Nuclear reactions produced in an operating electrolysis cell

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Abstract

We report the results of experiments in which CR-39 plastic particle-detection chips were exposed in various environments within and surrounding operating electrolysis cells. Because CR-39 detectors record only particles with energies in excess of about 0.2 MeV the detected particles must have arisen in nuclear reactions. Evidence for such reactions was found in deuterium gas behind a palladium cathode that served as part of the cell enclosure, in air behind a similarly disposed nickel cathode, in air beyond the glass wall of the electrolysis cell, and in oxygen gas above the anode when anode and cathode were placed in separate arms of a U-tube cell. These results, augmented by earlier work indicating nuclear reactions within the electrolyte and in the hydrogen-oxygen gas over the electrolyte, cannot be understood in terms of conventional nuclear theory.

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I. INTRODUCTION

Energetic charged particles can be detected by the damage tracks they generate when penetrating various solid materials[1]. When the surface is attacked by a suitable etchant damaged material is removed more rapidly than undamaged material and etch pits are formed where tracks intersect the surface. In our studies we employ detector chips that are commercially available for recording alpha particle tracks from radon decay. After appropriate calibration, analysis of etch pit sizes, shapes, and cone angles can indicate the types and energies of the responsible particles, which can be protons, alpha particles, or more massive ions.

In prior work tracks of particles having energies of a few MeV have been observed in CR-39 detector chips immersed in various electrolyte solutions in operating electrolysis cells, indicating that nuclear reactions have occurred in these electrolytes. The systems studied have included D_2O/Li_2SO_4 as electrolyte with palladium as the cathode[2], H_2O/Li_2SO_4 electrolyte with palladium as cathode, and H_2O/Li_2SO_4 electrolyte with nickel as cathode[3]. Nuclear tracks were also found in detector chips suspended in the oxygen-hydrogen gas above an H_2O/Li_2SO_4 electrolyte using palladium or nickel as cathode material[4]. In all these experiments controls were carried out with detector chips immersed in the electrolyte solutions or suspended in the vapor above the solutions as appropriate, but in the absence of electrolysis, for the same length of time as the duration of the electrolysis experiments. The density of etch pits was observed to be on average greater for chips exposed during active electrolysis than for chips exposed in control experiments. The probabilities that the results from the electrolysis experiments and those from the controls could have arisen by chance from a single population ranged from 10^{-4} to 10^{-10}. Thus we demonstrated that a nuclear reaction of some sort in the electrolyte or in the vapor over the electrolyte can indeed accompany the electrolysis of either heavy or ordinary water using either palladium or nickel cathodes.

Beyond this we have observed clusters of tens of thousands of nuclear tracks on detector chips in the $H_2 + O_2 + H_2O$ vapor above the electrolyte of an operating electrolysis cell[5]. Analysis of one such event has shown that the tracks were caused by high energy charged particles that originated in the gas a few millimeters from the surface of the closest chip. The reaction produced a shower of about 150,000 alpha particles with energies of approximately

2 MeV of which we recorded about 40,000 on a pair of opposing detector chips. Figure 1 shows the pattern of etch pits on the more heavily pitted chip in a region having about half of the maximum track density. Figure 2 plots the variations in track density over the surfaces of the two opposing detector chips. It is evident that the particle source lay between the chips and closer to the more heavily pitted one.

