J. Condensed Matter Nucl. Sci. 13 (2014) 6–12

Research Article

Detecting Energetic Charged Particle in D_2O and H_2O Electrolysis Using a Simple Arrangement of Cathode and CR-39

H. Aizawa, K. Mita, D.Mizukami, H. Uno and H. Yamada*

Department of Electrical Engineering and Computer Science, Iwate University, Japan

Abstract

Electrolysis of D_2O and H_2O solutions is carried out under several DC current patterns using a Ni film cathode. A CR-39 track detector is set in close contact with the cathode to detect an energetic charged particle. An impressive increasing in number of etch pit is occasionally observed.
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Keywords: CR-39, Low-energy nuclear reaction, Light-water electrolysis, Ni-film cathode

1. Introduction

The plastic track detector has become a popular method to detect energetic charged particles in low-energy nuclear reaction (LENR) studies especially in electrolysis experiments. In these studies, the evidence of the reaction is in the form of nuclear damage trails made visible by etching of the plastic chips. Oriani et al.[1,2], Lipson et al. [3,4] and Roussetski [5] have performed light and heavy-water electrolysis using the plastic track detector and have reported the generation of charged particle emission during the electrolysis.

However, there still exist technical complexities in using plastic detector in electrolysis experiment. In the previous studies, there have been a thin layer of electrolyte and/or a solid film between the cathode electrode and the plastic detector. Such construction could cause a considerable decrease in the energy of the charged particle emitted from the cathode.

In this present study, a chip of the plastic track detector CR-39 is positioned just under the Ni film cathode to limit energy decrease; a CR-39 chip of 30×30 mm in size is set in close contact with the rear surface of the cathode film. This construction avoids chemical attack on the chip by ions generated by the electrochemical reactions on the Ni film cathode. The present technique is simple but capable of detecting energetic charged particles produced on the cathode during electrolysis with higher efficiency. Using the present technique, we have studied energetic charged particle emission from the metal film cathodes for light and heavy-water electrolysis [6–8]. The primary purpose of this study is to establish a simple technique producing new convincing evidence that a nuclear reaction as LENR could accompany

*E-mail: yamadahi@iwate-u.ac.jp

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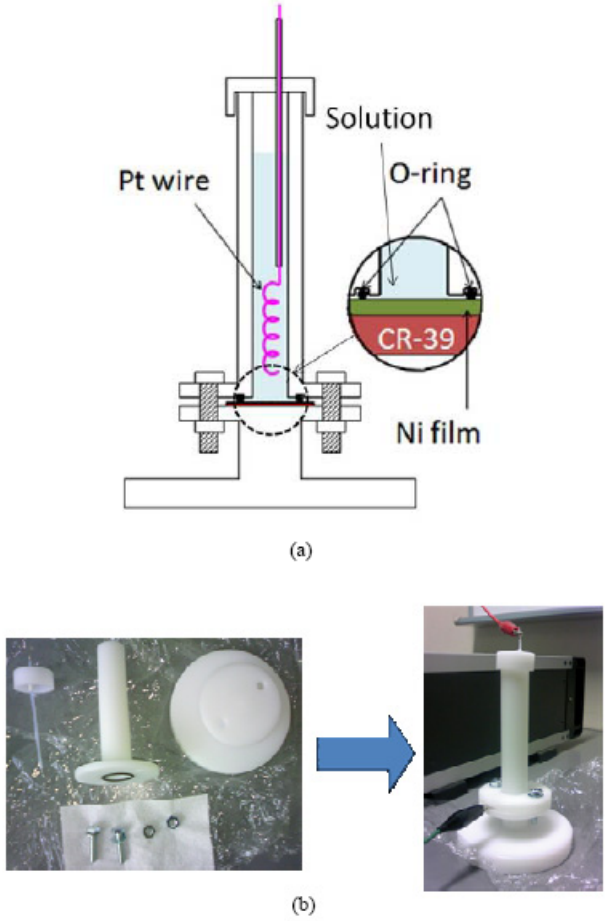

Figure 1. Test cell for the electrolysis, (a) vertical cross section, (b) the view of the component of the cell (*left*) and its assembled (*right*).

both heavy and light water electrolysis. Anomalous increase in number of etch pit has been observed in one out of seven and two out of five electrolysis conditions for D_2O and H_2O solutions, respectively.

