Analysis of an attempt at detection of neutrons produced in a plasma discharge electrolytic cell

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R. Faccini et al. [1] have attempted a replication of an earlier experiment by D. Cirillo et al. [2] in which neutrons [as well as nuclear transmutations] were observed in a modified Mizuno cell. No neutron production is observed in the recent experiment [1] and no evidence for microwave radiation or nuclear transmutations are reported. A careful analysis shows major technical differences in the two experiments and we explore the underlying reasons for the lack of any nuclear activity in the newer experiment.

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I. INTRODUCTION

For over a decade, concentrated experimental efforts have been dedicated to perfecting conditions appropriate for igniting nuclear activity in modified electrolytic plasma Mizuno cells. Detection of a distinct neutron flux using modified CR-39 neutron counters in a host of specially prepared electrolytic cells was presented in [2] and nuclear transmutations were also observed in a series of such experiments.

Hence, the lack of any nuclear activity in [1] done with a meagre set of three runs, yet purporting to replicate the earlier exhaustive sets of experiments culminating in [2], may at first sight appear contradictory. But we shall show in this paper that there are substantial technical differences both in the preparation of the conditions within the electrolytic cell as well as in the neutron measurement technique to render the two experiments strikingly apart. Ignition of a nuclear reaction occurs only under specific experimental conditions and hence they need to be followed. From the details of the set up described in [1], it would appear as if the newer experiment was designed to suppress the onset of any nuclear activity.

In Sec. (II), the differences in cathode preparation, its cover and its positioning relative to the anode in the two experiments are discussed. Plasma conditions between the two experiments are reviewed in Sec. (III). The choice and physical positioning of their neutron detectors are considered in Sec. (IV). In the concluding Sec. (V), we briefly indicate how the drastically modified conditions in [1] are responsible for their null results.

II. PREPARATION AND POSITIONING OF THE CATHODE & THE ANODE

Surface dynamics is notoriously difficult to control and hence specific conditions must be satisfied for a proper comparison between two experimental set ups. Workers experienced in the workings of a Mizuno type cell know how important is the preparation and positioning of the cathode surface. For the purpose at hand (ignition of nuclear activity), the cathode surface needs to be cracked, with sharp points but certainly not a regular surface. The theoretical reason for a “rough” versus a smooth surface is that near a sharp or irregular point the electric field is much larger thus leading to a larger \( \gamma \) factor for the excited electron mass [2][3]:

\[
m^* = \gamma m,
\]

and \( \gamma \geq 2.5 \) for neutron production. Sharper points on the electrode surface also give rise to hot spots on the surface where extensive nuclear activity can occur. Absorption of a significant number of protons on the metal surface produces a non-smooth surface. No details are available in [1] about this point.

The inner diameter of the tube covering the cathode is an important parameter. A given diameter shall lead to a specific plasma condition and different choices would lead to different plasmas. We stress the obvious point that different plasmas give different results. Some fundamental requirements have to be carefully considered for a given set up and the inner diameter has to be appropriately chosen. No discussion about this matter has been provided in [1].

The positioning of the anode and other features such as its mesh and dimensions are important conditions to obtain a given plasma. There is no information given on this subject in [1].

Another important discernible difference between the
two experiments is the following. In [1], there is a thick quartz wall between the cathode and the anode. Its presence modifies the experimental set up considerably. There is no such wall separating the two electrodes in [2]. We shall return to this point in the next section.

**III. PLASMA CONDITIONS**

The cathode cover used in [1] is quartz and alumina in [2]. This cover serves to expose a proper surface for the plasma and for driving the electronic paths (the electrolytic current) in a region far from the plasma (an area of higher quiescence). It has to provide a correct passage for the electric current essential for a sustained stable plasma. If the conditions are not met, the plasma remains unstable. Hence, the inner diameter of this pipe cover is a sensitive parameter that ultimately determines whether an experiment is of a good quality.

The quality referred to in the last paragraph concerns the stability of the plasma in the cell. It is discerned quite reliably through the voltage-current characteristic. It is well known from Mizuno cell type experiments under discussion, such as in [2], that stable glow discharges with stable currents are achieved for voltages in a given range particular for each set up. We show in Fig.(1) the voltage V and the current I as a function of time for one of the cells in [2]. For this case, the appropriate range is between about (210 ± 20) Volts. The region of voltage below this range for this cell would be unsuitable.

No V – I characteristic is shown in [1]. However, the trend of CR-39 neutron flux shown there for one of the runs [Run 1A] is (280±32) n/cm²sec for (150 – 200) Volts whereas it decreases to (166±32) n/cm²sec. for the larger range (150 – 300) Volts in another run [Run1D]. Such an odd and unphysical result confirms our assertion that at best their current and hence their plasma cannot have been very stable. This is a serious lacuna in the Rome experiment [1].

In Fig.(1) of the Rome paper [1], the colour of the plasma shown due to potassium excitation appears violet interspersed with cloudy light around the cathode and quite likely the temperature reached is insufficient for the purpose at hand. By contrast, there is a steady glowing white plasma in [2].

**IV. NEUTRON DETECTION**

Next we turn to an analysis of the neutron detection techniques employed in the two experiments.

