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Exploration of the Feeling Sensing Analysis via Electrochemical In-Vitro Carbon Nano Tube Paste Tattoo Working Sensor

Jongwan Choi [1], Jiwon Min [2], Jason Sahngwook Kim [3], Jung Hyun Park [4,*] and Suw Young Ly [5,*]

[1] Department of Chemistry and Life Science, Sahmyook University, Seoul 01795, South Korea. Email: jchoi@syu.ac.kr
[2] College of Pharmacy, University of Rhode Island, Kingston, Rhode Island 02881, United States of America.jiwonskye@gmail.com
[3] Jason Sahngwook Kim; Biosensor Research Institute. sahngwook@gmail.com. This idea and experiments from Jason Sahngwook Kim. Field of study: Biomedical Chemistry
[4] JungHyun Park, Biosensor Research Institute
[5] Biosensor Research Institute, Seoul National University of Science & Technology, 01811, Seoul, South Korea 139 743
* Correspondence: clairpark10141014@gmail.com (J.H.P.); suwyoung@snut.ac.kr (S.Y.L.)

Abstract: As the human-body controls depend on the brain neuro current, here assay is related to thinking nerve detection. For this purpose, the brain current was analyzed by electrochemical three-electrode systems using 0.1-mm micro wire in vivo probe, which probe was made by using carbon nanotube paste coated needle type. Here working electrode was inserted in the rat brain's muscle core with a 0.3-mm-diameter needle type Ag/AgCl Cl-coated Ag wire reference, and counter electrode of 0.1-mm-diameter Pt micro needle was inserted 5 mm deep into the in vivo muscle skin, under anesthesia with 2.0 ~ -2.0 V potential windows, 50 mv/s cyclic scan and 1.0×10^{-5}A chrono amperometric sensitivity on the body systems. Under the optimum conditions, diagnostic application was performed to such as smell signal, muscular strength, five sense assay and thinking neuro current.

Keywords: voltammetry; bio current; feeling sense; in vivo; brain wave

Introduction

In *vivo* brains, the neuro signals depend on the molecular transmitters in the nerve systems. Here detection of the extracellular nerve current is related to the evaluation of sophisticated *in-vivo* electro physiologic methods such as electro encephalogram [1], magneto encephalography [2], neurological disease [3], brain computer interfacing and other analogous methods. The signal detection of these methods, however, requires complicated magnetic amplification [5], spectrometric separation [6], nuclear magnetic resonance [7,8], and photometric scanning. Moreover, these methods can be used only under laboratory conditions, are not applicable in *in-vivo* direct implantation, and demand expensive instrumental systems. The electrochemical voltammetric method, however, is usable for *in-vivo* implementable micro or macro probe techniques such as *in-vivo* bladder assay [9], live-brain application [10], skin cell detection [11], and *in-vivo* vascular assay [12]. Furthermore, electrochemical-circuit systems have long been recognized as simple [13], fast-response, and powerful tools for signal amplification [14], and accumulated stripping voltammetric methods are very sensitive for nano- or pico-range detection [16,17]. As such, in this study, highly sensitive [18,19] neuro detection was optimized by a handheld voltammetric circuit. Added to this, diagnostic application was performed to feeling-sense assay for human psychological neuro signals and *animum* brain activity. So can be applicable for in vivo human plasma assay and in vitro [22–24]

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Experimental Design

Sensor Preparation A micro-carbon working electrode was developed by mixing 0.5-mL standard liquid metal mercury and 0.5 g carbon nanotube paste (Nanostructured & Amorphous Materials, Inc.). This was prepared overnight via catalyzed chem ical vapor deposition (catalytic CVD) prior to use, magnetic stirring in a 2M nitric-acid solution, and cleansing with triple purified water. The resulting material was then mixed with reagent-grade mineral oil (New Jersey USA, 1-800-01, Acro) and water in a 40:40:20% ratio, relatively. The resulting modified-paste was inserted into a 1-mm-diameter, 10 mm long needle-type plastic syringe with copper wire connect ing the electrode to the voltammetric workstation. Counter and reference graphite pencil electrodes were prepared using 0.5 mm diameter Hipolymer HB pencil leads; the frontal part of the lead was connected with copper wire using parafilm (iNexus, South Korea, Inc.)

