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Characteristics of Electrochemical Detector with Biological Material for Efficient Detection of Neutrinos

by

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Abstract

Electrochemical detectors were fabricated to consist of two electrodes with raw silk and purified water in a Teflon container. The detectors generated output voltage through copper conduction wires in the environmental neutrino circumstances. The influences of electrode gold purity, conduction wire materials and fast-reactor neutrino irradiation were studied on the output voltage of the detectors. The detectors with higher-purity gold electrode promoted the faster time-evolution of the output voltage. Use of wire materials of gold produced the highest output voltage, while that of iron gave the almost half voltage. The irradiation of fast reactor neutrinos reduced the output voltage to an half level.

Keywords: Electrochemical detector, Neutrino, Mass-generation mechanism, Weak charge, Neutral scalar field, Raw silk, Gold purity, Conduction wire material, Fast-reactor neutrino

1. Introduction

Neutrinos are one of leptons, which own the spin 1/2 and a quite small rest mass[1)]. Although neutrinos are abundant in nature, they interact with other matter quite weakly. This property makes them extremely difficult to be detected. We consider that neutrinos have an elaborated mass-generation mechanism on the basis of axial-vector (AV) type neutral scalar field B_0[2)]. We assumed the three hypotheses[3)] for the mechanism: 1) Interaction potential of neutrinos is generated from weak charge and weak electric moment under Fermi (Feynman) gaze[4)], 2) The motion of neutrino component complies with the Dirac-type and Klein-Goldon-type equations, 3) The motion of neutrino components is written in the same way in both the normal space and the transferred subspace. Under these hypotheses, the self-electromagnetic energy and momentum mass are differently effected[3)] by the neutral scalar field B_0. If the neutral scalar field exists in the detector, it

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may be possible to break neutrinos into weak-charge type and magnetic-moment type fragments.

According to this idea, we have examined to detect neutrinos by using an electrochemical detector with the neutral-scalar-field-producing material. Raw silk is the substance finally selected from a number of experiments among biological materials. It seemed that the electrochemical detector was capable of responding to both environmental and reactor neutrinos[5]. In addition, the influence of the temperature was reported on the output voltage of the detector[6].

The voltage generation mechanism of electrochemical detector, however, is not completely clarified. In this study, the effects of the gold electrode purity and the conduction wire materials were attempted to be studied on the output voltage. The electrochemical detector should probably have responded to the artificial neutrinos from the Fugen nuclear reactor (advanced thermal reactor)[5]. It is of interest to study the response to neutrinos from a fast reactor. The experiment with fast-reactor neutrino irradiation was carried out at the experimental fast reactor Joyo[7] (thermal power of 140 MWt).

2. Experiment Apparatus

2.1 Basic detector principle

Generally speaking, hydrogen ion (H^+) and hydroxide ion (OH^-) are generated by the dissociation of water molecule, and the separation energy is written by $\Delta G = -RT \ln([H^+][OH^-])$, where R is the gas constant 8.314 J K^{-1} $mole^{-1}$, and T is a temperature typically taken as 300 K. The concentrations of hydrogen ion $[H^+]$ and hydroxide ion $[OH^-]$ are both close to 1×10^{-7} mole per liter purified water. The separation energy of water becomes to 0.84 eV per molecule.

We explain the principle of raw-silk type electrochemical detector. The AV-type neutral scalar field B_0 is supposed to be generated around the raw silk. The field may disturb the mass generation mechanizm of neutrino, and break the neutrino into two fragments. Hydroxide ions move to the anode, which generates the free electron and the oxygen molecules. The oxygen molecules diffuse in the solution toward the cathode. The electrons are conducted to the cathode through copper wire. Meanwhile, the hydrogen ions diffuse to the cathode, and they absorb the conducted electrons to form water molecules. The process is described as

Dissociation of water molecule	: $H_2O \rightarrow OH^- + H^+$
Anode reaction	: $2OH^- \rightarrow H_2O + (1/2)O_2 + 2e^-$
Cathode reaction	: $2H^+ + (1/2)O_2 + 2e^- \rightarrow H_2O$.

The current is thus induced in the outer circuit of the detector. Consequently, the voltage of the detector appears through voltage logger and a resistor that produced input impedance of 1 MΩ (standard resistor circuit).

