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Letter to the Editor

Comments on Co-deposition Electrolysis Results: A Response to Kowalski

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Abstract

In 2009, it was reported that the tracks observed on the front surface of CR-39 detectors as a result of co-deposition were due to 0.45–0.97 MeV protons, 0.55–1.25 MeV tritons, 1.40–3.15 MeV ^{3}He, and/or 1.45–3.30 MeV alphas. Recently those conclusions have been challenged. In this communication, additional experimental data and further analysis of our earlier results are provided that support our original conclusions.

Keywords: CR-39, Pd/D co-deposition

1. Introduction

In 2007, we reported the observation of tracks in CR-39 resulting from the co-deposition process [1]. The tracks were dark in color and primarily circular or oval in shape. When the microscope optics were focused inside the tracks, a bright spot was observed inside. This bright spot is due to the bottom of the track cone acting like a lens when the CR-39 detector is backlit. These features are diagnostic of a nuclear generated track. A series of control experiments were done to show that the tracks were not the result of radioactive contamination nor to mechanical damage. The most noteworthy of these control experiments was electrodeposition using $CuCl_2$ in place of $PdCl_2$. In both the $CuCl_2$ and

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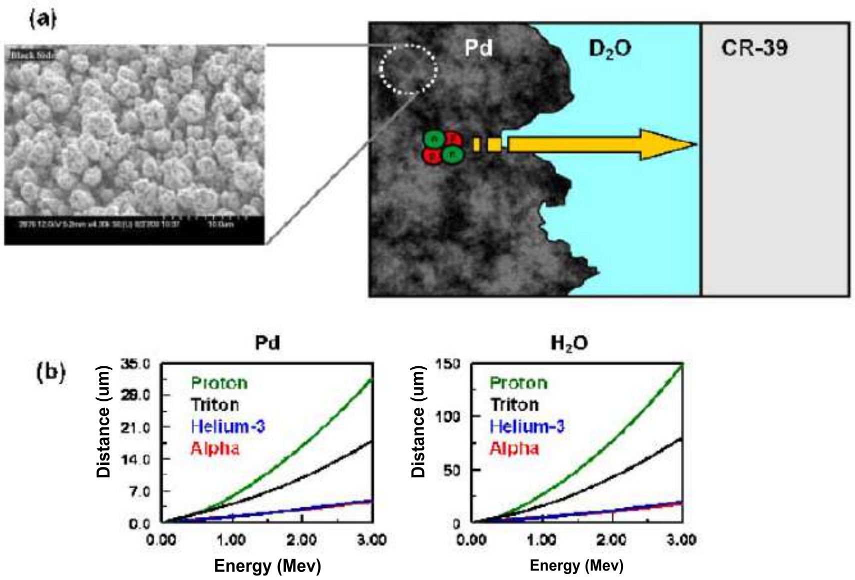

Figure 1. (a) Schematic describing the layers a charged particle has to negotiate before it impacts the CR-39 detector. After its birth, a charged particle has to exit the metal lattice and cross a thin water layer before it impacts the CR-39 detector. An SEM of the Pd deposit formed as the result of the co-deposition process is shown. The cauliflower morphology of the deposit traps pockets of water. (b) LET curves calculated for charged particles traversing through palladium and water.

$PdCl_2$ systems, the same electrochemical reactions are occurring. At the cathode, a metal is plating out in the presence of evolving deuterium gas while oxygen and chlorine gas evolution occurs at the anode. The only significant difference between the two systems is that Pd metal absorbs deuterium and Cu does not. While tracks were observed in the Pd/D system, none were observed in the Cu/D. These results indicate that the observed tracks in the Pd system were not due to chemical attack of the surface of the CR-39 by either D_2, O_2, or Cl_2 present in the electrolyte; nor to mechanical damage due to the impingement of D_2 gas bubbles on the surface of the detector; nor to damage caused by the metal dendrites piercing into the CR-39; nor to localized production of hydroxide ions that etch into the CR-39.