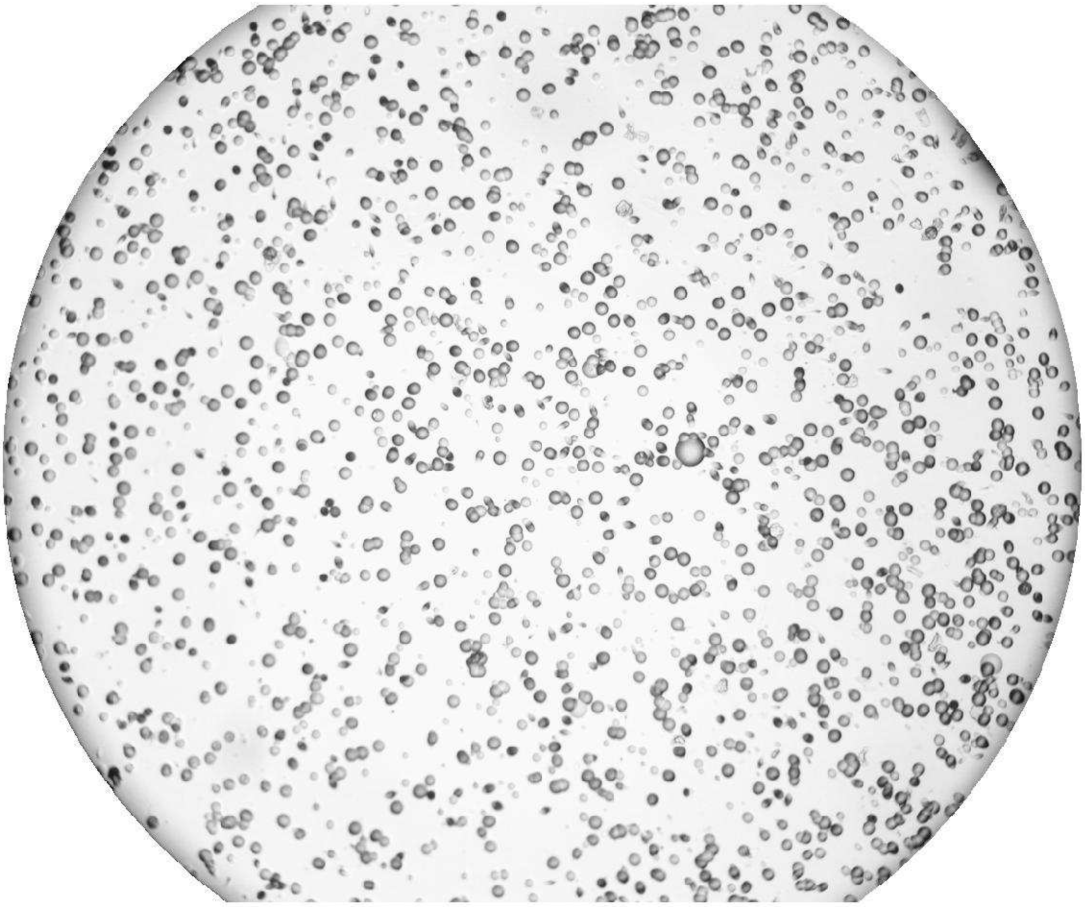

FIG. 1: Etch pits on a detector chip supported in the $O_2 + H_2 + H_2O$ vapor over an active electrolysis cell[5].

These experimental results cannot be explained by nuclear physics as currently understood, nor can the generation of excess energy during electrolysis first observed by Fleischmann, Pons and Hawkins[6]. An extension of nuclear theory is required. The present work was carried out to further extend the range of electrolysis phenomena that must be explained by any successful theoretical treatment.