2.2 Structure of electrochemical detector

The electrochemical detector is composed of Teflon container, five kinds of Teflon parts, gold plate, glassy carbon plate, raw silk, and purified water. The overview and cross section of the electrochemical detector are shown in **Fig. 1**. The main part of the electrochemical detector was fabricated in the Teflon container with a size of 5.8 cm in diameter and 9.0 cm long. A gold and a glassy carbon plates were used as the cathode and anode, respectively. These plate sizes were both 20 mm × 50 mm in surface, and the thicknesses were 0.1 mm (gold plate) and 1.0 mm (carbon plate), respectively. The raw silk of 0.5 g was set on the each side of the gold electrode and supposed to generate the AV-type neutral scalar field. Both plates worked as electrodes, and were

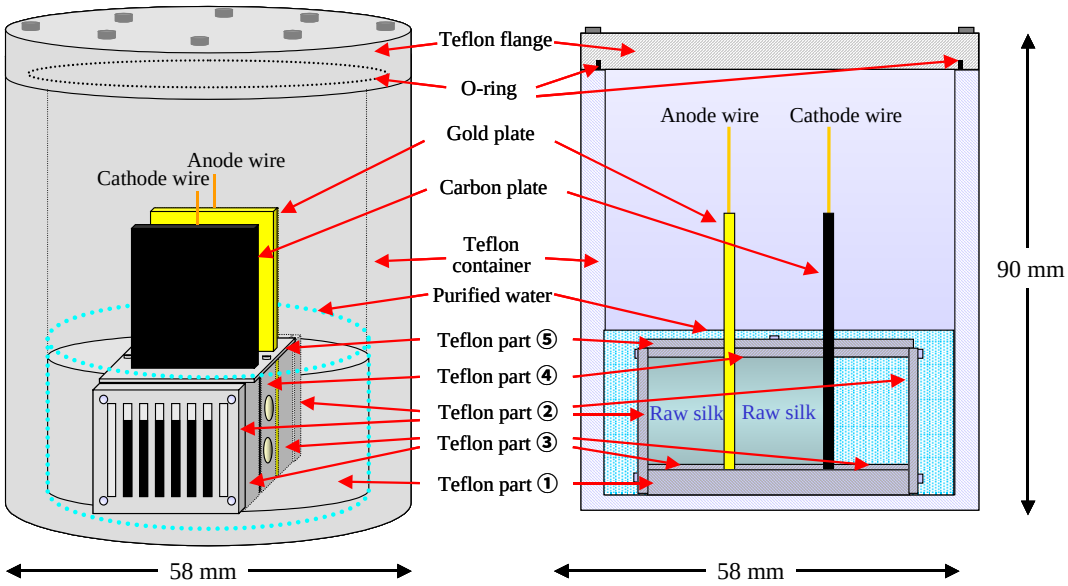

Fig. 1 Overview and cross section of the electrochemical detector.

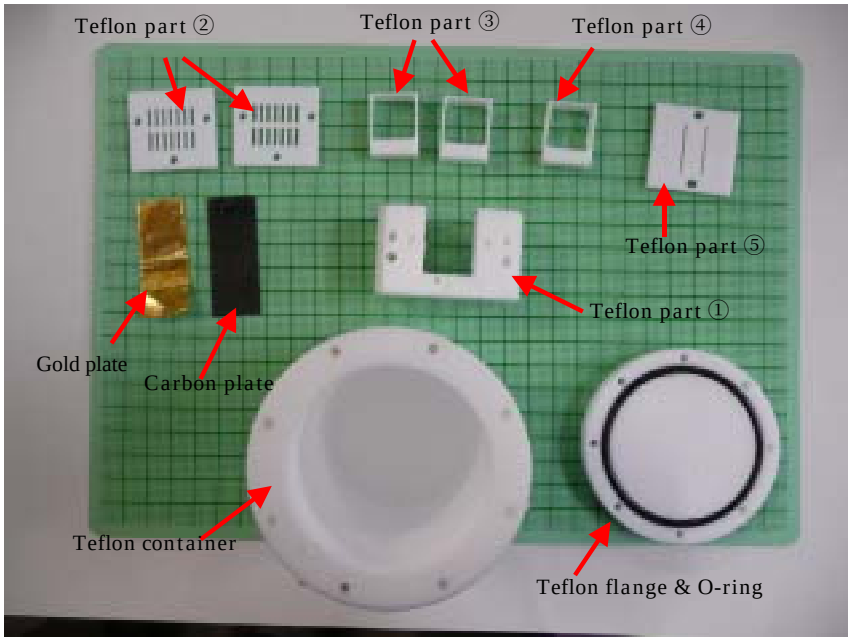

Fig. 2 Photograph of parts of the electrochemical detector.

connected to a standard resistor circuit of input impedance 1 MΩ thorough the copper conduction wires.

