Slow Neutron Generation
by Plasma Excitation in Electrolytic Cell

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INTRODUCTION

This paper is part of the panel session "Discussion of Low-Energy Nuclear Reactions" and it presents some significant experimental findings in the LENR field. We review recent and updated results of neutron generation and significant results of earlier transmutation results. A low neutron flux emitted by the cathode region of an electrolytic cell with alkaline solution and triggered by cathodic plasma activity is reported. The experimental evidences obtained in the last three years are discussed. Such evidences may be summarized as follows: given the correct conditions in the electrolytic plasma in our cell, emissions of low fluxes of neutrons and nuclear transmutations have been observed. A method based on a CR-39 nuclear track detector coupled to a boron converter $^{10}B(n,\alpha)^7Li$ was used for neutron detection.
This method is insensitive to the strong plasma-generated electromagnetic noise that made results of all the previous attempts to identify neutrons in electrolytic plasma environment by means of electric detection techniques inconclusive.

DESCRIPTION OF THE EXPERIMENT

The generation of an electrolytic plasma of suitable current, voltage and frequency may produce unexpected experimental results. Several studies on similar test configurations have been performed since 1997 [1-6]. The common path has shown that a plasma ignited under high voltage conditions in an electrolytic cell may give: a thermal power generation that exceeds the input electric power [1-6] and the revelation of new elements on the cathode surface and/or in the electrolytic solution, absolutely absent in the experimental set-up components before the experiment [1,2,6].
In order to find an origin for these anomalous phenomena, a quest for slow neutron measurements has been performed . We started considering that the neutrons may easily excite the atomic nuclei because they are insensitive to Coulomb repulsion.
During past experimental campaigns, we and other groups have tried to measure a possible neutron flux near the plasma discharge through the use of electronic detectors (BF_3, He_3), or other modes (indium activation) but the strong electromagnetic noise produced during plasma tests, or the saturation time required, have falsified that previous evidence [1]. Until now, no indisputable evidence of neutron generation during such experiments has been reported. In this paper we report such experimental evidence. The first main objective was simply to reveal evidence, in general, (without an exact measurement) for a possible emission of neutrons in the solutions subjected to plasma action. We used CR-39 solid-state nuclear track detectors ($C_{12}H_{18}O_7$ polymer - density 1.3 g/cm^3) which are commonly used for alpha or heavy particle dosimetry. Through this method, the particle tracks are mechanically recorded. The neutrons are detected through a boron converter that, in reaction with slow neutrons, may produce alpha particle emission. Particle tracks recorded by CR-39 detectors become visible after chemical etching treatment and are studied using a microscope.

Experimental details and results

An electrolytic cell, working in a glow discharge plasma, was used for the experiments.

The cell is a simple Pyrex vessel (with a thermostatic double wall) of 100 mm internal diameter and 220 mm height. The cathode is composed of a tungsten rod, completely covered at the upper extremity by a ceramic casing (Al_2O_3) which allows precise control of the length of the lower portion of the electrode which is exposed to electrolysis (fig.1).

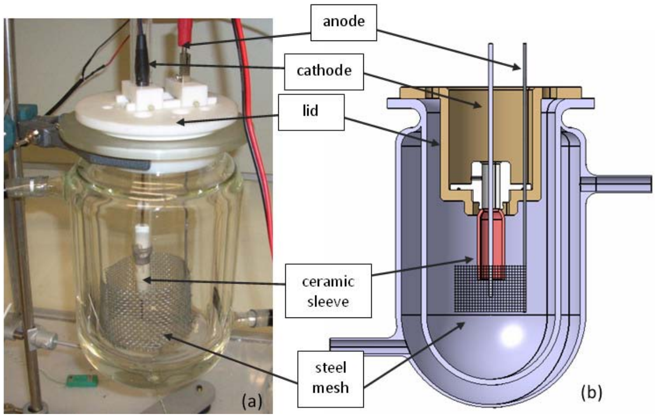

Fig. 1. Electrolytic cell: photo (a) and scheme (b).

The anode is a steel mesh placed around the cathode. The electrolytic solution (pH > 10) is composed of light distilled water, with 0.5 M analytical-grade potassium carbonate, K_2CO_3 (solution). The cell was DC powered through a stabilized power supply. An electronic interface system were designed for data acquisition and online monitoring of: voltage and current in the cell, temperature and water flux in the cooling equipment. The right conditions for plasma activation are reached when the electrolyte goes over 70°C, obtained through an external heating cartridge. This temperature's threshold is the edge for high electrical conductance required by testing (about 12000 µS).