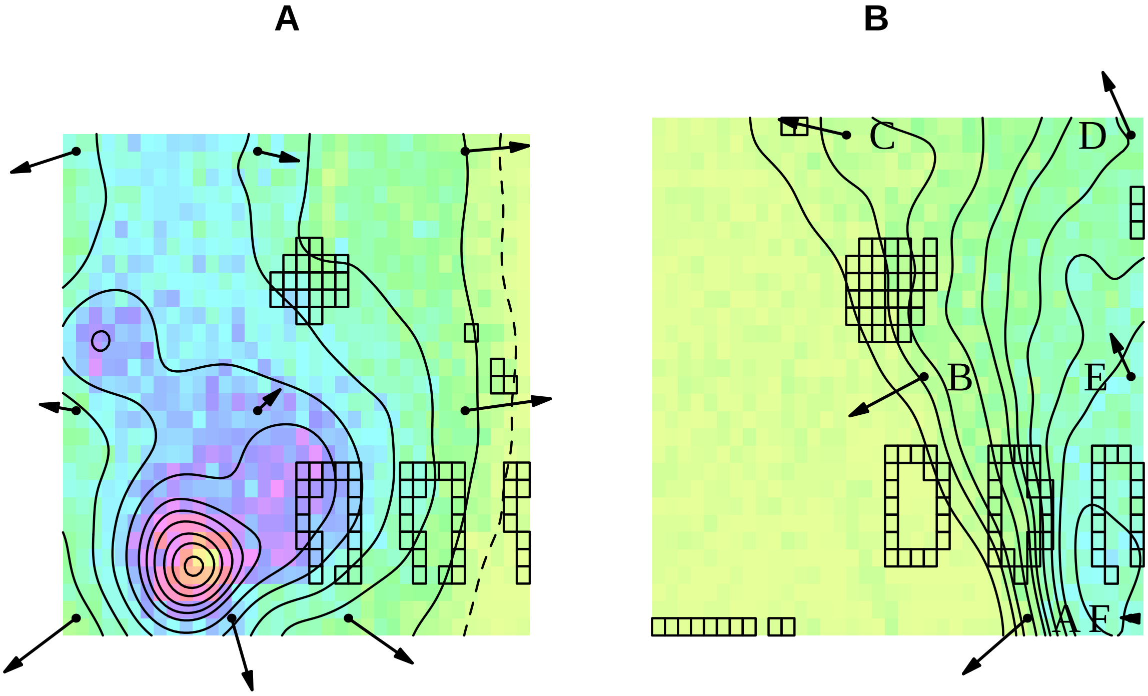

FIG. 2: **A**. Contour plot of the density of etch pits on the surface of the detector chip in Figure 1. Density in pits/image is indicated by the color scale for a mosaic of 1044 images that span the approximately 8 mm square surface. Outlined images could not be counted and etch pit densities were interpolated for them. The solid contour lines are spaced at 10 pits/image and range from 10 pits/image along the right side to 110 pits/image near the peak. Arrows indicate mean orientations of the tracks in various locations. **B**. Contour plot of the density of etch pits on the detector chip facing the chip in Figure 2A at a distance of approximately 1 cm. Here the solid contour lines are spaced at 3 pits/image and range from 3 pits/image on the left to 30 pits/image at the peak.

II. DETECTORS BELOW THE CATHODE

Electrolyses were carried out in a small tubular glass apparatus shown schematically in Figure 3. The cathode, either palladium or nickel sheet, was clamped between O-rings fitted into a flanged joint whose lower half connected to a gas-handling and vacuum system. The anode was a platinum wire spiral. All electrolyte solutions had the approximate concentration of 0.02 g Li_2SO_4 per ml of either D_2O or H_2O. By means of the gas-handling system the lower surface of the cathode could be maintained in an atmosphere of air or deuterium.

CR-39 plastic detector chips obtained from the Fukuvi Chemical Industry Company,

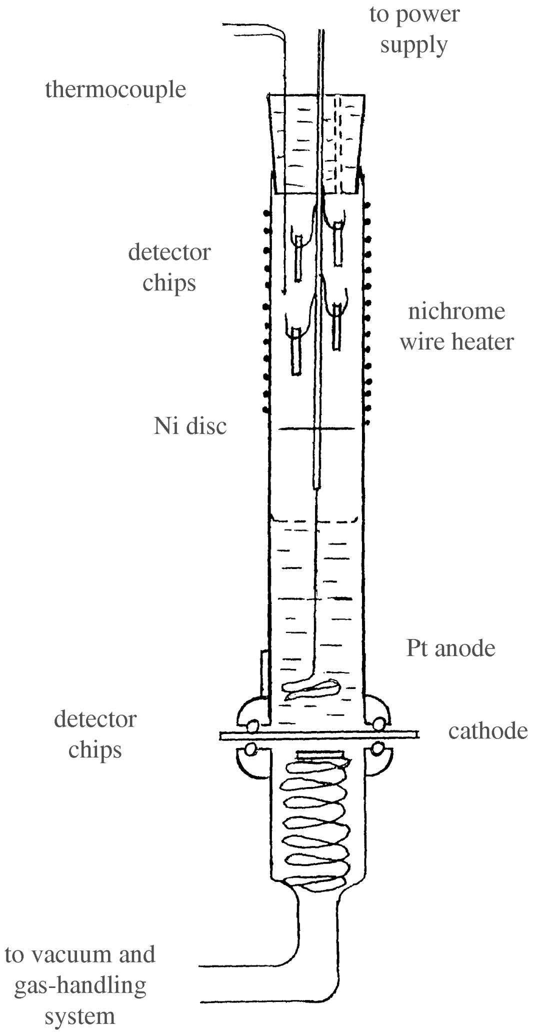

FIG. 3: Schematic diagram of the linear electrolysis cell employed for detection of energetic charged particles in the vapor above the electrolyte, outside the cell under the cathode, and outside the cell beyond the glass enclosure.

Japan, were etched in 6.5N KOH for about 20 hours at 65 C, the standard etching procedure for all controls and experiments. They then were examined at 100X for pre-existing nuclear tracks including those produced by alpha particles from radon in the laboratory air. A pre-etched chip then was placed below and parallel to the cathode sheet, and in some instances pre-etched chips were also placed in the vapor above the electrolyte in the cell. The detector chip situated below the cathode was enveloped either by air or by deuterium gas at one atmosphere pressure. In experiments with palladium cathodes and light water for the electrolytic solution the air below the cathode was admixed with hydrogen gas by permeation of hydrogen electrodeposited on the upper surface of the cathode. Electrolysis usually was carried out for three days at various current densities ranging from 0.1 to 0.4 A/cm^2, after which the chips were again etched and examined. The density of new nuclear tracks per unit area of detector chip was compared with that found in controls subjected to the same experimental procedure except for the absence of electrolysis.