In 2009, experiments were conducted to characterize the Pd/D co-deposition generated tracks [2]. Specifically, an experiment was done in which a 6 μm thick Mylar film separated the CR-39 detector from the cathode. In addition track modeling was done using TRACK_TEST, a computer program developed by Nikezic and Yu [3]. Both the Mylar experiment and track modeling indicate that the energy of the particles are $\sim$1 MeV by the time they reach the CR-39 detector. To reach the detector, the particles have to traverse a thin water layer. Linear energy transfer (LET) curves, calculated using the SRIM-2003.26 code of Ziegler and Biersack [4], were used to evaluate the impact of water on the particle energies. Assuming water thicknesses varying between 0 and 10 μm, it is estimated that the majority of the particles formed as a result of Pd/D co-deposition are 0.45–0.97 MeV protons, 0.55–1.25 MeV tritons, 1.40–3.15 MeV ^{3}He, and/or 1.45–3.30 MeV alphas. However, Kowalski has questioned these conclusions. In particular, he has made the allegation that the tracks obtained on the CR-39 detectors are too large to be due to 1 MeV alphas. In this communication, we address the issues raised by Kowalski.

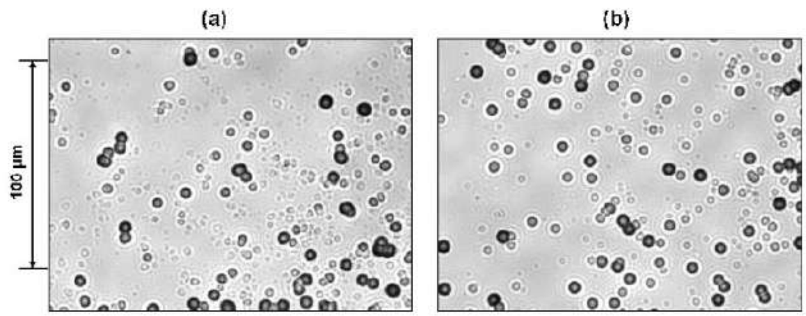

Figure 2. Photomicrographs obtained at 500× magnification for (a) Pd/D co-deposition tracks and (b) ∼1 MeV alpha tracks.

2. Discussion

In his introduction, Kowalski said that 'nearly all tracks disappear when $PdCl_2$ is replaced by $CuCl_2$.' The implication of this statement is that tracks were observed in the $CuCl_2$ electrolysis experiment. This is not true. As discussed in [1], no tracks above background were observed in the Cu deposition experiments. Also in his introduction, Kowalski stated that 'dominant SPAWAR type pits were significantly larger than pits due to alpha particles.' He further stated that photographs shown in [2] support his claim. However, he does not indicate which photographs in [2] support his claim. In [2], we examined the impact traversing through a water layer has on the energetics of the charged particles. Figure 1a describes the processes involved when an alpha particle impacts a CR-39 detector used in a Pd/D co-deposition experiment. An SEM of the Pd deposit is shown in Fig. 1a. The deposit has a cauliflower-like morphology that traps pockets of water. As shown in the schematic in Fig. 1a, after birth, the particles have to pass through the Pd lattice and the water layer before impinging the detector. Figure 1b shows LET curves calculated for protons, tritons, helium-3, and alpha particles in palladium and water. These LET curves are used to determine the magnitude of the effect of Pd and water on the energies of the particles. The LET curve for Pd indicates that, in order for particles to be detected by the CR-detector, the particles need to originate near the surface of the Pd. Particles formed deeper inside the deposit will simply not have enough energy to exit the lattice and travel through the deposit and water layer to reach the CR-39 detector.

The 6 μm Mylar experiment described in [2] resulted in a $\sim$90% reduction in the number of tracks. The LET curve for Mylar indicated that 6 μm thick Mylar blocks $<$0.45 MeV protons, $<$0.55 MeV tritons, $<$1.40 MeV helium-3, and $<$1.45 MeV alphas. The Mylar experiment indicates that, on average, the particles have energies on the order of 1 MeV when they reach the detector. Figure 2 shows a side-by-side comparison of Pd/D co-deposition tracks with $\sim$1 MeV alpha tracks formed by placing 24 μm of Mylar between an ^{241}Am alpha source and the CR-39 detector. The Pd/D and $\sim$1 MeV alpha tracks are indistinguishable. This was also discussed in [2]. The purpose of the experiment placing 24 μm of Mylar between the ^{241}Am source and the detector was to simulate the effect of water on the particles. One of the main criticisms raised about the tracks oberved in CR-39 detectors used in Pd/D co-deposition experiments is the sparsity of elliptical tracks. As shown in Fig. 2a, the observed tracks are primarily circular in shape. Likewise the ∼1 MeV alpha tracks are primarily circular in shape, Fig. 2b. The results in Fig. 2 indicate that only particles with trajectories normal to the surface have sufficient energy to get through the water layer and Mylar to impact the detector. Particles traveling at oblique angles are deflected and do not reach the detector. It is worth noting that in his blog [5], Kowalski has stated 'Alpha particles of approximately 1 MeV can be used and their tracks can be compared with tracks produced during electrolysis. Suppose that the two kinds of tracks turn out to be very similar. That would reinforce the SPAWAR hypothesis.'

