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Research Article

Diamond-based Radiation Sensor for LENR Experiments. Part 2: Experimental Analysis of Deuterium-loaded Palladium

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Abstract

The purpose of this paper is to report on the continued work on utilizing a palladium electrode on a diamond sensor in a pressurized hydrogen or deuterium environment to investigate the release of radiation during low energy nuclear reactions (LENR). In this investigation we conducted a long hydrogen exposure to see if palladium electrode delamination occurred due to chemical reactions and it was found that after seven days the electrode did not delaminate. A pressurized deuterium run was conducted immediately following the hydrogen exposure on the same sensor and some interesting count burst data was observed. Further analysis is required to determine what the observed effect could be attributed to.

Keywords: Charged particle spectroscopy, Diamond sensors, Low energy nuclear reactions

1. Introduction

There is the possibility that radiation particles can be created in low energy nuclear reactions (LENR) experiments and that a correlation (or anti-correlation) between the creation of radiation particles and excess heat may exist. To try and understand the underlying mechanism of LENR, a sensor was developed for gas loading experiments that is further described in [1]. In this work a palladium electrode was made on the diamond sensor for deuterium loading through pressurized environments. In this report it was shown that the diamond sensor had an energy resolution for 5.4 MeV ^{239}Pu alpha particles of 2.1% and that the diamond material seemed to be stable in the hydrogen-like environment. However, the initial test run showed that the palladium electrode was sensitive to the pressurized hydrogen environment but it was unclear what reaction caused the delamination of the electrode, specifically if it was chemical or nuclear in

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origin. To continue the work this report presents the results obtained in the second experimental run with modified experimental technique to help answer some of the questions that were raised in the first test run.

2. Pressurized Hydrogen Experiment

2.1. Experimental set-up and procedure

In this experimental run, the diamond sensor was prepared with a metallization pattern of Diamond/DLC/Au/Pd (10/100/100 nm) to try and increase mechanical adhesion of the palladium electrode through the addition of the intermediary gold layer between the palladium and diamond-like-carbon (DLC) layers.

In each run (hydrogen and deuterium) the sensor was placed in a pressurized gaseous environment and this chamber was encased in several inches of lead on all sides to reduce cosmic ray interactions. There were two main runs in this experiment; one in hydrogen and another in deuterium. Based on the first trial results previously reported [1], it was shown that delamination occurred. To see if this effect was due to a palladium–deuterium chemical reaction the sample was placed in a hydrogen environment at 690 kPa with a stainless steel 316 boundary. After a set period of time, usually around one day, the system was depressurized, removed from the chamber and the electrode was inspected. Then the system was restored to its previous state and the experiment continued. This process was repeated until a total exposure time of 7 days was reached.

2.2. Experimental results

The spectra obtained for a lower and higher amplifier gain are shown in Fig. 1 and the count rate data obtained is given in Fig. 2. The spectra were normalized to a single spectrum and the normalization factors in time and total peak counts are given in Tables 1 and 2 for the low and high gain amplifier output signals, respectively. It can be seen in the supplied data that there are some differences in the spectra obtained, specifically in the tail end of one or more spectra reaching into higher energies and it can be seen that the count rate seems to growing slightly over the entirety of the experiment with few high count rate spikes that are currently unexplained. In Fig. 3, a picture of the top palladium electrode at various times is shown. It can be seen that some damages do show up on the electrode in the form of missing sections that represent a small area over the entire electrode. This could account for the count rate bursts as electrode flaking during experimentation would produce significant voltage spikes. However, the results seem to not be out of the normal operation and the fluctuations seen are due to electronic noise and drifting but needs to be further verified.

Table 1. The normalization factors in time and total peak counts low gain amplifier output signals for "Pressurized hydrogen experiment".