Markedly positive results were obtained in 10 of the 26 experiments of this kind that were carried out. In these ten the densities of nuclear tracks formed during electrolysis were far larger than in the controls. Etch pits were observed to form localized clusters suggesting that showers of particles had emanated from compact sources in the vapor near the detector chips. Figure 4 shows a cluster of pits on a chip suspended in air about 1.5 cm below a nickel cathode and employing Li_2SO_4 in H_2O as electrolyte. This figure and all others are at the same magnification as Figure 1. Arrows mark the directions in which energetic particles impinged on the detector chip, as revealed by microscopic examination of the etch pits. (Recall that pits that mark pre-existing tracks have been etched twice, and for this reason are nearly twice the diameters of pits that mark tracks that formed during the experiment. Several doubly-etched pits are visible in Figure 4 and others are visible in figures below.) It is apparent that the experimental particles have radiated outwardly from a source in the surrounding air just a few millimeters distant from the surface of the detector. They record a shower of charged particles that is qualitatively similar to the roughly 1000-fold larger shower shown in Figures 1-2 for detectors suspended over the electrolyte.

Figure 5 shows a sample of the extended distribution of etch pits that cover a detector chip suspended in air under a nickel cathode.

Figure 6 shows a shower of etch pits on a chip that was held 1.5 cm under a palladium cathode, enveloped initially in air for about one day, then for about two days in deuterium gas that diffused through the cathode and displaced the air.

Figure 7 shows another shower of etch pits on a chip that was enveloped in air for about a day then in deuterium gas for about two days.

In cases where detector chips were placed below the cathode and also in the gas above the electrolyte large numbers of tracks appeared on the latter whenever significant numbers of new tracks appeared on the chips held below the cathode. We note that the tracks