2. Experimental

Electrolysis is carried out in a small plastic (polyoxymethylene) cell shown schematically in Fig. 1. It consists of a vertical plastic cylinder with 105 mm long and 10 mm inside diameter, a plastic stopper holding a wire anode, a lower portion of plastic base and a film cathode. The left-hand side and right-hand side of Fig. 1(b) display the components of the cell and the cell assembled, respectively. The top of cylindrical portion of the cell is covered by the plastic stopper with loose contact, which permits the escape of the gas produced by electrolysis. A 5 μm thick Ni film is used as the metal cathode for both heavy and light-water electrolysis. The film forms the inner bottom of the test cell and serves as cathode; the diameter of the cathodes is 10 mm. The anode is ϕ 0.5 mm Pt wire. The upper portion of it is sheathed by heat-shrinkable FEP tube surrounded with TFE and the lower part ($\sim$60 mm long) is formed a crude spiral with the

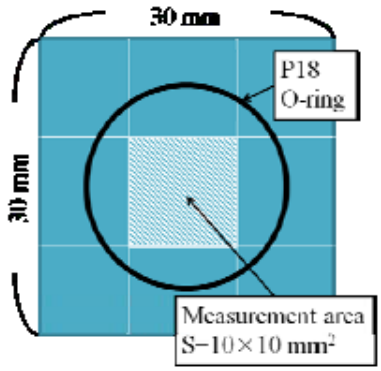

Figure 2. CR-39 chip.

diameter and length of ∼5 mm and ∼30 mm, respectively. The lower end of the spiral plane is parallel to the cathode surface with a gap distance of ∼10 mm.

A 30×30 mm chip is cut from a sheet of the track detector CR-39, produced by Fukuvi Chemical Industry Co. The chip is carefully manipulated with tweezers. The center area of the front surface, which contacts to the metal film, is scratched to form a 10×10 mm square line, before removing the manufacture-supplied blue protective film. The CR-39 chip is mounted in the electrolysis cell immediately after removing the protective film. The scratched surface is referred to as the front surface upon which the metal film cathode is overlaid. The rear surface of the Ni film cathode area is set in close contact with the surface of the inside area bounded by the scratched 10×10 mm square line on the front surface of the CR-39 chip. Both the Ni film and the CR-39 chip are clamped together on the disc forming the bottom cap of the cell with an O-ring seal.

The arrangement of the cathode and the CR-39 chip is shown in the small circle of Fig. 1(a). This construction is able to avoid chemical attack on the CR-39 chip by ions generated in the electrolyte and keep the ideal distance between the cathode and the detector chip. Thus, the construction could minimize the energy loss of charged particle, which is produced on the surface of the thin Ni film and penetrates through it in the electrolysis process, and would maximize the efficiency of the detecting particle.

The electrolyte solutions for the heavy water electrolysis are Li_2SO_4/D_2O and $LiOH/D_2O$. Those for the light water electrolysis are Li_2SO_4/H_2O, $LiOH/H_2O$ and Na_2SO_4/H_2O. The concentration of all the solutions is commonly 0.1-M. After the lower portion of the cell is assembled to form a small vessel, the ∼6 ml electrolyte solution is poured into the cell. Then, the stopper cap holding the anode is put on the upper opening.

The electrolysis is conducted mainly for 168 h under DC current range 3–160 mA at voltage range 3–30 V. The current for the electrolysis is supplied by a constant-current power supply and no water is added during the electrolysis.