Carbon Nano Tube (CNT) paste probe

Sensor Preparation A micro-carbon working electrode was prepared by mixing 0.5-mL standard liquid metal mercury and 0.5 g carbon nanotube paste (Nanostructured & Amorphous Materials, Inc.). This was prepared overnight via catalyzed chem ical vapor deposition (catalytic CVD) prior to use, magnetic stirring in a 2M nitric-acid solution, and cleansing with triple purified water. The resulting material was then mixed with reagent-grade mineral oil (New Jersey USA, 1-800-01, Acro) and water glass in a 40:40:20% ratio, relatively. The resulting modified-paste was coated on the 0.1-mm-micro diameter copper wire and 0.1 mm thick copper paper with a 5-mm-diameter-circle electrode, then 0.3 mm copper wire connected to the voltammetric workstation. Counter and reference electrodes were prepared using 0.5 mm diameter Hipolymer HB pencil leads; the frontal part of the lead was connected with copper wire using parafilm (iNexus, South Korea, Inc.)

Preparation of electrode and detection systems

The three-electrode sensors of the counter, reference, and working probe prepared using 0.2-mm-thick copper paper with a 5-mm-diameter-circle electrode (CUE) were connected to voltammetric systems using a 0.3-mm Cu wire. (Figure 1(A) insert photo shown), The voltammetric workstation was made in these authors' institution. A method employing electrochemical neuro detection was employed using cyclic voltammetry and chronoamperometric circuits. It was carried out using the new bioelectronics-2 system, which was pioneered by these authors' institution. The computer-controlled voltammetric system was developed with a +-2.0 V potential range, a 2 mA current range, a 10 pA measuring current, and a compact 3"×2"×1" size. The power input and data interface were connected by the USB port of a PC. The instrument is compact, as big as the usual cellular phone (Figure 1(A) insert photo shown), and it can be used for biological, microorganism, and environmental trace assay. *In-vivo* detection was performed using a 0.5-mm-diameter x 10-mm copper-wire-type implantable probe.

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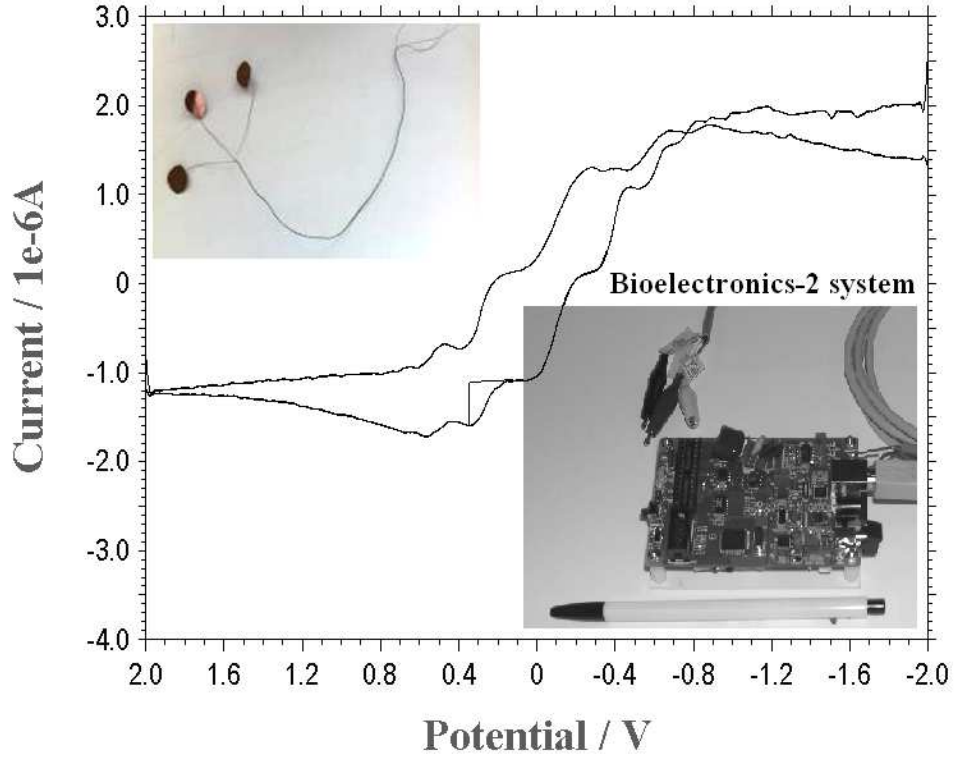