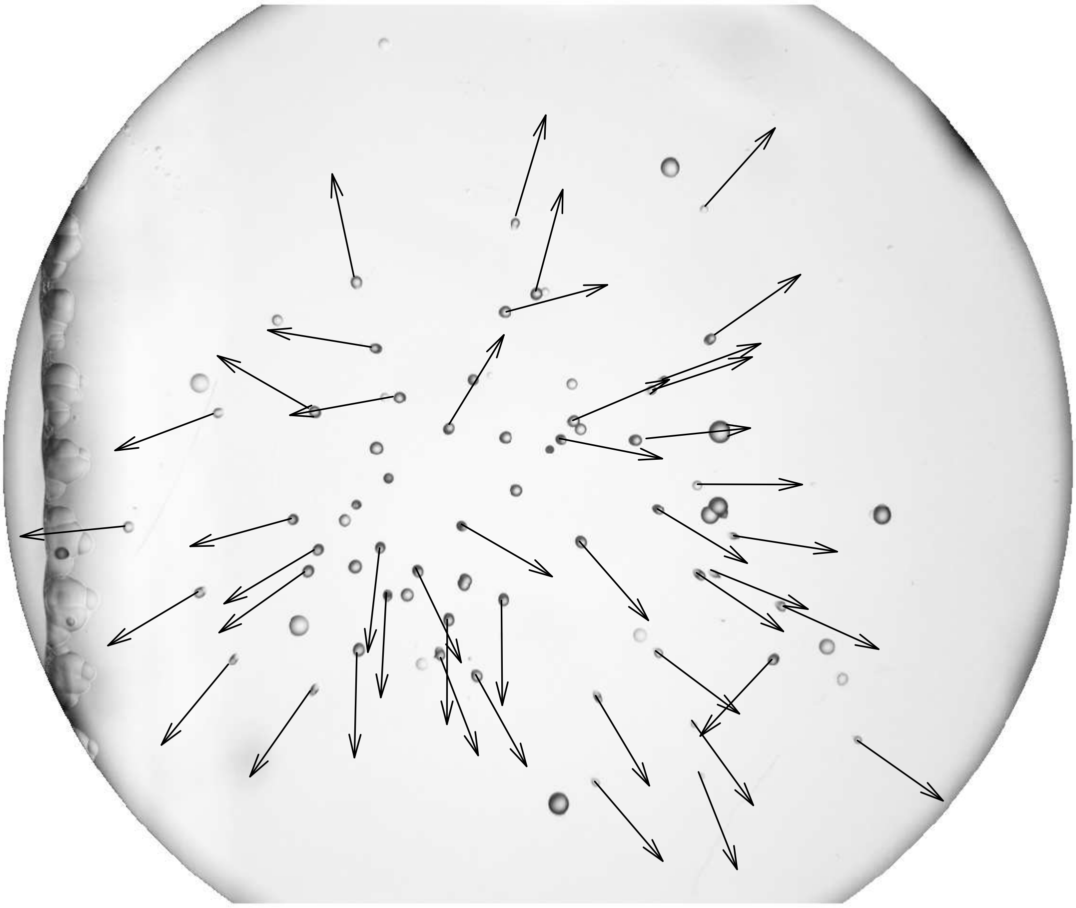

FIG. 4: Cluster of etch pits on a detector chip suspended in air under a nickel cathode. Arrows indicate the directions in which charged particles impinged on the chip. The electrolyte was Li_2SO_4 in H_2O.

appearing on detector chips below the cathode could not have been produced by energetic charged particles arising within the cathode or on its wetted surface because the mean free path of such particles is too short to penetrate the 0.125 mm thickness of the cathode. The energetic charged particles must have arisen at the lower surface of the cathode or more likely within the gas below it.

III. DETECTORS ABOVE THE ANOLYTE

An electrolysis cell in the form of a U-tube was devised, fitted with wire spirals within each leg to serve as electrodes, and with nichrome wire heaters surrounding the upper

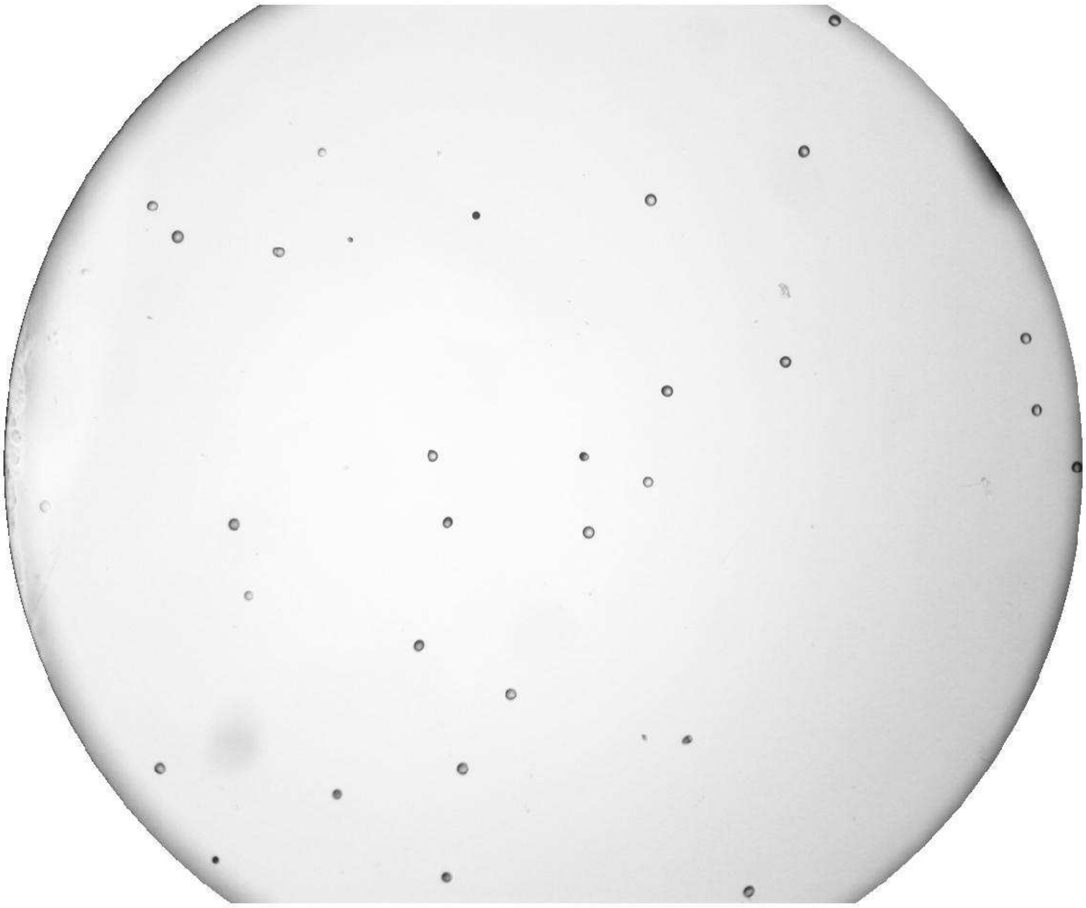

FIG. 5: Sample of the extended distribution of etch pits covering a detector chip suspended in air under a nickel cathode. The electrolyte was Li_2SO_4 in H_2O.

portions of the legs of the U. The anode was made of platinum and the cathode was either platinum or palladium. The electrolyte was contained in the lower portion of the U-tube and extending upward to cover the electrodes in each leg. Detector chips were suspended in the legs above the level of the electrolyte where they were exposed either to the vapors generated in the anolyte at the anode or to the vapors generated in the catholyte at the cathode. The detectors were maintained at about 60 C by the nichrome heaters.