Photographs of the parts used in the electrochemical detector are shown in **Fig. 2**. The Teflon part ① supported the main structure of the detector. The main structure was assembled by such components as Teflon part ②, Teflon part ③ filled with 0.5-g raw silk, gold plate, Teflon part ④ filled with 0.5-g raw silk, glassy carbon plate, Teflon part ③, and Teflon part ②. To extract the two electrode plates, Teflon part ⑤ with two slits was placed on the upside of the Teflon part ①. The Teflon parts ② and ③ were fixed by acrylic plastic screws. Raw silk was minced by using scissors into a short length below 1 mm for ease of packing in the Teflon parts. The photograph of

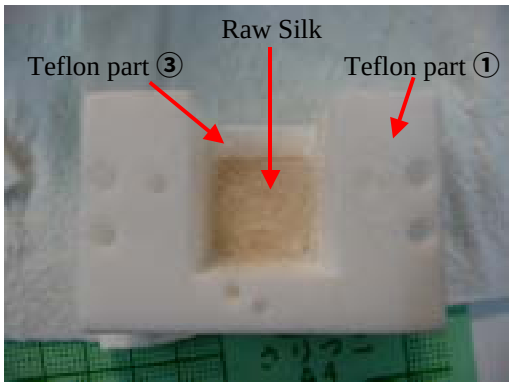

Fig. 3 Assembled Teflon part ① and ③ filled with raw silk.

the raw silk packed in the Teflon part ③ is shown in **Fig. 3**. Purified water of 50 g was filled in the cylindrical Teflon container. The copper wires were connected to the gold and glassy carbon plates and these went across an O-ring to the outside of the Teflon container. The Teflon flange was attached to the Teflon container by using the O-ring and stainless-steel screws.

The output voltage from the electrochemical detector was measured by using a data logger (Hioki Co. Voltage Logger 3635-04). The detector was placed in a temperature-controlled incubator and of which temperature was set 27 degrees centigrade. The experimental data were transferred from the data logger into a computer by a communication unit base of Hioki 3910.

2.3 Reproducibility check of the electrochemical detector

We fabricated three respective electrochemical detectors to check the dispersion of the output voltage across the standard resistor circuit of input impedance 1 MΩ on different days. The measurement signals of three detectors are shown in **Fig. 4**, where the voltage is also plotted for an apparatus without use of the raw silk. The output voltage of the apparatus without raw silk was measured on the day besides three other measurements. These results indicate that the electrochemical detector require the raw silk to generate the output voltage.

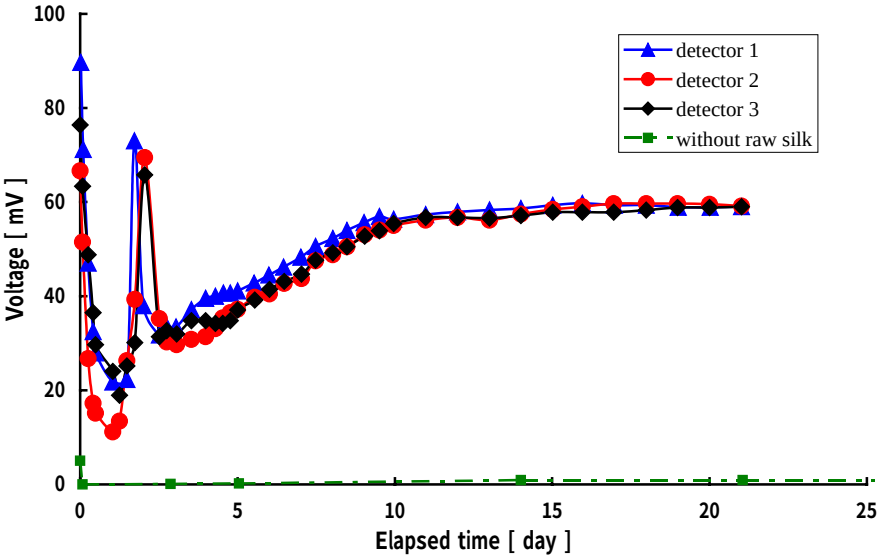

Fig. 4 Output voltage of the three raw silk type electrochemical detectors and detector without raw silk.