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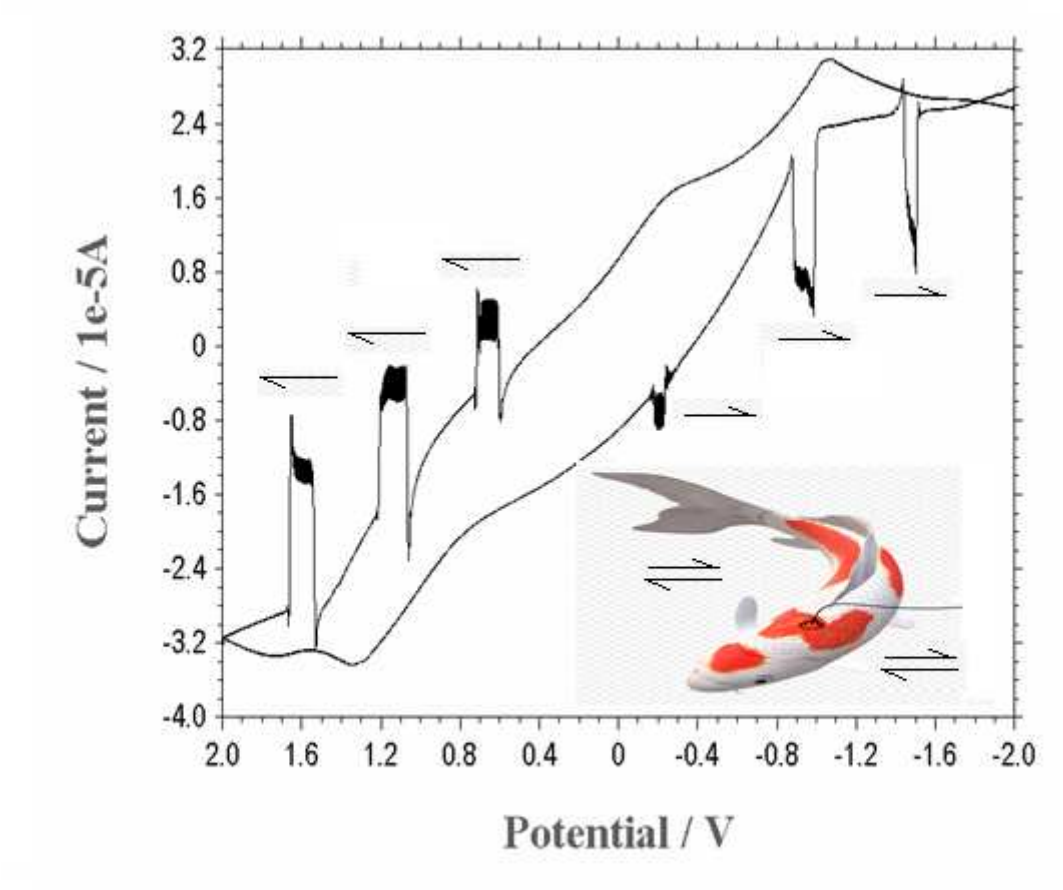