The CR-39 chip used for control experiments is always cut from the same sheet, neighboring to that for the corresponding electrolysis experiment and is carefully handled in exactly the same way as that used in the electrolysis experiment. In the control experiment, which is designated "Control" in the figures, the CR-39 chip is mounted in the same designed test cell as that for the electrolysis with an unused Ni film and a solution and is positioned in the near the ongoing electrolysis cell during the electrolysis. The exposure time of CR-39 for the control experiments in the absence of electrolysis is same length as that for the electrolysis experiment. After the electrolysis and control experiments, the cell assemblies are immediately disassembled to remove the CR-39 chips and the Ni films used.

The CR-39 chip is etched in 6 N NaOH solution for 7 h at 70°C immediately after each experiment. The measurement

Table 1. Electrolysis condition and result

Solvent	Electrolyte	Current pattern	Total electrolysis period/run	Number of runs	Number of impressively positive runs
D_2O	Li_2SO_4	20 mA	168 h	5	0
		20 mA/20 min-R	200 min	5	0
		20 mA/24 h-R	168 h	5	1
		3–160 mA	168 h	5	0
	LiOH	20 mA	168 h	5	0
		20 mA/24 h-R	168 h	5	0
		3–160 mA	168 h	5	0
H_2O	Li_2SO_4	3–160 mA	168 h	3	2
	LiOH	20 mA	168 h	5	0
		3–160 mA	168 h	5	1
	Na_2SO_4	20 mA/24 h-R	168 h	5	0
		3–160 mA	168 h	5	0

of etch pit is carried out using a digital microscope system (KEYENCE VHX-200), consisting of an optical microscope with a camera and a PC. The measurement area 10 × 10 mm is the center of the chip surface as shown in Fig. 2.

The electrolysis experiment is performed under total 12 electrolysis conditions for H_2O and D_2O solutions and all the electrolysis conditions are compiled into Table 1. There are 4 DC application patterns in the 12 electrolysis conditions. The patterns are designated "20 mA", "20 mA/20 min-R", "20 mA/24 h-R" and "3–160 mA", as indicated in Table 1. The "20 mA" means that the application current is constant DC 20 mA for one week. The "20 mA/20 min-R" consisted of eight cycles; the application current is DC 20 mA with negative cathode for 20 min, followed by DC 20 mA with positive cathode for 5 min in each cycle. Thus, the total electrolysis time is 200 min. The "20 mA/24 h-R" consisted of seven cycles; the application current is DC 20 mA with negative cathode for 23 h and 55 min, followed by DC 20 mA with positive cathode for 5 min in each cycle. The total electrolysis time is 168 h. The "3–160 mA" means that DC is changed from 3 to 160 mA in stepwise every 24 h.

3. Result and Discussion

It may generally be necessary to distinguish nuclear pits produced during electrolysis from artifacts caused by manufacturing defects in the detector plastic. The appearance of the nuclear pits is thought to have much darker wide rim in the microscope. Because the pit has a relatively deeper bottom and the diameter of the bottom is rather small compared with that of the rim. However, there still exist many ambiguous pits whose origin, nuclear or artifactual, is hardly determined. Thus, the etch pits with narrow darker rim are not excluded in counting in this study; all the etch pits observed are counted. The pits are counted only within the inside area bounded by the scratched 10 × 10 mm square

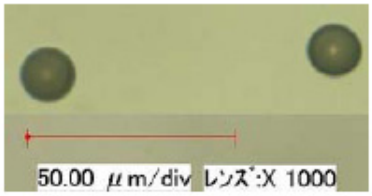

Figure 3. Photomicrograph of a surface of the CR-39 chip, providing a pair of etch pits.

