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Research Article

Visible Blue-White Scintillation by Energetic Charged Particle Emission From Ni Film Cathode in Light Water Electrolysis at Room Temperature

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Abstract

The primary purpose of this study is to establish a simple method producing new convincing evidence for the anomalous emission of an energetic charged particle in the electrolysis at room temperature. Electrolysis of H_2O solution is carried out using a Ni film cathode under the DC condition. The scintillator of ZnS(Ag) is positioned in close contact with the rear surface of the thin Ni film cathode to observe the visible scintillation and to recognize the energetic charged particle emission from the Ni film cathode. Using the simple technique, visible scintillation is identified during the electrolysis. The scintillation appears in a very short moment with the color of blue-white. The considerably high count rate of the flash from the scintillator in the electrolysis experiment is obtained comparing with the rate in the control experiment.
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Keywords: Energetic charged particle, particle emission, Ni film, light water electrolysis, scintillation, ZnS scintillator.

1. Introduction

The excess heat production and the anomalous emission of the energetic charged particle from condensed matter by several experimental methods have been reported, even though those results do not seem to be accepted generally. The difficulty in the acceptance is supposed to owe to the complexity of the experimental procedures employed and the low reproducibility of the results reported. While the experimental method using track detectors is simple to confirm the evidence of the particle emission. The evidence of the emission is in the form of damage trails made visible by the etching of the plastic chips [1]–[9]. We have reported a remarkable increase in the number of etch pits on the plastic track detector CR-39 in light water electrolysis [10]–[12].

The test cell used in these prior works is shown in Fig.1. The remarkable increase has occasionally been observed only in the electrolysis experiment and has not in the control one. For instance, a significantly large number of 638 etch pits has been observed on a single CR-39 chip in an electrolysis experiment. Contrary, only 2 etch pits have been

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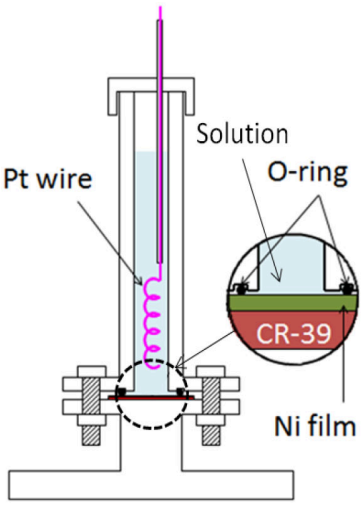

Figure 1. Test cell used in the prior work. The same cell except the bottom portion is used in the present work.

observed on the corresponding control chip [12]. The results suggest that an energetic charged particle is produced in the Ni film [13]–[15]and penetrate it to reach the track detector in the electrolysis process. The energy of the particle emitted is considered to be in the range of 1–15 MeV [3]. Considering that the Ni film cathode is set in close contact with the chip and in the form of Ni film covering the chip, it is hard to exclude the view that the pitting is correlated with the Ni film. However, the possibility of producing the energetic charged particle in the solution close to the surface of the Ni cathode is not excluded from the prior works [11], [12].

These results lead the author to investigate the particle emission in the light water electrolysis by another simple method capable of realizing the production of the energetic charged particle. The visual experimental method using a scintillator without electronics is an ideal one chiefly because it can avoid electric noise and would provide a reliable result. The present visual method might be the simplest one ever known to identify the anomalous emission of the energetic charged particle produced by the possible low-energy nuclear reaction.

2. Experimental

Electrolysis is carried out in a small plastic (polyoxy methylene) cell at room temperature in this present work. The cell is the same that used in the prior works [10]–[12], except that the track detector and the base block in the lower portion are replaced by a scintillator composite and a transparent plastic plate, respectively. The structure around the scintillator composite positioned in the lower portion of the test cell is shown in Fig.2.

For further details, the cell consists of a vertical plastic cylinder of 105-mm long and 10-mm inside diameter, a plastic stopper holding a wire anode, a Ni film cathode, the scintillator composite, and the transparent plastic plate in the lower portion. The top of the cylindrical portion of the cell is covered by the plastic stopper with loose contact, which permits the escape of the gas produced by electrolysis. The 5-μm thick Ni film is purchased from The Nilaco Corporation, Japan. Since the light of the midday sun at fine weather is not visible at all from the opposite side of the Ni film, visible rays will not penetrate through the Ni film from the solution to the scintillator side. The Ni film is carefully handled before the setting to avoid being mechanically damaged.