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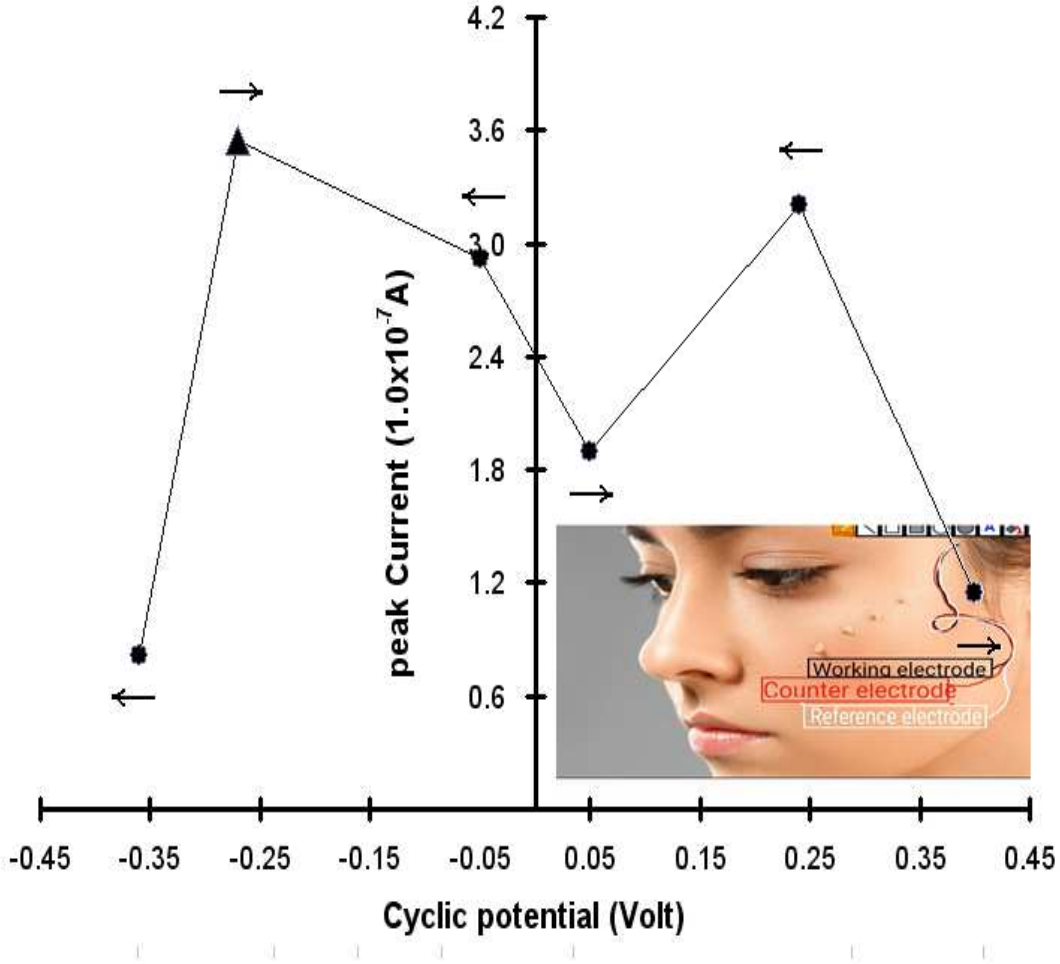

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Figure 1. Cyclic-voltammetric-potential variation from -2.0 to 2.0 V, with a 50 mv/sec scan rate, in the forehead cutis, under three-electrode conditions. (A) No-sensing condition for the steady state. (B) -1.6, -1.1, and -0.3 V cyclic anodic action scan, and 1.6, 1.1, and 0.6 V cathodic action. (C) Cyclic redox peak current of (B).

