Journal of Scientific Exploration, Vol. 23, No. 4, pp. 411–417, 2009 0892-3310/09

RESEARCH

"Extraordinary Evidence" Replication Effort

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Abstract—In 2006, *New Energy Times* reported the "Extraordinary Evidence" of the observation of copious pitting of CR-39 nuclear track detectors placed in close proximity to the cathode in cold fusion experiments conducted by Pam Boss and Stan Szpak of the US Navy's Space and Naval Warfare Systems Command (SPAWAR) laboratory in San Diego, California (S. Krivit & B. Daviss, *New Energy Times,* 2006, http://newenergytimes.com/v2/news/2006/NET19.shtml#ee). They claimed that this pitting is evidence of nuclear activity in the cell. Our laboratory replicated this experiment and our first attempts were highly successful. The CR-39 "chips" were heavily pitted in the immediate vicinity of the cathode. This report details our efforts to determine the origin of these "SPAWAR pits."

Keywords: CR-39—SPAWAR—cold fusion—replication

Initial Replication

During the initial phase of replication, we performed four experiments, the first three based on a previously published paper by Szpak et al. (2005). Soon after we began our replication effort, Steve Krivit of *New Energy Times* began a coordinated replication effort named The Galileo Project (TGP; n.d.). The SPAWAR team collaborated with Krivit to provide a detailed protocol that we followed for our fourth initial experiment.

The TGP experiment consists of an open (no recombiners) electrolytic cell with approximately 25 ml of electrolyte. The anode is 20 cm of 0.3 mm platinum wire and the cathode is several centimeters of 0.25 mm silver wire. The cathode wire is wrapped around the CR-39 chip to ensure that it is in contact with the chip. The electrolyte is 0.3M LiCl in heavy water plus 0.03M $PdCl_2$. The current starts at 0.1 mA and is raised to 100 mA in several steps over the course of almost 3 weeks. During this time, virtually all of the palladium from the electrolyte is deposited onto the cathode.

All four of these experiments produced results very similar to those reported by SPAWAR. Upon removing the cathode from the cell at the end of the 3 weeks, a cloudy area on the chip was visible in the area directly beneath the cathode. After etching, this cloudiness resolved into well-defined and copious pits (approximately 10^6 pits/cm^2).

Investigating the Origin of the Pits

Having successfully replicated the SPAWAR experiment, we began a campaign to determine the origin of SPAWAR pits. The *New Energy Times* article (Krivit & Daviss, 2006) strongly suggests that the pits could only be due to nuclear particles. Compared to the often troublesome behavior of electronic detectors, CR-39 is generally considered to be an artifact-free method of detecting energetic particles (Meyer et al., 1994; Nikezica & Yub, 2004). However, in the majority of applications, CR-39 chips are exposed only to air during use. In contrast, the SPAWAR experiment exposes the chips directly to the electrolyte and to the ions produced by the electrolysis in the vicinity of the cathode. This at least raises the possibility that chemical attack is involved in the making of SPAWAR pits.

Comparison to Alpha Particle Tracks

We exposed CR-39 chips to alpha particles under a variety of conditions by varying the length of the air path between an Am-241 alpha source and the chip we were able to explore the effect of alpha energies from near zero (3–4 cm spacing) to ~5 MeV (nearly in contact). We also used other alpha emitters such as uranium ore placed in contact with the chip to observe the effects of highly oblique incidence.

We noted that the SPAWAR pits were strikingly different from the alpha tracks we created with Am-241 and other sources in our laboratory, as seen in Figure 1.

- Under the same etching conditions, 4 MeV alphas produced tracks about 7–8 microns in diameter, 1 MeV alphas produced a track about 15 microns in diameter, and the SPAWAR pits averaged about 25 microns in diameter.

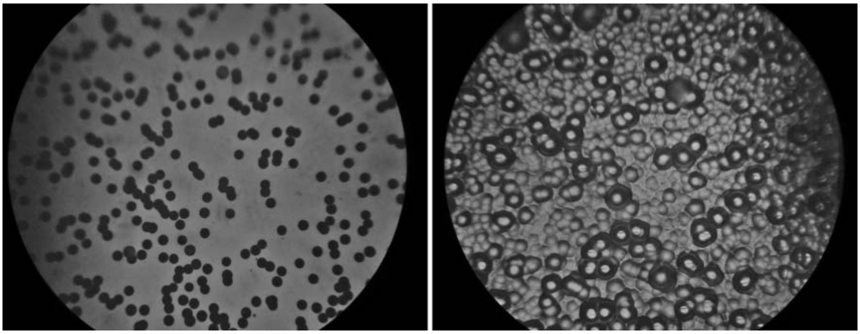

Fig. 1. Comparison of alpha tracks and SPAWAR pits. (Left) Normal incidence 4 MeV alphas (×400). (Right) SPAWAR pits (×400).