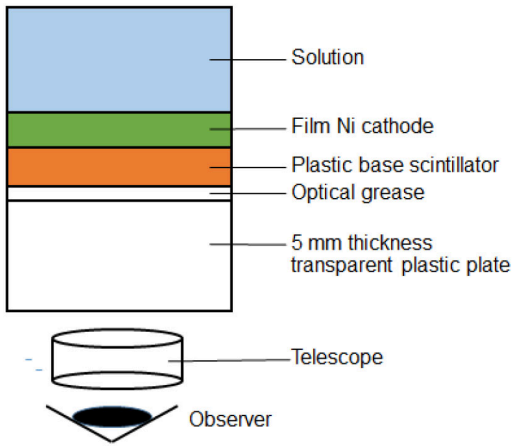

Figure 2. The structure around the scintillator composite positioned in the lower portion of the test cell used in the present work.

The 5-μm thick Ni film with 30×50-mm in size is set in the lower portion. The center area with the diameter of slightly less than 20 mm of the film forms the inner bottom of the test cell and serves as the metal cathode. The excellent idea of the metal bottom serving as the cathode has been presented by Oriani and Fisher [4]. The edge of the 30×50-mm Ni film is sandwiched by a folded 30-μm thick small piece of a gold film to form a steady terminal of the electric cord. The anode is a ϕ0.5-mm Pt wire. The upper portion of it is sheathed by a heat-shrinkable FEP tube surrounded by TFE. Its lower part of ∼60-mm long is formed a crude spiral with the diameter of ∼5 mm and with the length of ∼30 mm. The lower end of the spiral plane is parallel to the cathode surface with a gap distance of ∼10 mm.

The ZnS(Ag) is used as the scintillator, which is deposited on a polyester sheet of 30×30×0.25 mm in size to form the scintillator composite. The scintillation composite is purchased from Oyokoken Industry Company, Japan. The ZnS(Ag) has the maximum amplitude of emitting photon at wavelength 460 nm with decay time of 200 ns. The density of the ZnS(Ag) is (3.25±0.25)mg/cm^2. The thickness of ZnS(Ag) is measured to be ∼0.12 mm. The surface of it looks smooth and good homogeneous.

An optical grease is coated on the front surface of the 5-mm thick transparent plastic plate, followed by mounting the scintillator composite on the optical grease. Then, the rear surface of the Ni film cathode is set in close contact with the front surface of the scintillator. Finally, both the lower portion of the cylinder, the Ni film, the scintillator composite, and the transparent plastic plate are clamped together with an O-ring seal of the diameter of ∼20 mm(P-18, silicone rubber). The transparent plastic plate takes part in the steady bottom base of the cell. After the lower portion of the cell is assembled to form a small vessel, the ∼8-ml H_2O solution is poured into the cell. Then, the stopper cap holding the anode is put on the upper opening. An unused Ni film is used for every run. After the electrolysis experiments, the cell assemblies are immediately disassembled to remove the Ni film used.

Fig.3 shows the photo of the observation setup. The distance between the transparent plastic plate and the eye of the observer is ∼12 cm. Though the scintillation is visible to the naked eye, a small telescope set under the transparent plastic plate improves effectively the visibility of the scintillation. The minimum unit of the continuous observation time is 10 min. The number of flashes during the 10 min is kept in mind of the observer. Then, the end of the 10-min observation is informed by an alarm from a timer. Finally, the number of flashes and the outline of it are immediately recorded by handwriting. It is not difficult for the observer to carry out manually the above procedure because the scintillation usually seldom occurs.

Figure 3. Photo of the observation setup.

One of the combinations of the solution and the applied DC condition for the present work is selected out of the 15 combinations in the prior work [12]. The combination selected has given the highest probability of the remarkable increase in the number of etch pits. The solution of the present light water electrolysis is Li_2SO_4/H_2O of 0.1 mol/L. The single run consists of the former run and the latter run. Total 6 runs are carried out. Pure water is added after the former run to fill up the test cell. The time interval between the end of the former run and the beginning of the latter run is $\sim$10 min.