Run	Time	Counts
Day 1	1.23	15.04
Days 2–3	0.54	12.56
Day 4	–	–
Day 5	1.00	1.00
Day 6	1.17	1.01
Day 7	1.21	2.07

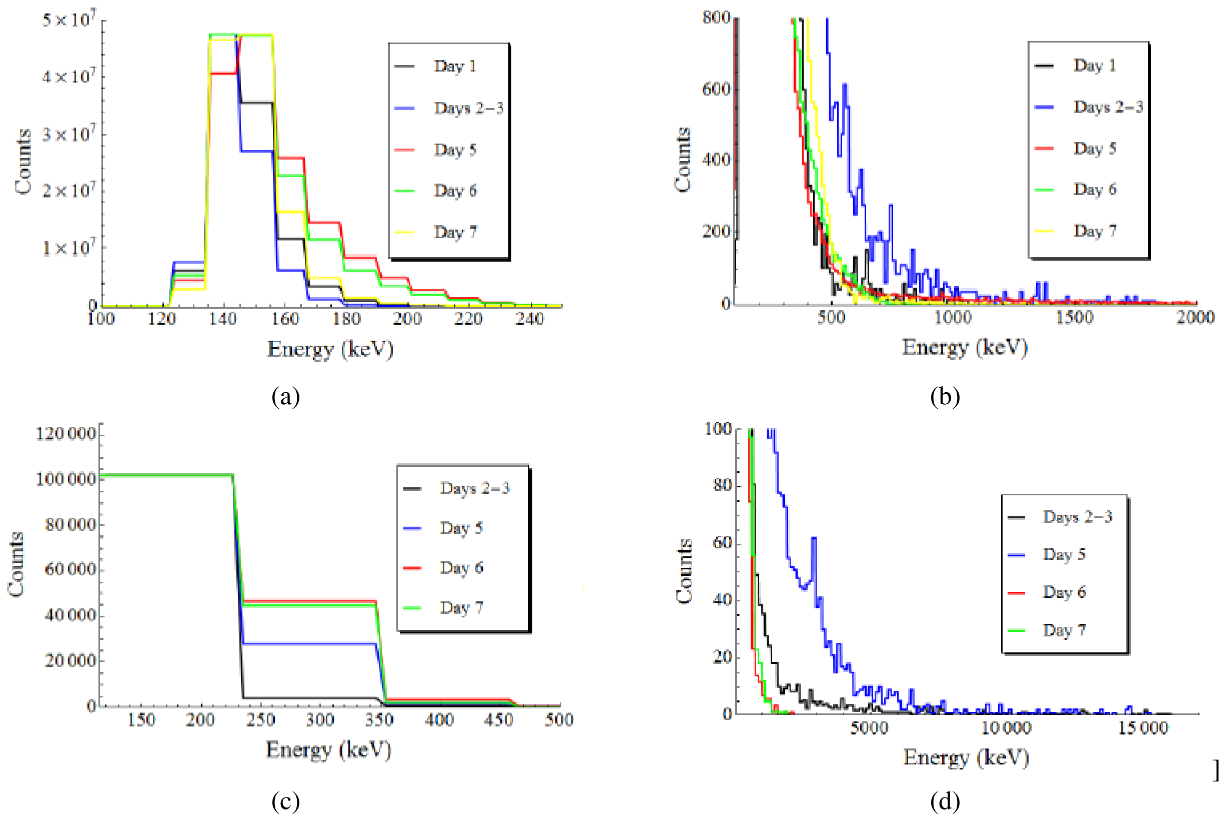

Figure 1. Spectra obtained during hydrogen exposures of the palladium coated diamond sensor with (a)–(b) low sensor gain and (c)–(d) high sensor gain.

3. Pressurized Deuterium Experiment

After the hydrogen exposure the palladium electrode on the diamond sensor seemed to be unaffected from the hydrogen exposure for 7 days. At this point the experiment was continued except that the hydrogen was replaced with deuterium. The spectra obtained for these exposures are shown in Fig. 4 and the normalization data are displayed in Tables 3 and 4

Table 2. The normalization factors in time and total peak counts high gain amplifier output signals for “Pressurized hydrogen experiment”.