Kowalski has also indicated that the 6 μm thick Mylar experimental results reported in [2] conflict with the results of a similar experiment performed by SRI [6]. Specifically, we reported that we saw a ∼90% reduction of tracks in the Mylar experiment while Lipson et al. reported a 99.9% reduction. Our estimate is based upon the results of the automatic scanning we have done of our detectors. In experiments conducted with the CR-39 in direct contact with the cathode, we typically obtain 20,000–30,000 tracks. For the Mylar experiment, the automated scanner identified 2387 tracks, which is close to a 90% reduction in the number of tracks. We cannot comment on the SRI results. A number of experimental factors, such as the proximity of the wires to the Mylar film, surface area, etc. could explain the reported differences between the SRI and our results. Also different cathode substrates were used in the two experiments. The cathode substrate used in the SRI experiment was Ag while our experiment used Pt and Au wires in series. In [1], we showed that cathode substrate does affect the production of charged particles. For example, it was observed that, when Ni screen is used as the cathode substrate, tracks are only obtained in experiments conducted in the presence of either an external electric or magnetic field. However for Ag, Au, and Pt cathode substrates, tracks were obtained in both the presence and absence of an external field. The difference between the SRI and our results is not due to the presence or absence of a magnetic field as Kowalski suggests. The SRI, Mylar experiment, like ours, was conducted in the presence of a magnetic field [7].

Kowalski reports that the pits obtained in the SRI experiment [6] were identified as 2.5 MeV protons and not alpha particles. This is not correct. Lipson et al. have developed a sequential etching protocol to aide in identifying tracks [6]. Applying this methodology to the analysis of the tracks obtained in the SRI experiment, Lipson et al. attributed the tracks to proton recoils resulting from the interaction of the detector with fast neutrons. The energy of the neutrons responsible for these recoils was determined to be 2.5 MeV. The reason why the Lipson et al. [6] paper was not referenced in [2] is due to the fact that the Lipson et al. paper deals with neutrons, while our 2009 paper is concerned with charged particles.

Kowalski claims that identifying particles tracks in CR-39 is difficult. This is not the case. Lipson et al. [6,8] have shown that sequential etching and placing films between the cathode and detector can be used to identify particles and determine their energies. Astrophysicists have developed a LET spectrum analysis of passive detectors that enable them to both identify the charged particles and determine their energy distributions [9–11]. In our own experiments, we have successfully used track modeling to determine the energies of alpha particles. Kowalski suggests using a silicon barrier detector would be better. He also states the following: 'The guaranteed background noise of some commercially available detectors is one count per hour, provided *the energy threshold is set up to* 3 MeV. Furthermore "extensive care regarding detector and chamber cleanliness can result in background count levels as low as 0.05 counts/h/cm^2 of active area, corresponding to 6 counts/24 h, for a 450 mm^2 active area," *at energies higher than about* 2 MeV.' The CR-39 results indicate that the particle energies are on the order of 1 MeV by the time they traverse a water layer and impact the detector. The majority of the particles are well below the energies optimum for the silicon barrier detector.

In his conclusions, Kowalski claims that there is a controversy as to the identity of particles causing what he refers to as 'dominant SPAWAR pits'. We disagree with this assessment. Figure 2 shows that the Pd/D co-deposition tracks are very similar to ∼1 MeV alpha tracks. This conclusion is supported by the Mylar experiment and track modeling [2].

3. Conclusions

In this communication, we have addressed the issues raised by Kowalski. Specifically we show, yet again, that the Pd/D co-deposition tracks are consistent with those observed for $\sim$1 MeV alpha particles. This is supported by a side-by-side comparison of Pd/D co-deposition tracks with 1 MeV alpha tracks, Fig. 2; track modeling; the 6 μm Mylar experiment; and using LET curves to determine the magnitude of energy losses as the particles travel through the Pd deposit, water layer, and Mylar film.

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