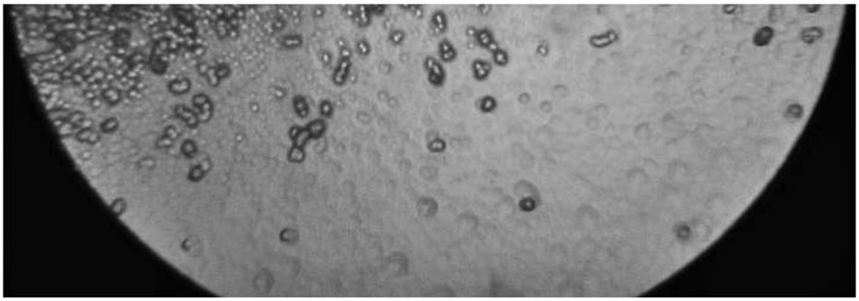

Fig. 2. Light tracks on the edge of the cathode zone.

- The SPAWAR pits were also shallower and clumped together. Even when the CR-39 was exposed to enough alphas that the tracks overlapped, they did not have the same "soap bubble" appearance as the SPAWAR pits.
- Additionally, none of the SPAWAR pits are elliptical. When a radioactive source is held in contact with the CR-39, tracks of all trajectories are recorded and particles with oblique incidence produce highly elongated tracks. However, even though the cathode wire is in contact with the chip in the electrolyte, we cannot discern any highly elongated shapes—all tracks appear to be nearly round.
- We also noticed a phenomenon that did not match with our experience with alpha particles. After electrolysis, but before etching, one can see "evidence" of the SPAWAR pits. They appear to be very small pock marks that later turn into well-rounded tracks upon etching. In contrast, the path produced by an alpha particle cannot be seen with an optical microscope before etching.
- Also we observed two distinct types of SPAWAR pits. In the center of the damaged area, the pits tend to be dark and well defined. At the edges, they become much lighter and shallower, as shown in Figure 2.

Other Damage to CR-39

As part of our search for possible artifacts, we attempted to make CR-39 tracks using various mechanical means. We quickly discovered that mechanical damage often leads to round, track-like marks after etching. Any scratch on the surface would resolve itself into a chain of circular pits after etching. The following photographs in Figure 3 show examples of pits created by various mechanical means, including nothing more than the casual handling of the chips.

Changes to the Protocol

We experimented with shortening the run time from the 3 weeks detailed in the TGP protocol. We ran at the maximum current, 100 mA, until the solution cleared

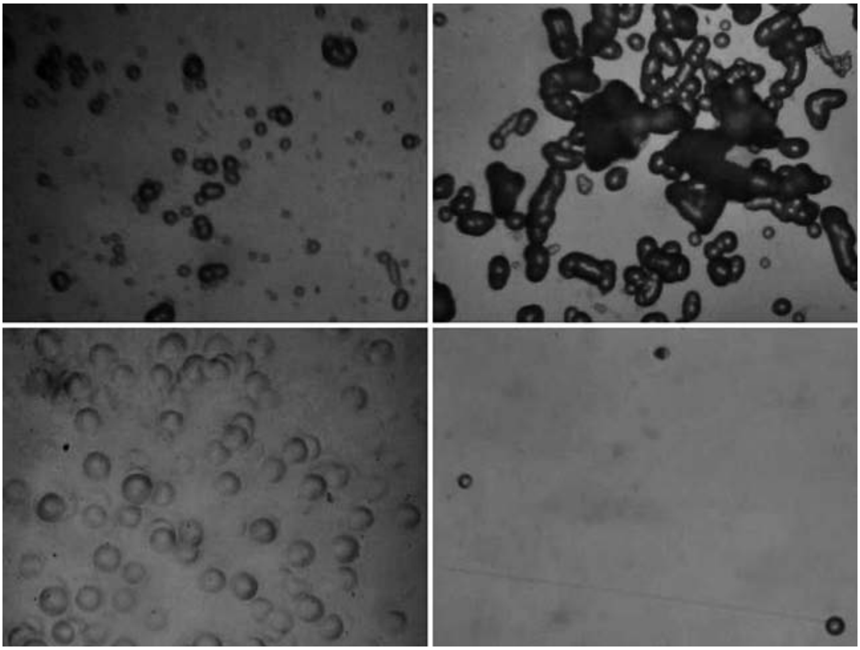

Fig. 3. Mechanical damage to CR-39.

(indicating that all the Pd had plated out). This process took less than 48 hours. The growth on the cathode was rather different than that of the long running cell. The Pd was deposited in a thin film of "mud" across most of the CR-39 surface. In the long experiments, the Pd forms brittle dendrites that are tightly clustered on the silver cathode wire. However, these short runs did produce the SPAWAR pits on the areas where the Pd was in contact with the chip. We also tried another short protocol that lasted for 3 days. This produced a slightly more compact cathode deposit that covered less of the chip surface and still produced SPAWAR pits.

Using the 3 day protocol, we ran a series of tests where parameters were held the same except for the electrolyte composition. Each test used the same molarity (0.3 M) but different chemicals—HCl, LiCl, NaCl, KCl. The test with HCl did not show pits, while the other three did.

In several other experiments, we also substituted light water for heavy water in the electrolyte. These tests showed no discernible difference in the quantity of SPAWAR pits produced. This seems quite significant as the nuclear behavior of deuterium, at least in high-energy nuclear experiments, is significantly different than that of protium.

