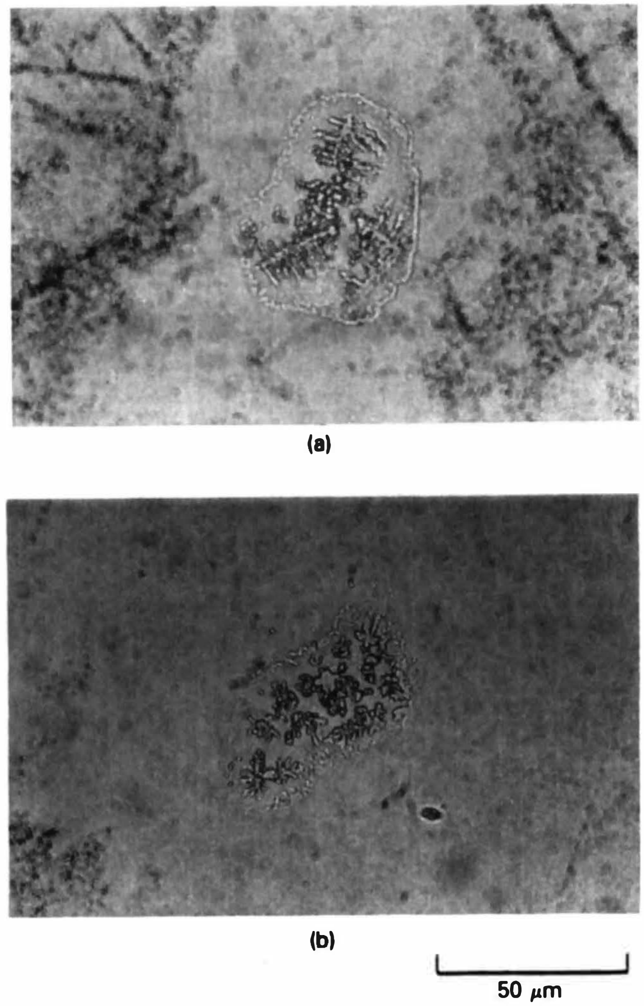



Fig. 8. Star (long traces are partly omitted).




Figs. 9a and 9b. Scattered itonic hydrogen atoms: frost.

It seems difficult to accept that gravity decay takes place on the neutron nucleus because the gravitational force is 40 orders of magnitude less than the comparably weak electromagnetic force. It should not be understood that the gravitational force predominantly works itself to collapse as soon as the neutron nucleus is produced. On the birth of the neutron nucleus, the itonic mesh covers it up so that it would not scatter neutrons, and it compresses the nucleus to destroy its nuclear structure. As the shrinking of the nucleus progresses, the gravitational force effectively begins to work on it. Finally, gravity decay takes place. As micro-explosions of neutron nuclei without an iton were found,[11] the compression process can somewhat be maintained initially after the breakup of the itonic mesh. Recently, traces of the white holes have been reproduced in an experiment involving alternating current charging with titanium bolts.[17] Tiny sparks have been observed, and the traces resulting from the sparks are very similar to those found in the white holes observed in this experiment.

## REFERENCES


1. M. FLEISCHMANN and S. PONS, "Electrochemically Induced Nuclear Fusion of Deuterium," *J. Electroanal. Chem.*, **261**, 301 (1989).

2. S. E. JONES et al., "Observation of Cold Nuclear Fusion in Condensed Matter," *Nature*, **388**, 737 (1989).

3. T. MATSUMOTO, "'NATTOH' Model for Cold Fusion," *Fusion Technol.*, **16**, 532 (1989).

4. T. MATSUMOTO, "Cold Fusion Observed with Ordinary Water," *Fusion Technol.*, **17**, 490 (1990).

5. R. L. MILLS and S. P. KNEIZYS, "Excess Heat Production by the Electrolysis of an Aqueous Potassium Carbonate Electrolyte and the Implications for Cold Fusion," *Fusion Technol.*, **20**, 65 (1991).

6. V. C. NONINSKI, "Excess Heat During the Electrolysis of a Light Water Solution of $K_2CO_3$ with a Nickel Cathode," *Fusion Technol.*, **21**, 163 (1992).

7. R. BUSH, "A Light Water Excess Heat Reaction Suggests That 'Cold Fusion' May Be 'Alkali-Hydrogen Fusion,'" *Fusion Technol.*, **22**, 301 (1992).

8. T. MATSUMOTO, "Searching for Tiny Black Holes During Cold Fusion," *Fusion Technol.*, **22**, 281 (1992).

9. T. MATSUMOTO, "Observation of Meshlike Traces on Nuclear Emulsions During Cold Fusion," *Fusion Technol.*, **23**, 103 (1993).

10. T. MATSUMOTO, "Observation of New Particles Emitted on Cold Fusion," *Fusion Technol.*, **18**, 356 (1990).

11. T. MATSUMOTO, "Observation of Quad-Neutrons and Gravity Decay During Cold Fusion," *Fusion Technol.*, **19**, 2125 (1991).