The method used to identify the plasma-generated neutrons was based on a CR-39 nuclear track detector coupled to a boron converter. CR-39 detector (10 × 10 × 1 mm^3 active volume) was inserted into a polystyrene cylinder (hermetically sealed) and covered by analytical-grade boric acid grains, H_3BO_3, (0.5 mm average grains size), used as neutron converter (Fig.2). The detector was positioned into the electrolyte in close proximity to the plasma discharge. Through the $^{10}B(n,\alpha)^7Li$ nuclear reaction [8-11], the neutron flux is converted into α particles detectable by the CR-39 sample. The H_3BO_3 that we have used contains boron that follows natural isotopic distribution: 18.7% ^{10}B and 81.3% ^{11}B. It is known that thermal neutrons (0.025 eV average energy) induce ^{10}B fission: the thermal neutrons hit the ^{10}B nuclei breaking them into α particles (detectable by the CR-39), excited ^{7}Li nuclei and γ–photons. Following possible reactions:

$$^{10}B + \text{n (thermal)} \rightarrow \alpha\ [1.47\ \text{MeV}] + {}^7Li + \gamma\ (93.6\%)$$

$$^{10}B + \text{n (thermal)} \rightarrow \alpha\ [2.79\ \text{MeV}] + {}^7Li\ (6.4\%)$$

The α particles have an energy compatible with the sensitivity range of the detector [0.04 ÷ 4 MeV]. The α particles leave damage tracks on the detector sample that become visible after an etching treatment in 6.2 M $NaOH$ solution at 63°C, for 5.5 h. The tracks were observed by means of an optical microscope (80X ÷ 1200X).

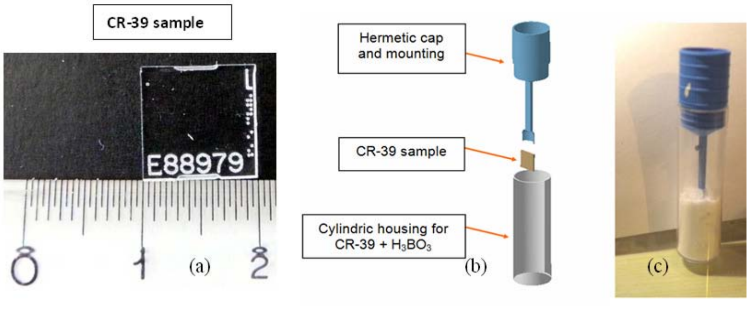

Fig. 2. CR-39 nuclear track detector (a), neutron detector diagram (b) and photo (c).

The detector was calibrated by exposure to a reference neutron flux generated by a Am-Be neutron source with graphite and polyethylene shield, regulated on a thermal neutron rate of 1.24 × 10^4 cm^{-2} s^{-1} equivalent to 0.12 µS/s, with an average energy of 0.025 eV (Maxwellian distribution) at the Italian Metrology Institute of Ionizing Radiations (INMRI-ENEA, Casaccia Research Center, Roma, Italy). 17 detector samples were exposed to the known flux of thermal neutrons (120 ns^{-1}mm^{-2}) for different exposure times: 1, 5, 20, 40, 60, and 0 min. (blank sample). Then all the samples were chemically etched and the resulting tracks were analyzed by means of an optical digital microscope with a magnification 80X. For each CR-39 sample, 10 images were recorded and the tracks counting was performed using a dedicated image analysis software (Fig. 3).

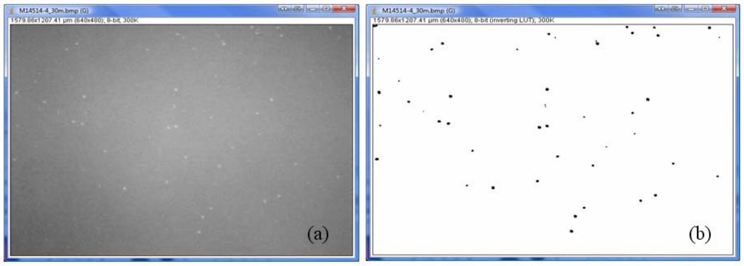

Fig. 3. CR-39 tracks in an image acquired by a 80X magnification digital microscope (a), and the same elaborated by the counting tracks software (b).

The samples were divided in several groups, each group with the same neutron exposure time. For each group, an average value of the neutron tracks density was calculated. The calibration results are reported in Table 1. Fig. 4 shows the average tracks density as function of the exposure time. We found a monotonic dependence of the track density on the exposure time to the calibrated thermal neutron flux.