Three detectors produced almost the same voltage behavior: The output voltage first quickly decreases from about 80 mV to 20mV in a day, then rises to about 70 mV in two days, goes down to about 30 mV sharply in three days, and gradually increases to 55-60 mV in about ten days. The first peak at two days is considered appearing due to presence of the dissolved oxygen. The anode reaction takes place with the remaining oxygen. Once the dissolved oxygen is consumed, the output voltage is reduced to a lower level. The voltage slowly rises with the diffusion the oxygen generated and accumulated at the cathode. The stable voltage around 15 days is ascribed to the result of neutrino reaction in an equilibrium condition. The variation of the three voltages after 10 days is within 2 % in the standard deviation (one sigma). The output voltage measured at the same time seems to show the same voltage shape. The first voltage peak and the time voltage becomes stable seem to be different depending on the measurement time.

3. Experiments on Metal Materials and Fast-Reactor Neutrino Irradiation

3.1 Gold plate purity effect

The gold plate with a purity of 99.99% (Furuuchi Chemistry Co.) is utilized for the present electrochemical detector, while that of 99.95% (Nilaco Co.) was adopted at the beginning stage of the experiments. The first voltage peak around 2 days tends to be different between the output voltages of the 99.95% and the 99.99% purity gold plates. To confirm the result of this difference we fabricated detectors with the two different gold plates.

The measurement signals for the different gold purities are shown in **Fig. 5**. The red line stands for the output voltage for the 99.99% purity gold plate, whereas the blue dotted line indicates that for the 99.95% one. Deviation appears in two different regions. First, the initial voltage peak around 2-3 days was different. The initial peak of the 99.95% gold plate was formed slowly and the peak value was about 20 mV lower than that of 99.99% one. Second, the output voltage shape of the 99.95% purity gold plate detector was appreciably slower in the region of 4-12 days than that of 99.99% one. In contrast, the initial voltage peak for 99.99% was consistent to that in **Fig. 4**. For the 99.95% purity gold plate detector, the initial voltage peak appeared after about 1 day later and the stable voltage appeared about 4 days later than the 99.99% one. The use of the 99.99% purity gold

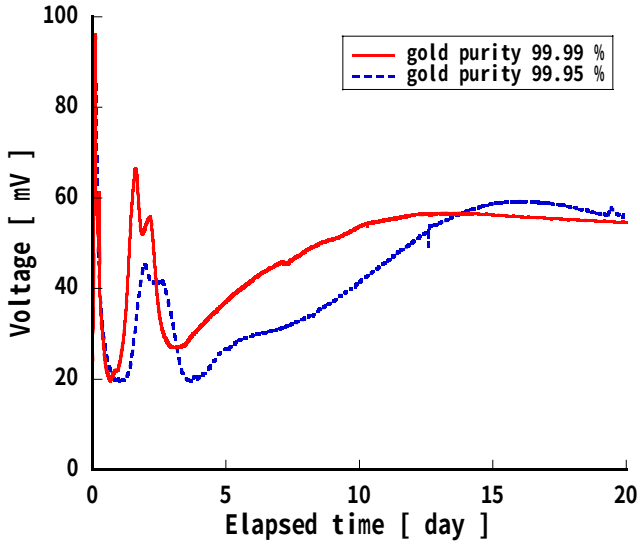

Fig. 5 Output voltage from the raw silk type electrochemical detectors using two different purity gold plates.

plate detector leads to smooth and efficient time evolution of the output voltage.

The impurity materials of the gold plates were measured by X-ray Fluorescence Analysis. The X-ray Fluorescence Analysis was performed using X-ray Fluorescence Spectrometer (EDX-800) at the Center of Advanced Instrumental Analysis, Kyushu University. The difference of impurity materials between the gold plates was dominated by iron element.