Prior to carrying out electrolysis the detector chips were as usual etched and examined for pre-existing tracks. Electrolysis with 0.1 to 0.4 A/cm^2 current density was carried out for two or three days, after which the detector chips were again etched and examined. New nuclear tracks were observed in chips exposed above the anolyte as well as above the catholyte. Of fourteen experiments with chips surrounded by oxygen and water vapor above the anode,

FIG. 6: Shower of etch pits on a detector chip suspended under a palladium cathode in air one day, then in deuterium gas two days. The electrolyte was Li_2SO_4 in D_2O.

five produced new tracks in numbers much larger than were produced in control chips held in the vapor above an electrolyte solution for two or three days without electrolysis. The successful experiments in $O_2 + H_2O$ over the anolyte all employed H_2O for the electrolyte. Figure 8 shows a small shower of etch pits on one of these chips.

IV. DETECTORS OUTSIDE THE CELL

We have in addition observed the production of nuclear tracks, in numbers significantly larger than in controls, in detector chips placed in near contact with the outside surface of the glass cell wall at the level of the electrolytic solution. This phenomenon was seen in six of eleven of this type that were carried out. Figure 9 shows some of the tracks produced in

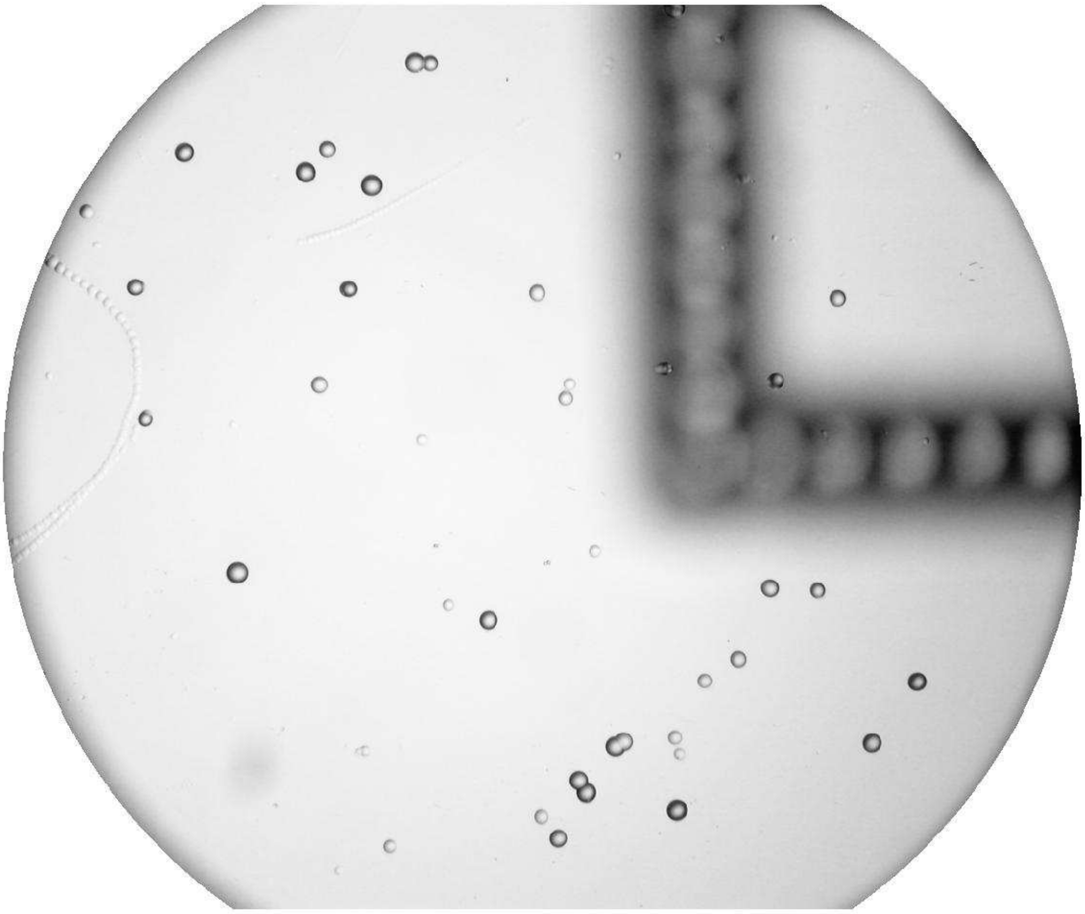

FIG. 7: Shower of etch pits on a detector chip suspended under a palladium cathode in air one day, then in deuterium gas two days. The electrolyte was Li_2SO_4 in D_2O.

one of these experiments. The electrolyte employed H_2O as solvent.