Results and Discussion

Optimization of the cyclic voltammetric potential

As *in-vivo* currents depend on the applied input potentials and sensing probe amplifications, CUE was attached to the forehead cutis, under stable conditions, and CV scan was performed from -2.0 to 2.0 V under optimum conditions. The redox voltammogram shown in Figure 1(A) is simple, and no signal was obtained from it. Thus, muscular-action signals were sought, and under optimum conditions, cyclic-potential variation was performed with 50 mv/sec movement, with three-time muscle strength, from positive to negative scan, which is related to the neuropotential windows. The results are shown in Figure 1(B). At the start, no action or peak current was obtained. Under these conditions, muscle actions were performed and were continued during the positive scan. In the -1.6, -1.0, and -0.3 negative direction, muscular actions were performed, then at 1.6, 1.1, and 0.6 V, same-strength muscular actions were performed, and a sensitive peak current appeared (i.e., sensitive during the positive then 0 potentials). The calculated peak results are shown in Figure 1(C), where the X scale represents the scan potentials and the Y scale, the peak current. Under these conditions, a very sensitive outcurrent was obtained at -0.25 and +0.25 V. These results can be used for neurosensing detection and *in-vivo* electrophysiological methods, such as electroencephalogram. Thus, more specific application was carried out.

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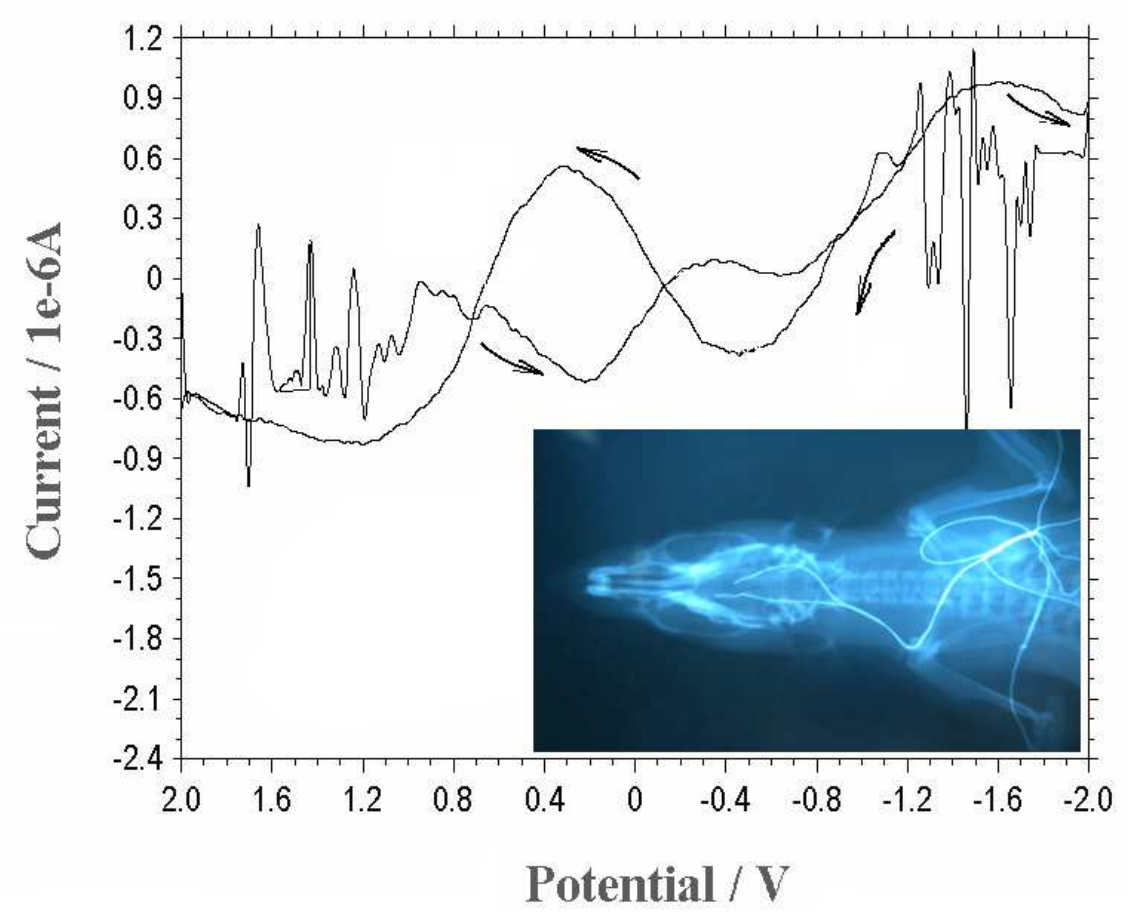
Chronoamperometry and current amplification