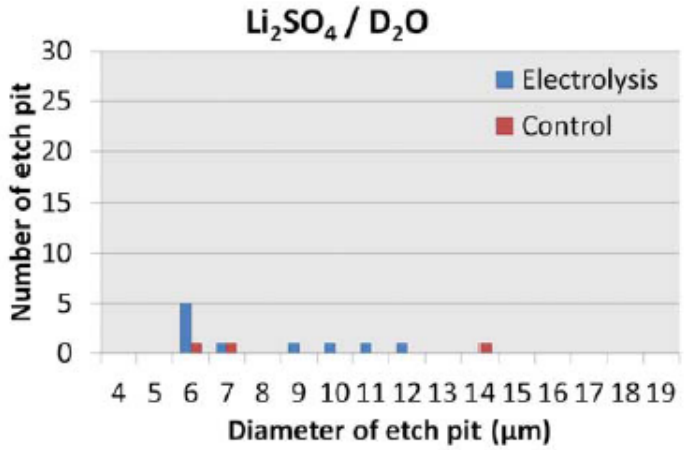

Figure 4. Distribution of etch pit diameter, indicating no difference in number of etch pit between electrolysis and control experiment.

line on the front surface of the CR-39 chip. The number of pit in the inside area is compared with that found in the control chip. Figure 3 shows the typical photomicrograph of pits, which are thought to have the nuclear origin.

The control experiment is expected to give some nuclear tracks already present in the CR-39 sheet as received from the supplier, as well as those produced during the entire experimental process by radioisotopes such as radon in the environment. Some of the pits originating from manufacturing defects will unavoidably have a similar form to that of nuclear pits. For instance, one of the lot of CR-39 sheets has provided higher density of etch pit in almost all the control CR-39 chips from the beginning [8].

The result for all the 12 electrolysis conditions is compiled into Table 1. Most of the experiments for 12 electrolysis

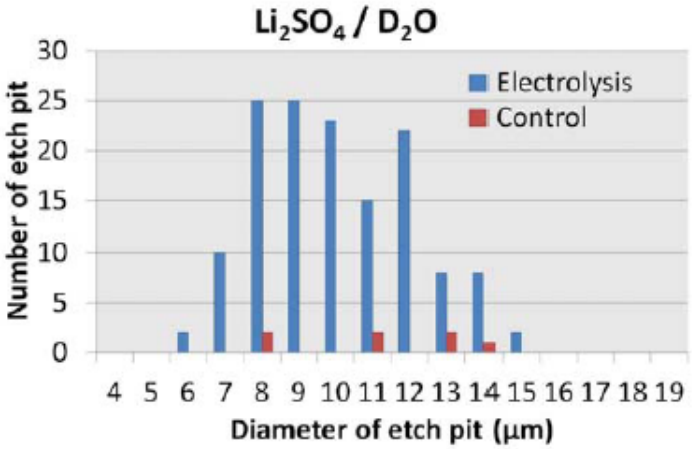

Figure 5. Distribution of etch pit diameter, indicating a marked difference in number of etch pit between electrolysis and control experiment.

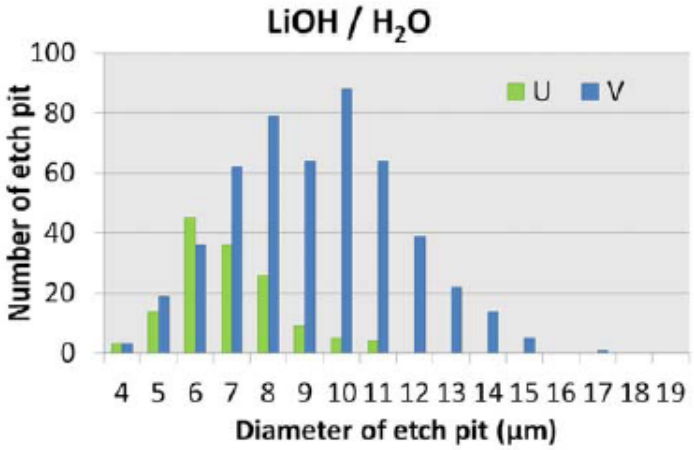

Figure 6. Distribution of etch pit diameter with a marked increase in number of etch pit for electrolysis experiment.

conditions using both solutions have revealed no apparent increase in number of etch pit as well as no apparent difference in the distribution of etch pit diameter between the electrolysis and control experiments. Figure 4 shows such typical relation between total number and the diameter of the etch pit for electrolysis and the corresponding control experiment. The electrolysis has been carried out under constant DC 20 mA application for 168 h with Li_2SO_4/D_2O solution, in this case.