V. CHALLENGES TO NUCLEAR THEORY

We note here the sporadic nature of charged particle generation in our experiments. As stated in previous publications we infer that the cause for the difficulty of replication is our ignorance of the full range of experimental parameters that should be controlled for nuclear reaction to occur. In addition, and probably equally important, is the strong probablity that detector chips may not be positioned sufficiently near to the location where reactions may have occurred. Our past work has amply demonstrated this possibility. Often one side of a detector chip bears a large number of new tracks and while other side does not.

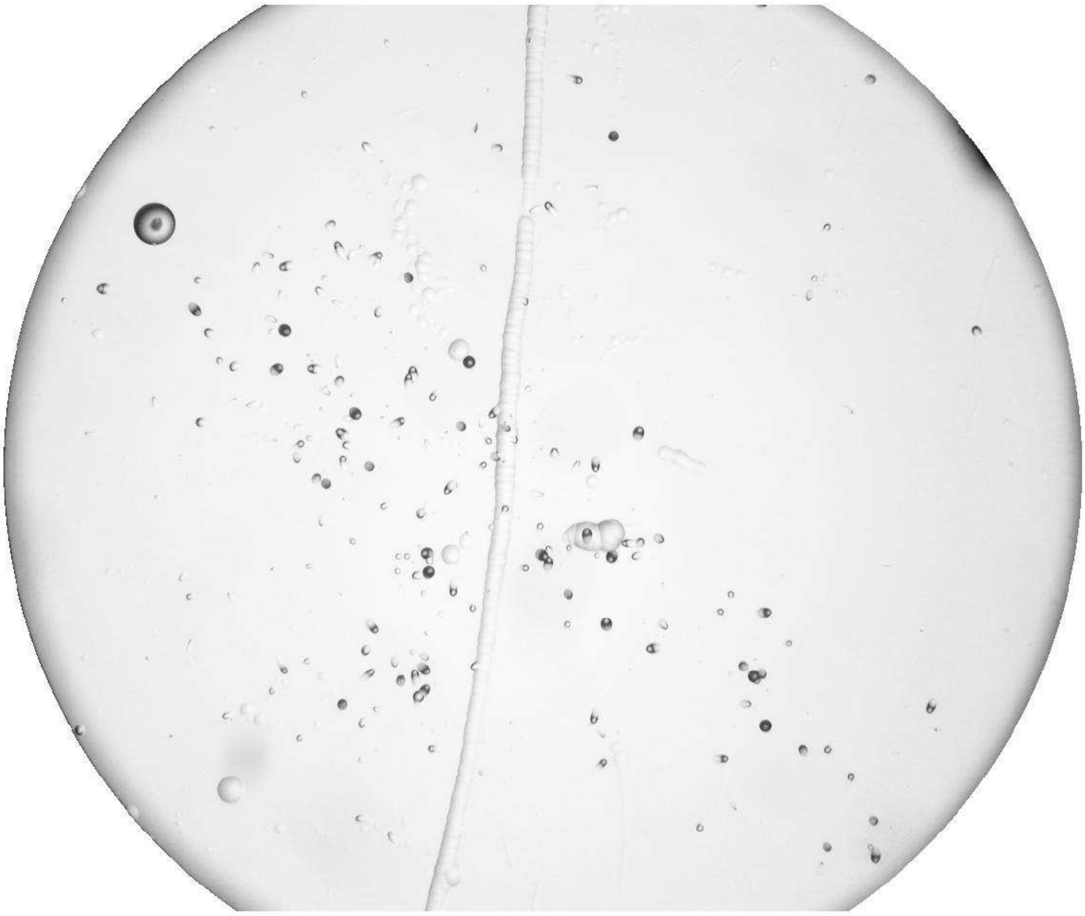

FIG. 8: Shower of etch pits on a detector chip suspended in the $O_2 + H_2O$ vapor over the anolyte in a U-tube experiment. The electrolyte was Li_2SO_4 in H_2O

We note also that the energy carried by the particles we detect is many orders of magnitude smaller than the total energy release as determined by calorimetric methods. Although we have presented strong evidence for nuclear reactions in the electrolyte and in various gases remote from the electrolyte, they cannot be the primary reactions that generate the reported excess energy. We presume that sustained primary reactions take place near the surfaces of the electrodes and that we observe transient secondary reactions associated with or triggered by products of the primary reactions.