As neurocurrent detection depends on the applied redox potentials, amplitude current ranges, and detection skin surface, a three-electrode probe was attached to the back hand skins, and fish brain core, after which more specific cyclic-potential ranges were examined from -2.0 to 2.0 V.

Figure 2(A) shows the results of the cyclic-voltammetric neurocurrent of redox scan. During oxidation scan, muscle tension was performed and was repeated at three points, from -2.0 to 2.0 V. Here, however, only negative potentials were obtained from -2.0 to -1.4 V scan, and only the $1.42x10^{-6}$, $17.8x10^{-6}$, and $0.98x10^{-6}$ A peak currents appeared. Thus, reduction scan was performed in the negative direction, but from 1.6 to 1.2 V, only the $0.92x10^{-6}$, $0.78x10^{-6}$, and $0.62x10^{-6}$ A peak currents appeared. Here, both signals can be used for neurodetection, but more sensitive amperometric-current ranges are required. Thus, more specific experiments were performed. Figure 2(B) shows the results from the $1.0x10^{-1}$ to $1.0x10^{-9}$ A exponential amplified variations, using a 50 mv/sec scan rate. Here, the linear curve represents the -1 to -9 amplifications, and the straight line is the sensing current for the backhand cutis through continuous muscular actions. A $1.0x10^{-3}$ A maximum peak current is shown, and the other ranges are linearly varied. Thus, $1.0x10^{-3}$ A was used for potentiometrics, and under this potential, the chronoamprometric-current sensitivity was examined, which can be applicable to direct neurodetection and sensing signals. Figure 2(C) shows the results for the 10^{-1}-10^{-9} A variations at the backhand cutis with the action current, and the inset curve shows the exact points. The first five points have no signal and are simple, but the 6th point is very sensitive, and a $5.0x10^{-7}$ A peak current was obtained, later decreasing to $3.0x10^{-7}$ A. Thus, the $1.0x10^{-6}$ amplification was fixed. The real current shown at this curve was from 10 to 50 sec, where the current was varied from 4.8 to $6.8x10^{-8}$ A. These results are applicable to any sensing detection. Under these conditions, the advanced redox potential and brain signals were examined in humans and animals.