12. T. MATSUMOTO, "Observation of Gravity Decays of Multiple-Neutron Nuclei During Cold Fusion," *Fusion Technol.*, **22**, 164 (1992).

13. T. MATSUMOTO, "Observation of Stars Produced During Cold Fusion," *Fusion Technol.*, **22**, 518 (1992).

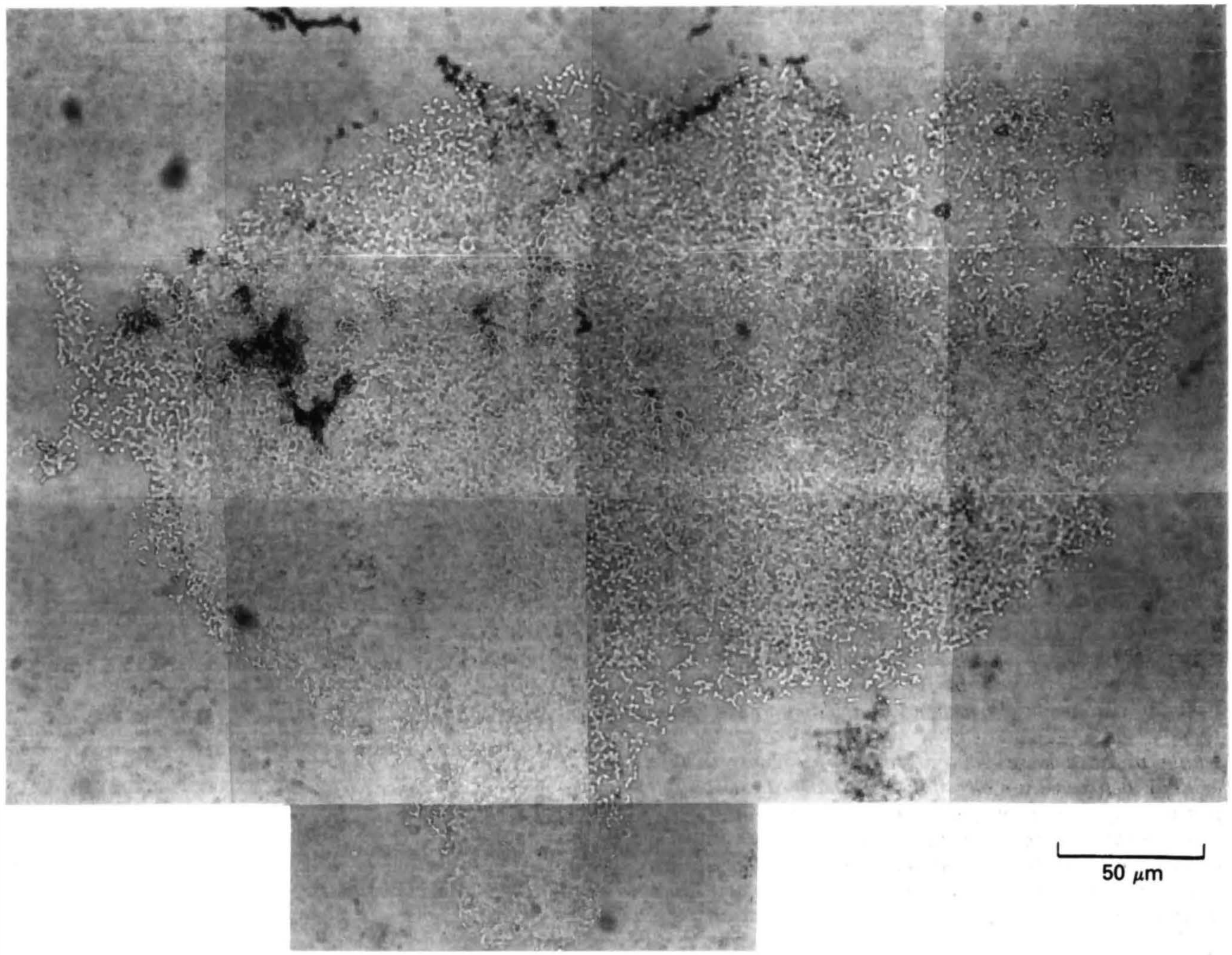



Fig. 9c. Scattered itonic hydrogen atoms: droplets.

14. T. MATSUMOTO, "Prediction of New Particle Emission on Cold Fusion," *Fusion Technol.*, **18**, 647 (1990).

15. T. MATSUMOTO, "Progresses of the Nattoh Model and New Particles Emitted During Cold Fusion," *Proc. Int. Conf. Anomalous Nuclear Effects in Deuterium/Solid Systems*, Provo, Utah (1990).

16. L. P. NIELSEN et al., "Nucleation and Growth of a H-Induced Reconstruction of Ni(110)," *Phy. Rev. B*, **44**, *23*, 13156 (1991).

17. I. YUKIMURA and T. MATSUMOTO, "Observation of Luminescences, Sparks, and Radiations During ac Electrolysis Cold Fusion," submitted to *Fusion Technol.*

Note: This technical note is a combined and condensed version of two earlier manuscripts submitted by the author on April 10 and 30, 1992.