Run	Time	Counts
Day 1	–	–
Days 2–3	0.51	5.75
Day 4	–	–
Day 5	0.86	1.44
Day 6	1.00	1.00
Day 7	1.04	1.09

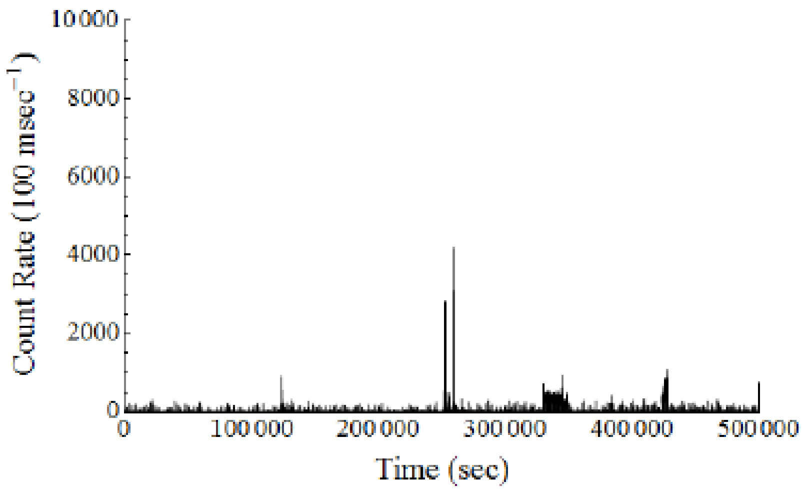

Figure 2. Count rate data for the hydrogen exposures of the palladium coated sensor.

mimicking the method of data presentation for the hydrogen experiment run. In addition, the count rate data collected for this experimental run are shown in Fig. 5 and the palladium electrode on the diamond between exposure days is displayed in Fig. 6.

From the results and from the deuterium exposures, it can be seen that the data collected are similar to the hydrogen runs until day 5 is reached. In the high gain data obtained it can be seen that there is many more counts than in any of the other days in the experimental run but this is not seen in the low gain data collected.

This is because the noise floor of the high gain data in the obtained spectra is higher and therefore the peaks seen

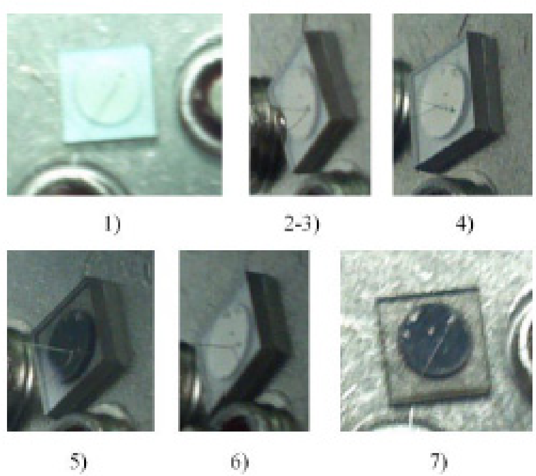

Figure 3. Pictures of the electrode on the diamond sensor between each data acquisition from the pressurized hydrogen run. The indexes of the pictures represent the days of exposure that has been completed.