Besides, there are several ambiguous runs hard to be excluded from positive result. Accordingly, we have focused our interest on only the impressive positive result in this study. The marked difference in number of etch pit and in the distribution of etch pit diameter between electrolysis and control experiment has been observed in one out of seven electrolysis conditions for D_2O solution.

The only significant difference is obtained from the current pattern "20 mA/24 h-R" by the Li_2SO_4/D_2O electrolysis, as shown in Table 1. Figure 5 provides the distribution as the relation between total number and the diameter of the etch pit for these electrolysis and control experiments. The number of etch pit for electrolysis quite different from that for control experiment is seen in the figure. There exists no peak in the distribution for the control experiment, similar to that in Fig. 4. While a semi-Gaussian distribution with large number of etch pit ranging 7–12 μm is seen for the electrolysis experiment. It should be pointed out, as mentioned above, that the difference of etch pit diameter between electrolysis and control experiment will not always appear in each run, even though the electrolysis is carried out under the same experimental condition.

The impressive difference in number of etch pit has been occasionally observed in two out of five electrolysis conditions for H_2O solution as well as D_2O solution. The marked increase in number of etch pit for electrolysis experiment has been obtained commonly using the current pattern "3–160 mA" for the H_2O solution, as shown in Table 1. Figure 6 shows one of these distributions for $LiOH/H_2O$ electrolysis. Only two etch pits have been observed for the control experiment. Contrary, considerable large number of 638 has been observed on single CR-39 chip for electrolysis experiment. Thus, the data for control experiment is excluded from the figure; it presents rare but possible feature.

Even though the pits with shallow form having narrow darker rim in the microscope are usually not distinguished from those with deeper bottom having much darker wide in this study, the 638 pits are classified into two types. One with shallow form and the other with deeper bottom are designated "U" and "V" in Fig. 6, respectively. Similar semi-

Gaussian distribution to that seen in Fig. 5 with a large number of etch pit ranging 6–12 μm is also seen in Fig. 6. It is interesting to note that the distribution of "U" looks different from that of "V". There exists a possibility that the two distributions correspond to two particles with different energies of the order of MeV.

It is demonstrated that the impressive increasing number of pit on the CR-39 chips could be attributed to a nuclear process occurring at the Ni film electrode in the operating electrolysis cell. The common key factors to increase number of the anomalous etch pit for both D_2O and H_2O solutions might be Ni film cathode, the long electrolysis time of 168 h and Li in the electrolyte solution. The diffusion constant of D/H in Ni is so small that the density of D/H in near surface of Ni film cathode could be saturated in short time. Consequently, the density of D/H in the uppermost surface region of Ni film might become large enough for the LENR to occur within the 168 h after beginning of electrolysis.

It has already been confirmed that the current flowing through the metal cathode, the solution temperature and mechanical stirring of solution have no effect on producing tracks at all [6].

4. Conclusion

A simple experimental technique using thin Ni film in conjunction with the track detector CR-39 is presented to detect energetic charged particles produced by a nuclear reaction in heavy and light water electrolysis. Anomalous increase in number of etch pit has been observed in one out of seven and two out of five electrolysis conditions for D_2O and H_2O solutions, respectively.

The result suggests a LENR occurring on the Ni film cathode during the light-water electrolysis as well as the heavy water one. The common factors to increase number of the anomalous etch pit in the CR-39 chip might be Ni film cathode, the long electrolysis time and Li in the electrolyte solution. All the results indicate a characteristic of LENR in the electrolysis that the reaction does not always takes place in every electrolysis experiment but occasionally does under the same experimental condition.

Acknowledgment

This work is financially supported by a Grant-in-Aid for a Challenging Exploratory Research (23656205) in the Scientific Research Foundation from MEXT in Japan.

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