The current for the electrolysis is supplied by a constant-current power supply. The DC supplied is 3, 5, 10, 20, 40, 80, and 160 mA. The DC range 3–160 mA corresponds to the voltage range 3–30 V. The DC changes from 3 to 160 mA in stepwise every 24 h for 7d in the former run. The time behavior of the current supplied in the former run is shown in Fig.4. The DC condition in the former run is the same as that of the combination selected out of the 15 combinations in the prior work [12]. Similarly, the DC changes from 5 to 160 mA in stepwise every 24 h for 6d in the latter run, namely, the first DC of 3 mA is skipped of the DC condition in the former run. Thus, the electrolysis of the single run continues totally 13d.

3. Results and Discussion

A remarkable increase in the number of etch pits has been occasionally but commonly seen in the electrolysis experiments under the DC of 160 mA in prior works [11], [12]. Accordingly, the interest of the author is focused on the appearance of the scintillation under the higher current condition. Consequently, the total observation time is different between the DC values, though the scintillation is observed under the DC of 20, 40, 80, and 160 mA. The observation is carried out in a dark room at an arbitrary time during the electrolysis. The observation of 6×10 min is typically conducted twice in 24 h under each fixed DC value. The total time of 120 min in 24 h in a fixed DC value is equivalent to $\sim$8% of the electrolysis time.

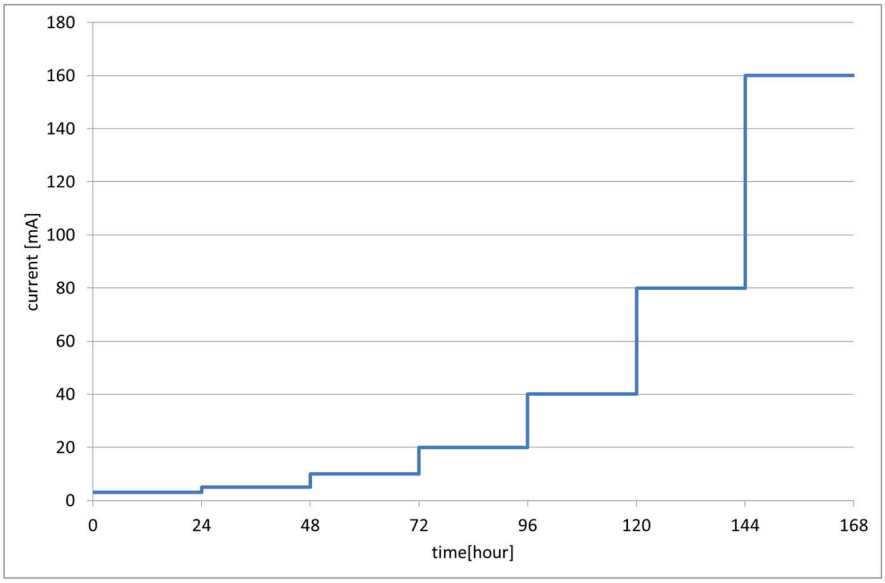

Figure 4. Time behavior of the current supplied in the former run.

Table 1. Total count of the flash in the total observation time for each DC value.

	Current	20 mA	40 mA	80 mA	160 mA
Former run	Total count	0	1	1	8
	Total observation time	180 min	180 min	610 min	880 min
Latter run	Total count	5	8	13	15
	Total observation time	770 min	780 min	960 min	1030 min

The color of the scintillation observed by the naked eye looks to be white mixed with a little blue. The scintillation appears in an extremely short moment and in different strengths between the scintillations. Thus, ambiguous flashes from the scintillator hard to be recognized are excluded from counting and only obvious those are counted as the visible scintillation. The time interval between the flashes is found to vary exceedingly. For instance, three flashes appear in 20 min in an experiment and the other three do in sequence within a minute in another experiment.