We also investigated the effect of metals other than Pd co-deposited on the cathode. We found that when the metal was deposited in a dense, dendritic mass on the cathode, pits were formed. When the metal formed a soft, spongy mass, no pits were formed. This differentiation is especially apparent in the case of $CuSO_4$. For the first experiment we ran with $CuSO_4$, we set the current at 100 mA and within 90 minutes, a soft mass had formed around the cathode and all of the color had gone out of the solution. The chip in this cell had no pits. However, when we ran the same electrolyte using the TGP current settings, a tight dendritic structure was formed and pits were formed. A third experiment with $CuSO_4$ behaved slightly differently. As the current was increased, the structure of the cathode began to fall apart. No pits were formed even though the Cu had formed a dendritic structure in the early stages of the run.

As a result of this experimentation, we found that the pits were formed under circumstances that are usually not considered favorable to cold fusion, i.e., the use of light water and the absence of palladium.

Isolating the CR-39 from the Electrolyte

We protected the CR-39 from contact with the electrolyte in various ways with varying degrees of success. When we were successful, we did not observe tracks (above the background).

We sealed a small piece of 6 micron Mylar to the bottom half of a CR-39 chip with Devcon 2-ton clear epoxy. The adhesive formed a complete seal around the edge of the Mylar. During electrolysis, the adhesive swelled and forced the cathode wire away from the chip surface. After removing the Mylar and etching the chip, faint tracks could be seen in the area not protected by Mylar and no tracks were visible underneath the Mylar.

In another experiment, we used the same epoxy to glue a piece of 6 micron Mylar on the bottom half of the chip but only with dots of epoxy in the corners. We ran the experiment at 100 mA for 2 days. We hoped that the Pd deposit on the cathode would not grow between the Mylar and the chip, but this was not the case. SPAWAR pits were found on the chip surface under the Mylar where Pd deposits had formed.

For two other experiments, we wrapped a piece of CR-39 in Mylar, forming a bag. The opening of the bag was above the electrolyte level and the entirety of the chip remained dry. The Mylar bag in one experiment inflated noticeably during the run and forced the cathode wire away from the chip surface. Upon removing the bag from the cell, it was obvious that the bag was full of gas. However, the gas filled gap (of about 0.5 cm) between the cathode and the chip surface would not cause significant attenuation of any nuclear particles. The bag in the other experiment did not inflate as much and the Mylar, and thus the cathode wire, remained nearly in contact with the chip. After etching, both of these chips exhibited minor mechanical damage—we sanded the edges of the chip to ensure that the Mylar would not be punctured. This caused some scratching of the surface, which produced track-like damage similar to that described above. Despite this complication, we observed orders of magnitude fewer tracks than in our replication experiments and no spatial correlation between tracks and the location of the cathode.

In a private communication, Richard Oriani reported positive results with a cell in which the CR-39 was located outside the cell and separated from the electrolyte by a Mylar window. We adopted a similar design for our next experiments. We machined an opening in the side of the cell and glued Mylar film over it (using Devcon 2-ton clear epoxy). The chip was held in contact with the outside of the window and the cathode wire was positioned against the inside. We ran four experiments with this set-up, each following the advice of different experimenters involved in the replication. The chip in the first of these experiments was scratched too badly from sanding to get an accurate track count, but clearly there was no copious distribution of tracks as seen in our replication experiments. The other three tests showed only background track densities.

Other Observations

Accelerated Etching

During our investigation, we observed one effect that was clearly caused by chemical damage to the CR-39. We carefully measured the thickness of the CR-39 at various stages of the experiment. The thickness did not change after exposure to the electrolyte. However, when chips that had been exposed to the electrolyte for weeks were placed in the etching solution, the etch rate was unusually high at first, but returned to a normal rate after a few hours. Normally, CR-39 will etch at a rate of 1.5 microns per hour using TGP etch parameters. However, these chips lost 80 microns in the first 1.5 hours. The cathode wire and associated Pd deposits provide some degree of protection from this effect. In our replication experiments, this area was only etched about 15 microns during this same time and therefore a perceptible ridge formed underneath the cathode.

It should be noted that the expected range of 5 MeV alpha particles in CR-39 is approximately 40 microns, considerably less than the thickness of CR-39 removed from the bulk of the chip in many of these experiments.

Conclusions

Our results do not provide a positive identification of the origin of SPAWAR pits. However, they do show that chemical origin is a distinct possibility and therefore that nuclear origin is not a certainty. The accelerated etching rate observed for CR-39 that has soaked in TGP electrolyte for several weeks proves that there is a significant chemical interaction when the CR-39 is immersed in the electrolyte. The observation that SPAWAR pits are visible before etching shows that they are unlike the tracks made by ionizing particles. The observation that SPAWAR pits are stopped by a 6 micron Mylar film is consistent with a chemical origin but only proves that they cannot be due to nuclear particles which would penetrate such a barrier (e.g. alpha particles of energy >1 MeV). The rest of our observations, such as the invariance of the result when the electrolyte is changed from heavy water to light water or palladium is removed from the cell, are less conclusive but are still consistent with chemical origin of SPAWAR pits.

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