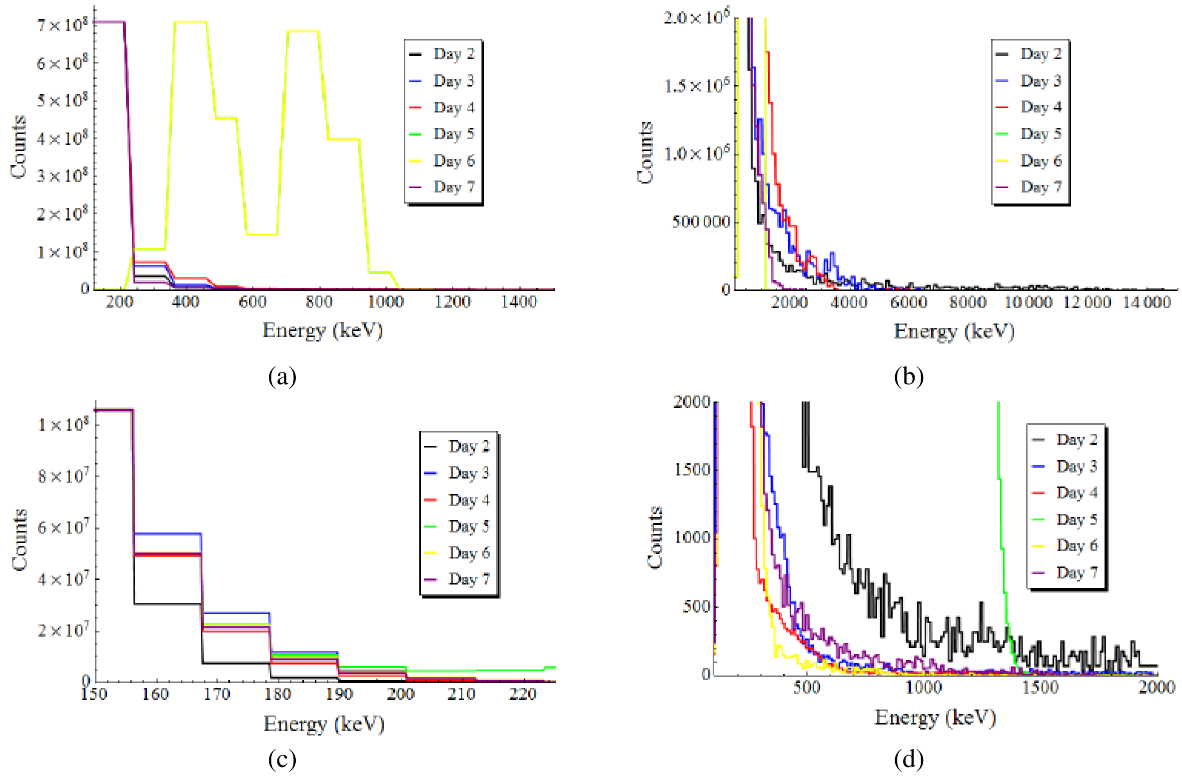

Figure 4. Spectra obtained during deuterium exposures of the palladium coated diamond sensor with (a)–(b) low sensor gain and (c)–(d) high sensor gain.

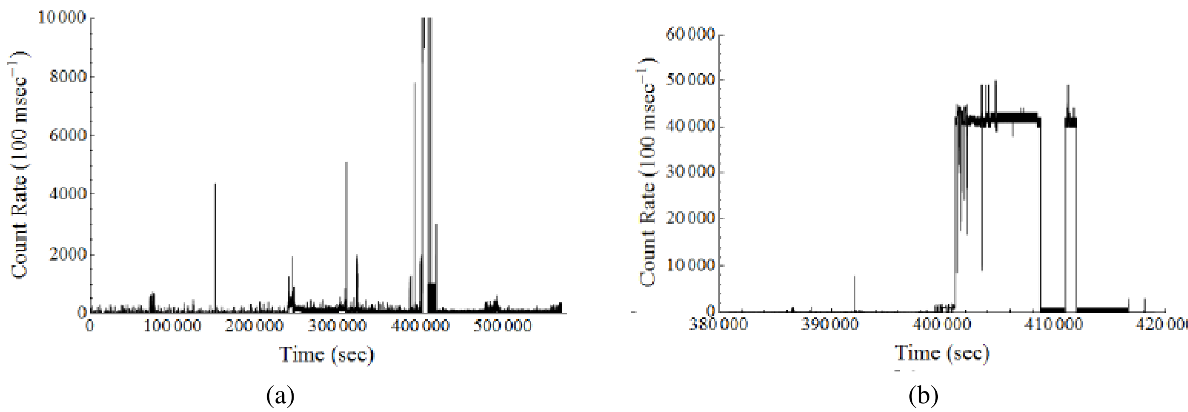

Figure 5. Count rate data for the hydrogen exposures of the palladium coated sensor for a) the entirety of the experiment and b) during the count rate burst.