The total count of the flash in the total observation time for each DC value is shown in Table 1. Average count per hour of the flash, which is defined as the flash rate, for each DC value is shown in Fig.5. Total 15 flashes are counted in the total observation time of 1030 min under the 160 mA in the latter run, as shown in Table 1. These values give the largest flash rate of 0.9/h in the present work. The control experiment with the solution but without the electrolysis is conducted by the same setup as that of the electrolysis experiment. Two flashes of unknown origin are observed in the control experiment in the total 900 min and these values give the flash rate of 0.1/h. The 900 min in the control experiment is comparable to the 1030 min in the electrolysis experiment under the 160 mA in the latter run. However, the flash rate of 0.9/h in the electrolysis experiment is obviously larger than that of 0.1/h in the control experiment. The result reveals that the electrolysis increases the flash rate. The scintillation could be attributed to the energetic charged particle produced in an unknown process occurring at the Ni film electrode in the operating electrolysis cell.

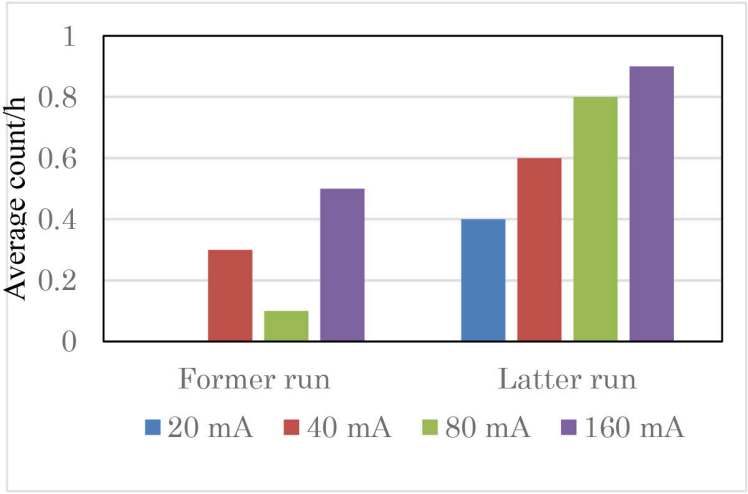

Figure 5. Average count per hour of the flash for each DC value.

Fig. 5 shows a tendency that the flash rate increases with the DC value in both the former and latter runs. Comparing each flash rate in the former run with that in the latter run, the rate in the latter is obviously larger than that in the former at any DC value. It should be noted that the former run is always followed by the latter run in all the 6 runs and the environmental condition is considered to be even in both the former, the latter, and the control runs. Accordingly, it is hard to think that the effect of the cosmic ray coming randomly results in the characteristics of Fig.5. The obvious change in the flash rate by the transition from the former run to the latter one could exclude the possibility of producing the energetic charged particle in the solution close to the surface of the Ni cathode. These characteristics of Fig. 5 might be explained by increasing the density of the proton absorbed in the Ni cathode during the electrolysis. The density of proton in the Ni film cathode would be high enough to cause a low-energy nuclear reaction and to produce the energetic charged particle after a long electrolysis time.

The ZnS(Ag) is the scintillator having efficiency better for the alpha particle than for the proton. The penetration distance in Ni of $\sim$5 μm is obtained for the 3-MeV alpha particles by a computer simulation. According to the result of the simulation, when an alpha particle is produced at the front surface of the 5-μm thick Ni film, $\sim$3 MeV is the lowest energy of the alpha particle to penetrate through the Ni film and to reach the scintillator. The short penetration distance suggests that the use of thin Ni film is a key factor for detecting the alpha particle.

On average, $\sim$42 etch pits have been registered after 7 d electrolysis in the prior works [12] under almost the same experimental condition as that in the former run of the present work. While by calculating from the total count of the flash in the former run in Table 1, $\sim$23 is expected as the count of the flash during 7 d, which is the whole period of the former run. This number of 23 is fairly comparable to the etch pit number of 42. The lower count of the flash than the count of the etch pit would be mainly due to the inferior ability of the naked eye of the observer.

4. Concluding Remarks

The simple experimental method using the thin Ni film in conjunction with the scintillator ZnS(Ag) is presented to observe the visible scintillation in the light water electrolysis under the DC condition. The flash from the scintillator with a considerably high count rate can be recognized. By carefully reviewing all the present and the prior experimental

works [11], [12] done, the scintillation could be attributed to the energetic charged particles produced by the possible low-energy nuclear reaction in the Ni film cathode during the light water electrolysis.

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