It is important to remember that these thermal neutron flux measurements have relatively low efficency. This is because of the sequence of events required to produce a track on the CR-39 detector: neutrons must be emitted into the detector at a solid angle, then they have to meet a ^{10}B nucleus contained in the boric acid grains (18.7 % ^{10}B among the total B contained in H_3BO_3), then the α particles must be emitted into the detector at a solid angle, reach the detector sample without being absorbed by the converter material and finally they must hit the detector leaving a new track in a sample area free of previous ones.

After the calibration stage, the same type of CR-39 samples were used to search for neutrons produced by the electrolytic plasma. The detectors were exposed to the electrolytic plasma generated at a voltage intensity exceeding 280 V DC, for a time of 500 s. After each test, the CR-39 samples were etched in the same conditions used for the calibration samples and the tracks were analyzed by the same procedure. During each test, control 'blank samples' of CR-39 detector were positioned in a laboratory area far from the electrolytic cell activity (> 5 meters).

A significant number of tracks were recorded by the CR-39 detectors exposed to the plasma discharge, while the corresponding blank samples did not reveal any relevant activity. Fig. 4 shows three typical track densities evidenced by the different CR-39 samples exposed to the electrolytic plasma for 500 s. The comparison between track density obtained during the calibration phase (thermal neutron flux 120 $ns^{-1}mm^{-2}$) and track density obtained during the plasma activity shows clear neutron activity produced by the electrolytic plasma.

CR-39 sample code	Exposure time (min.)	Average track density (tracks/mm^2)	Group average track density (tracks/mm^2)
N97514	0	5	5
N99276	1	5	7
N99284	1	10	
M14678	1	6	
N97550	5	10	9
N99310	5	12	
N99142	5	8	
N99117	5	8	
N99121	20	18	28
N99120	20	37	
N99113	40	23	32
N99311	40	36	
N99143	40	36	
N99262	60	40	47
N99321	60	41	
M14565	60	53	
M14620	60	55	

Table 1. CR-39 track density after different exposure times 1, 5, 20, 40, 60, and 0 min. (blank sample) to a calibrated thermal neutron flux of 120 $ns^{-1}mm^{-2}$.

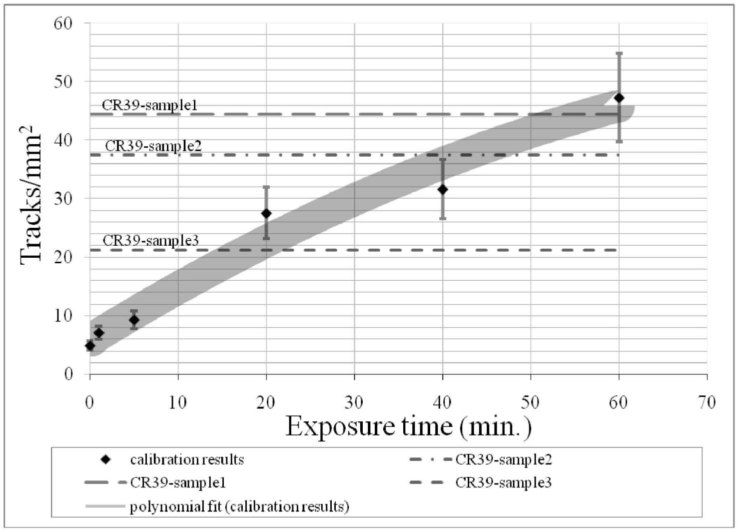

Fig. 4. Average track density vs. exposure time for three CR-39 detectors exposed to calibration source and for three samples exposed to plasma electrolysis.

RESULTS

The neutron detection method based on CR-39 nuclear track detectors, coupled with a boron converter, has demonstrated neutron generation by plasma discharge in an electrolytic cell with alkaline solution. A significant number of tracks were revealed by the CR-39 detector samples positioned in close proximity to the plasma discharge, next to the tungsten cathode of the electrolytic cell, while the blank detectors show no tracks. The comparison between the track density values obtained under both plasma and controlled neutron-flux exposure shows equivalent results. This enabled us to state that the plasma discharge obtained through decribed conditions is a source of thermal neutrons. The low efficiency of this neutron detection method, that requires the thermal neutrons conversion into α particles and their subsequent capture on the detector sample, may provide a qualitative measurement for the plasma-generated neutron flux. Nevertheless, the proposed method provides clear evidence of thermal neutron generation in this low energy system.

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