3.2 Conduction wire material effect

Electrons flow the copper conduction wires to produce the output voltage across the resistor. The resistance of the copper conduction wire 0.2-mm in diameter and 20-cm long is estimated to be about 200 mΩ, which is negligibly small compared with the input impedance of voltage measurement system, 1 MΩ. Even if the copper is replaced by other metallic elements, therefore, the voltage from the detector is expected not to change at all. To confirm this, experiments were performed by using four different element metals.

Four raw-silk-type electrochemical detectors were prepared with wires (0.2 mm in diameter) of gold, silver, zinc, and iron. These detectors were set in incubators, of which temperature was kept at 27 degrees centigrade. Two detectors of gold and silver wires were placed in one incubator, and the other two detectors of zinc and iron were placed in another incubator. Each conductor was wired so as not to touch the purified water in the electrochemical detector in the same way as in the detector with copper wire. The measurement signals are shown in **Fig. 6** together with that of copper wire. The irregular decrease of output voltage around 4 days is ascribed to a temperature decrease of incubator because of the interruption of electricity service.

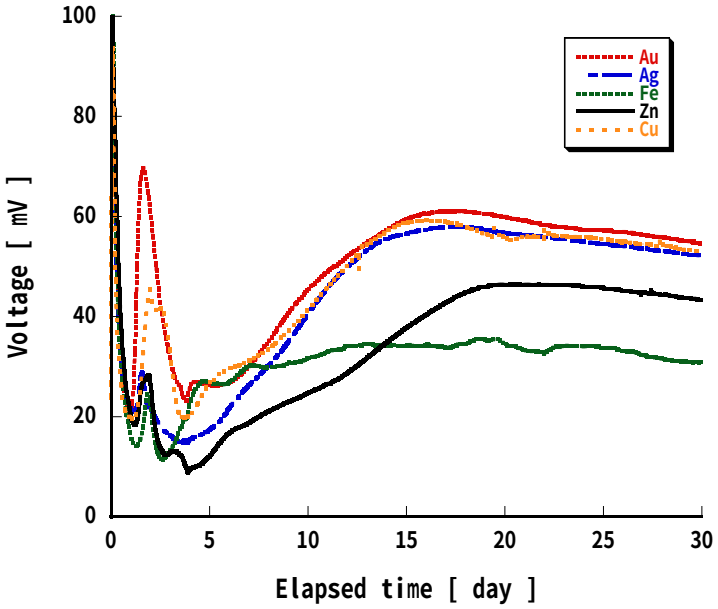

Fig. 6 Output voltage of the four raw silk type electrochemical detectors using different kind's lead wires and of the normal detector.

Both the initial voltage peaks around 2-3 days and the stable voltage around 15 days were different from that of the normal output voltage of the electrochemical detector. The detector with gold wire showed the highest initial voltage. The voltage was lower in the order of silver, zinc, and iron than the copper-wire one. The stable voltage around 15 days was almost the same for gold, silver, and copper wires, while zinc and iron showed appreciably lower value. The experimental

fact is not understandable from the electric resistance of these wires, since they are in a range of 0.1 to 10 Ω and negligibly smaller than 1 MΩ. This suggests that some weak-interaction particles flow in the conductor together with the electrons. The magnetic-moment type neutrino fragment[3] should have a magnetic spin. The conduction of this fragment may be largely dependent on the metallic wire elements.

3.3 Measurement at experimental fast reactor Joyo

The electrochemical detector after completion is not suited to be transported in a long distance, due to effect of vibration during the movement. The electrochemical detector was assembled with parts that were brought to experimental fast reactor Joyo. Subsequently, the detector was set in the incubator, which was set at the standard temperature of 27 degrees centigrade. The measurement was made outside the radiation controlled area at Joyo. The distance from the reactor core was 20.3 m at this place. When the reactor operated, the neutrino flux was about 6×10^{12} [neutrinos/(cm^2・sec)] at this place. The detector was measured with the standard resistor circuit of input impedance 1 MΩ. The experimental result with the reactor thermal power of Joyo is shown in **Fig. 7(a)**, and short time result until 20 days together with the output voltages in **Fig. 4** is shown in **Fig. 7(b)**. The orange line stands for the output voltage of the detector, and the green line indicates the thermal power of Joyo. The detector produced the stable voltage value of about 30 mV after 20 days. The output voltage largely differed from those in **Fig. 4**. Since the reactor neutrino irradiation brought out the difference, this indicates that the electrochemical detector is sensitive to neutrinos. A voltage peak appeared in 2 days. The voltage increase after 5 days in **Fig. 4** was incomplete in **Fig. 7(b)**.