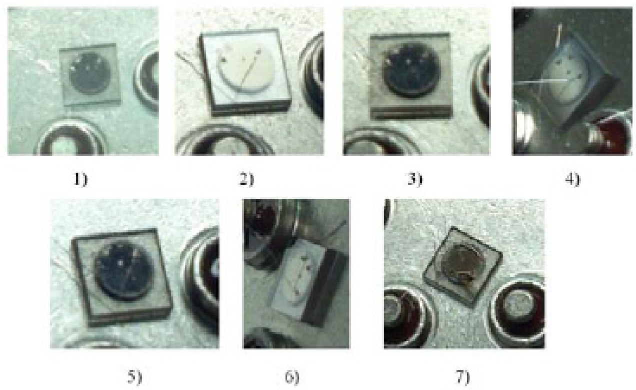

Figure 6. Pictures of the electrode on the diamond sensor between each data acquisition from the pressurized hydrogen run. The indexes of the pictures represent the days of exposure that has been completed.

in Fig. 4(b) account for this large difference. Still, the resolution of these peaks is poor due to the gain and the better resolution is in the low gain data collected but the curve is not shown in Fig. 4 but is shown in Fig. 7 with an interpolation order of one. In this figure, it can be seen that there are three peaks seen. The results are interesting in that the peaks increase in intensity as the energy increases. The three peaks seen are at 312.5, 658.5, and 881.7 keV. With the count rate data shown in Fig. 5, it is suspected that these peaks occurred during a 20 000 s interval in day 5. The count rate seems to jump quickly and plateau as can be seen in Fig. 5(b) but an analysis of the hardware used implies that the count rate ceiling was not reached.

After day 5, the count rate lowered back down to expected levels and then the cathode delaminated after day 7. The surface was scanned with a microscope to identify any anomalies, such as crater formation reported in other reports in LENR. There are two regions where there seems to be some sort of feature that could be regarded as crater formation but at this time it is not clear because the electrode was not scanned immediately before the experiment was conducted.

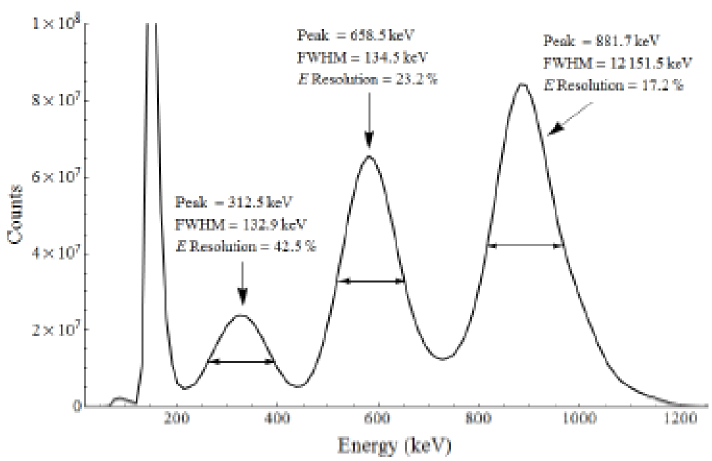

Figure 7. Spectrum obtained from day five of the deuterium run with low amplification of the acquired signal.