Yet in spite of the difficulty of replication and the modest energy represented by the observed nuclear tracks our experiments pose significant challenges to theory. We have shown that nuclear tracks can be generated during electrolysis in detector chips positioned within the electrolytic solution, in the $H_2 + O_2 + H_2O$ gas over the electrolyte in the straight-

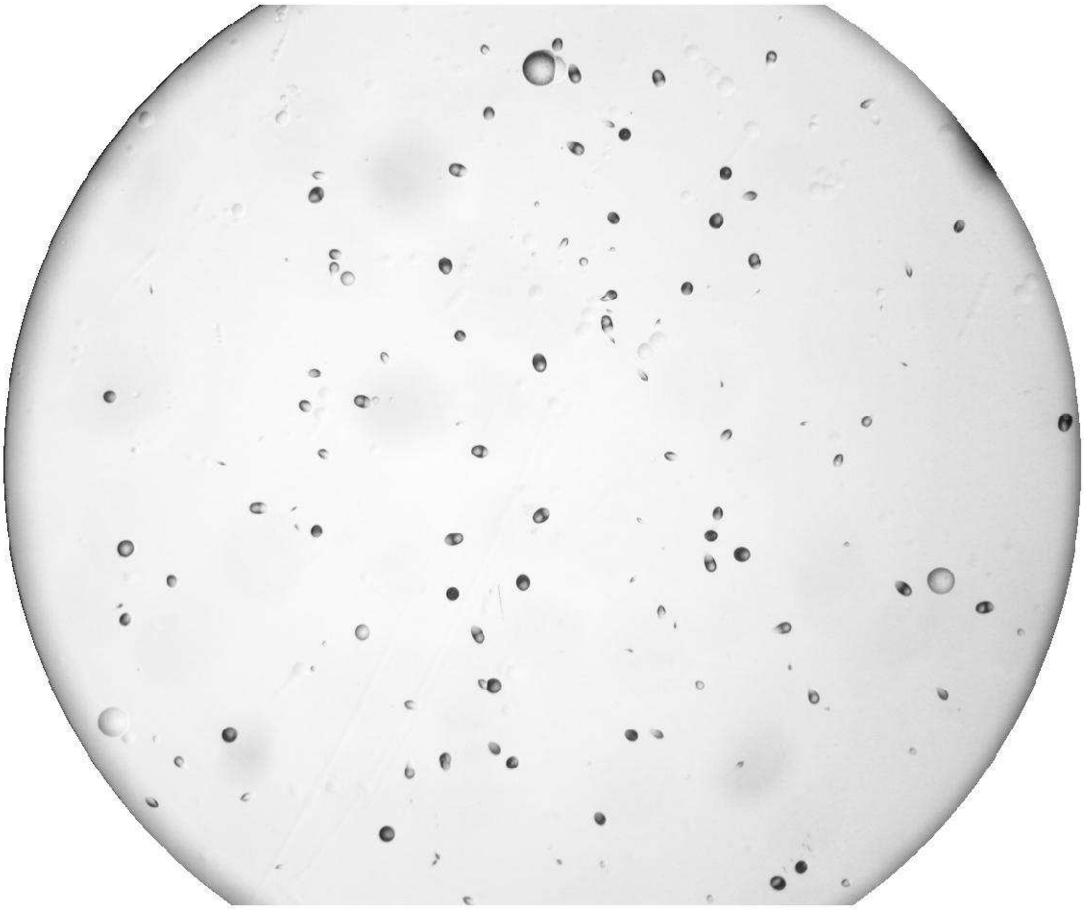

FIG. 9: Etch pits formed near the center of a large shower on a detector chip mounted just beyond the outside surface of the glass wall of the linear electrolysis cell. The electrolyte was Li_2SO_4 in H_2O.

tube cell, in the $O_2 + H_2O$ gas over the anolyte of the U-tube cell, in air below the cathode, in air just outside the glass wall of the electrolysis cell, and in deuterium gas below the cathode. These experiments indicate that nuclear reactions can be suported by oxygen and by deuterium, and that reactions can be triggered by unidentified agents that are able to pass through nickel and palladium cathodes and through the glass cell wall.

Acknowledgments

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