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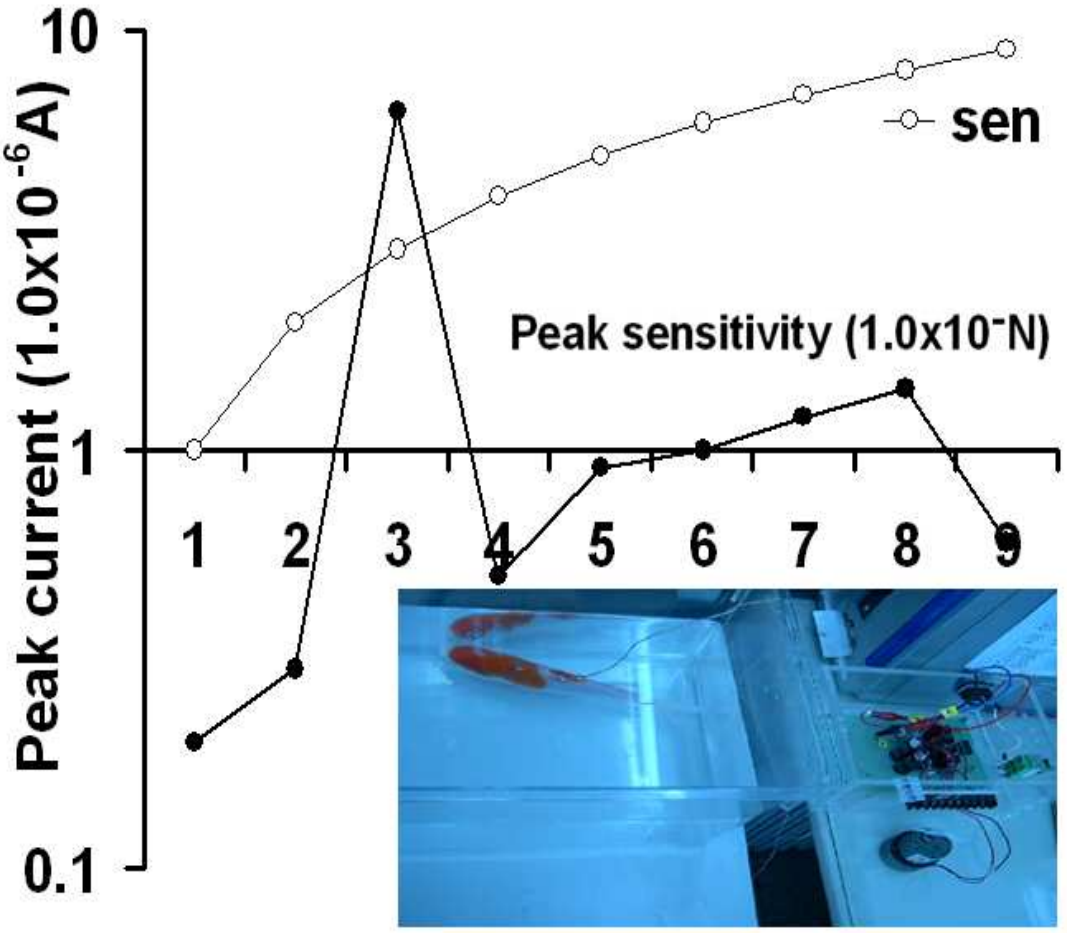

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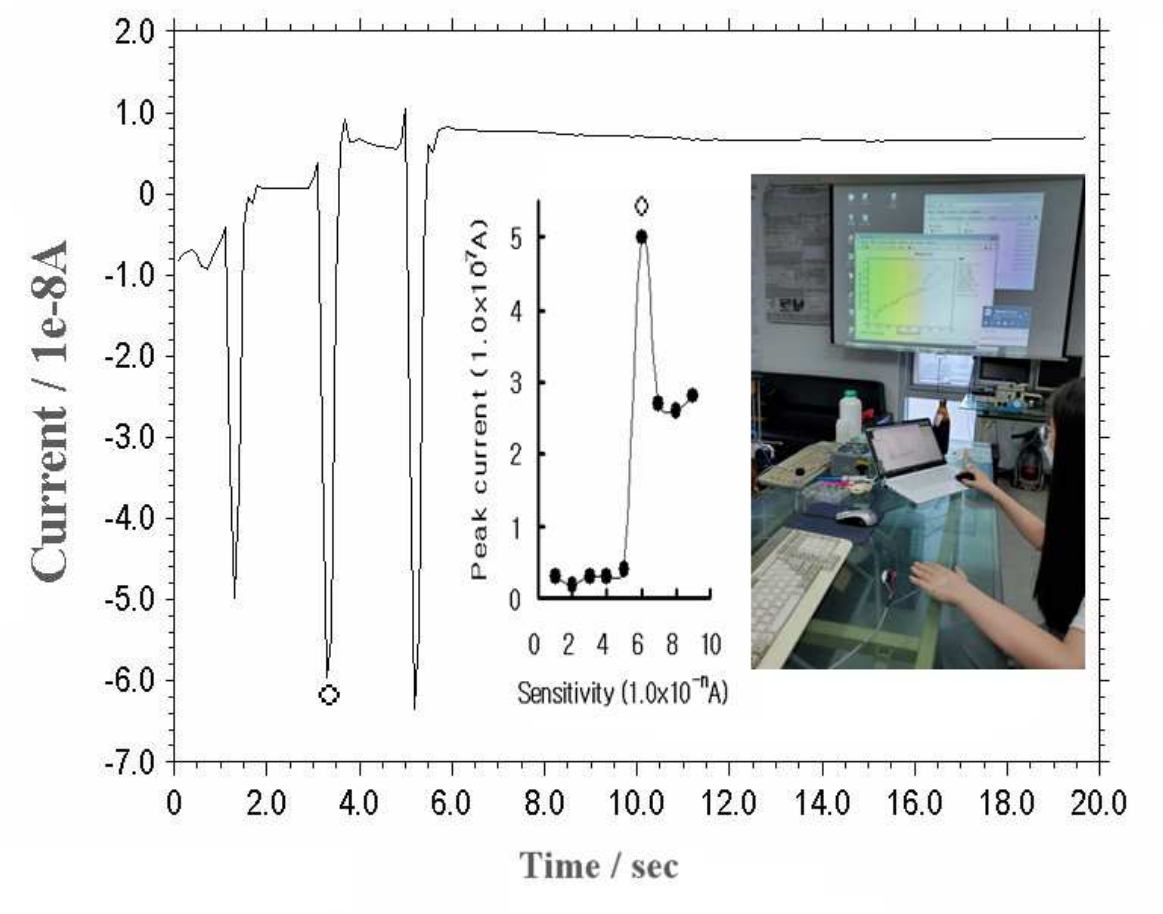