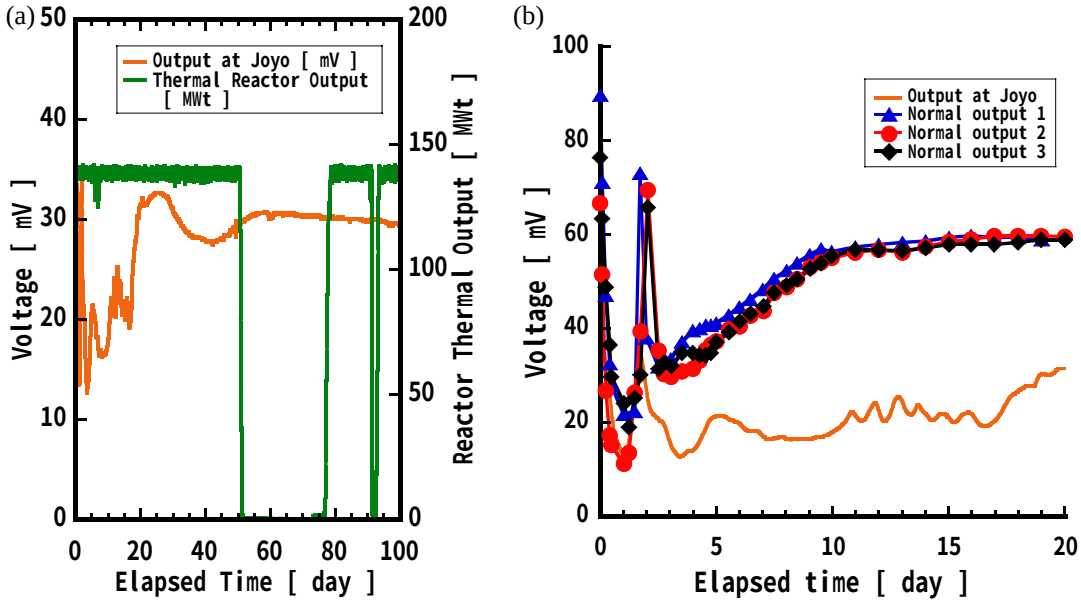

Fig. 7 Output voltage of the raw silk type detectors at Joyo and the thermal power of reactor of Joyo.
(a) The experimental result with the thermal reactor power of Joyo.
(b) The short time experimental result until 20 days together with the output voltages in **Fig. 4**.

It is considered that the electrochemical detector reacts mostly with low-energy environmental

neutrinos because all measurement except this was carried out at Kyushu University, which is far from artificial neutrino sources like reactor. It was reported that the output voltage at FUGEN nuclear power station indicated higher value than that at Kyushu University[5]. Reactor neutrinos from a light water reactor are dominated by anti-electron neutrinos, but contain low energy neutrinos from proton-rich nucleus that are originated by processes such as (n, 2n) reaction[8]. The experimental value at the fast reactor Joyo suggest that the effect of low energy anti-electron neutrinos overwhelms that of low energy electron neutrinos due to reduction of proton-rich nuclei in the fast reactor.

4. Conclusion

The experiments of raw-silk type electrochemical detector were carried out for effects of gold plate purity, metallic wire element and fast-reactor neutrino irradiation on the output voltage. Use of the gold plate of 99.99% promoted the increase of output voltage, particularly for the initial peak. The equilibrium voltage after 15 days was almost the same in the gold plates of 99.99% and 99.95%. For the experiments with different conduction wires, the equilibrium voltage was higher for gold, silver, and copper wires than for zinc and iron. It is suggested that some weak-interaction particles flow in the conduction wires together with electrons. The conduction of such particle is considered to depend on wire materials. The irradiation of neutrinos at the experimental fast reactor Joyo gave the lower output voltage than in the standard experiment in the environmental circumstances. Since the output voltage change appeared with presence of the reactor neutrinos, this reveals that the raw-silk type electrochemical detector should react with either neutrinos or anti-neutrinos. Difference of experimental results between thermal conversion reactor Fugen and experimental fast reactor Joyo is supposed to be ascribed to that of neutrino constitutions in the two reactors.

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