Low energy neutron production on an electrode surface (via surface plasmon polaritons for example) is theoretically expected to occur through random bursts, it is not a continuous production process. It is for this reason that neutron detection through indium detectors that are calibrated from known continuous neutron sources is not a reliable device [4]. In fact, no neutrons were detected through indium detectors in [2]. Not surprisingly a similar result was found also in [1].

On the other hand, there is a sharp difference between the results of the two experiments with CR-39 detectors. The method based on CR-39 + boron can provide a measurement of the plasma-generated neutron flux albeit with a low efficiency. Hence, this method can and has been used to obtain clear evidence of thermal neutron generation, whereas other methods might fail (i.e. conventional sample saturation, electromagnetic detectors).

In the Rome experiment [1], the CR-39 etching treatment had a duration of around 90 minutes at a temperature of 70°C with 6.25 N KOH. In the Naples experiment [2], such a process had a duration of around 5 hours at 63°C with 6.2 M NaOH. Considerable time period difference in the etching process can cause a substantial change in the counting of tracks.

When CR-39 is covered with boron, the granularity of the boron layer used in [1] is unknown whereas for the experiment [2] the granularity of the boron powder is an important parameter for detection efficiency. This parameter determines the “mean free path” of the emitted alpha particles.

In the Rome experiment [1], CR-39 + boron gave no signal when exposed to a known thermal neutron flux. We quote from [1]: “At the same time, CR-39 detectors covered with a thick boron coating were exposed to the calibration flux, but no significant signal was observed”.

This is a strong clue towards substantial differences in the detector assembly of the two experiments. Apparently, the CR-39 + boron detector in [1] did not work properly.

By contrast, we show in Fig.(2) the calibration of the CR-39 + boron detector. At the top of each sample, one can find the value of the measured number of tracks/mm².

In Fig.(3) we show the measured track density through the apparatus [2]. In this figure, the horizontal plots (CR-39 Sample 1, 2, 3, 4, 5) show a given sample exposed for a given time to the known thermal neutron flux so that we know that the track density measured by CR-39 sample 1, for example, is similar to the track density exposed to
FIG. 2: Calibration of the CR-39 neutron detector. This figure shows the track density for each calibration sample P/N (i.e. the sample N97514 shows 5 tracks/mm$^2$). The samples in this plot were exposed to a well known thermal neutron flux at ENEA.

FIG. 3: The number of tracks/mm$^2$ is shown as a function of the time of exposure (in minutes). See text for explanations and more details about this plot.

V. CONCLUSION

Our analysis identifies several important differences between the two experiments both in the preparation of the cell, the characteristics of the plasma, the choice of the neutron detectors etc., so much so that it would be inappropriate to call [1] a replica of [2]. On this basis, it is also safe to conclude that all of the three runs described in [1] were geared to produce no nuclear activity and hence no neutrons, no microwave radiation and no nuclear transmutations [7]. Hence, this experiment fails to provide any valid criticism against substantial neutron production and nuclear transmutations found through myriads of experiments with stable plasma as in [2].

Notwithstanding uncertainties inherent in the neutron detection processes as discussed in [2] and in previous experiments, the Rome experiment [1] is not a falsification of the nuclear activity results found in [2]. A true falsification of an experimental result requires an accurate and exact replication of it by another experiment. The experiment described in [1] does not do this correctly.

VI. ACKNOWLEDGEMENT

YS would like to thank Dr. V. Violante for useful correspondence regarding changes in his conclusions about his past experiment with surface plasmon polaritons and the experiment described in [1].

Such a measurement system is insensitive to electromagnetic noise (such as Geiger or other measurement devices when the plasma is switched off). However, it also implies as stated in the text, the inadequacy of the indium device for reliable measurements from bursts or spiked emissions due to lack of statistics for the flux to activate the sample in the conventional way (to wit, as with a continuous flux). The cross section for thermal neutrons with $^{115}$In is 170 barns.

[1] R. Faccini et al., arXiv: 1310.4749v1[physics.ins-det] 17 October 2013.
[2] D. Cirillo, R. Germano, V. Tontodonato, A. Widom, Y.N. Srivastava, E. Del Giudice, and G. Vitiello Key Engineering Materials 495, 104 (2012); ibid. 124 (2012).
[3] A. Widom, J. Swain and Y. Srivastava, arXiv:1305.4899v1 [hep-ph] 19 May 2013.
[4] Very briefly, the results from experimental observations in [2] are as follows. Exposing an indium sample ($^{115}$In; with 96% isotopic abundance) to a known thermal neutron flux for twice the half life of indium (the metastable indium $^{116}$In$^*$ has a half life of 54 minutes to beta decay into $^{116}$Sn), one obtains its “saturation”, or otherwise said, a nuclear indium activation. If one then takes the indium far from the flux, insert the sample in a lead box containing a Geiger counter switched for beta decay measurements, one may follow the decrease of indium nuclear activity until the half life i.e., after 54 minutes. Analyzing this rate allowed them to determine the activating neutron flux.

[5] Dr. Violante has kindly pointed out that his earlier preliminary observation of a substantial change (by a huge factor of 1360%) in the ratio between two isotopes: Cu$^{65}$ vs Cu$^{63}$ after a surface plasmon polariton process initiated by a laser beam, was due to contaminants. See [6] (Private communication to YS).
[6] P. Avino, E. Santoro, F. Sarto, V. Violante and A. Rosada, J. Radioanal. Nucl. Chem.; DOI 10.1007/s10967-011-1296-3, 2011.