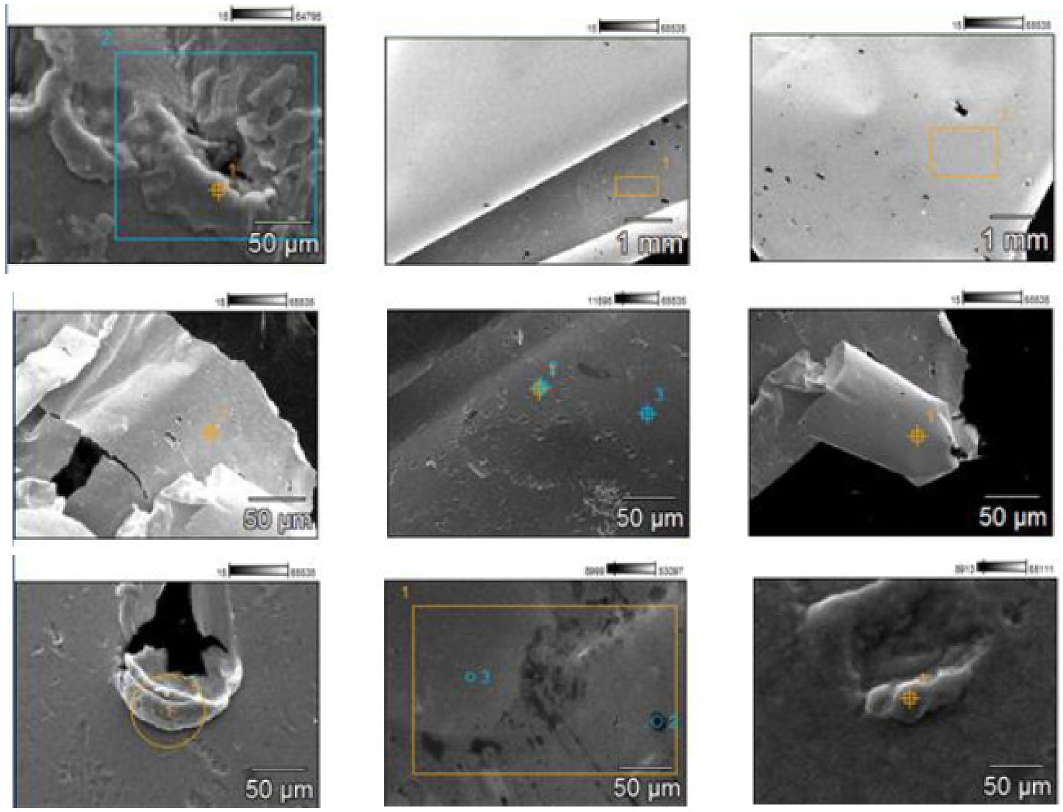

Figure 8. Microscopic analysis of the delaminated palladium electrode of the deuterium run after day seven.

4. Conclusion

The results shown for the deuterium run raise some important questions. First, if the radiation released where monoenergetic then this type of spectral response would not be seen. This suggests that the results are from a polyenergetic source such as beta particles or is a facsimile of the system. Since there was only one result from two experimental

Table 3. The normalization factors in time and total peak counts low gain amplifier output signals for "pressurized deuterium experiment".

Run	Time	Counts
Day 1	–	–
Day 2	0.58	35.57
Day 3	0.92	4.00
Day 4	1.00	1.00
Day 5	0.62	1.26
Day 6	0.77	5.79
Day 7	0.79	8.07

Table 4. The normalization factors in time and total peak counts high gain amplifier output signals for "pressurized deuterium experiment".

Run	Time	Counts
Day 1	–	–
Day 2	1.01	139073
Day 3	1.58	124573
Day 4	1.56	105499
Day 5	1.00	1
Day 6	1.33	307092
Day 7	1.38	327650

runs that produced this result, it is very possible that the data seen is due to spikes that overtook the power conditioner from the electrical lines in the building or even a loose cable. The former is a definite possibility while the latter is less likely because of when the effect took place in time in the experimental run. If the spectra seen was indeed from beta particles then there is the question of why there is a sharp spike in count rate and correspondingly, a sharp decrease. If any sort of transmutations were occurring to produce radioactive beta emitters such as Ag-104, then it begs to reason that the count rate should follow some sort of exponential decay. Still, there could be another mechanism that does not correspond to this type of reaction mechanism.

Suffice it to say there are many questions raised by these results. The results may be from charged particles, RF noise, or from some other phenomena and the experiment must be reproduced with more scrutiny and detailed analysis of the system to verify the source of these signals. Further, a correlation of any count rate spikes with excess heat generation should be made to help better define what reactions could be responsible for the observed results.

Acknowledgements

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References

[1] Eric Lukosi, Mark Prelas, Joongmoo Shim, Haruetai Kasiwattanawut, Charles Weaver, Cherian Joseph Mathai and Shubhra Gangopadhyay, Diamond-based radiation sensor for LENR experiments Part 1: sensor development and characterization, *17th ICCF Conf. Proc.*, Seoul, South Korea, August 12–17, 2012.