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Figure 2. (A) Cyclic neurosignals with a -2.0 V initial potential, a 2.0 V switching potential, and a 50 mv/sec scan rate. (B) Cyclic-voltammetric-amplitude variation from $1.0x10^{-1}$ to $1.0x10^{-9}$ A, under the same conditions as in (A). (C) Chronoamperometric-current variation from $1.0x10^{-1}$ to $1.0x10^{-9}$ A, using 0 V potential.

Application in the forehead cutis

For sensing detection, human skin and animal brain signals were analyzed. Under optimized conditions, a patch-type probe was attached to the forehead cutis and arms, after which the rat brain with action showed that the current in Figure 3(A) is a real chronoamperometric peak. First, eye action was performed using the optimum parameters, and obtained with three points through three-time eye actions at 1.5, 3.5, and 5.5 sec/V were the $5.2x10^{-11}$, $11.2x10^{-11}$, and $7.5x10^{-11}$ A sensitive peak currents, which responded to the muscle currents. Under these conditions, arm action was sought using the same method. Figure 3(B) shows the results for the arm action for the chronoamperogram, for the three-point 4.0, 4.8, and 5.0 sec/V actions. Here, the peak currents were $0.09x10^{-8}$, $0.12x10^{-8}$, and $0.11x10^{-8}$ A. They can thus be assayed for neurosignals. Then more specific experiments were performed using a rat brain in *in-vivo* implantation, which indicated greater sensitivity when applied to living brain tissue. A working electrode was inserted in the rat brain's 0.5-mm core using a 0.3-mm-diameter needle-type micro hand drill, under anesthesia. A 10-mm-long, 0.1-mm-diameter Ag/AgCl Cl-coated Ag wire was used as the reference electrode. A counter electrode (0.1-mm-diameter Pt) was inserted 5 mm deep into the backbone tissue, and all the electrodes were cemented with a tooth binder and were connected to a 0.05-mm enamel-coated copper wire with a voltammetric system. Figure 3(C) shows the chronoamperometric peak current results, under no-sensing conditions, with light, smell, noise, and any vibration. At the first peak, a simple, linear curve was obtained. Then a small test was performed three times, using ammonium solutions. Here, the chrono-range 24, 0.11, and $0.07x10^{-5}$ A peak currents were obtained at 3.58-5.98 sec/V. As satisfactory sensing-

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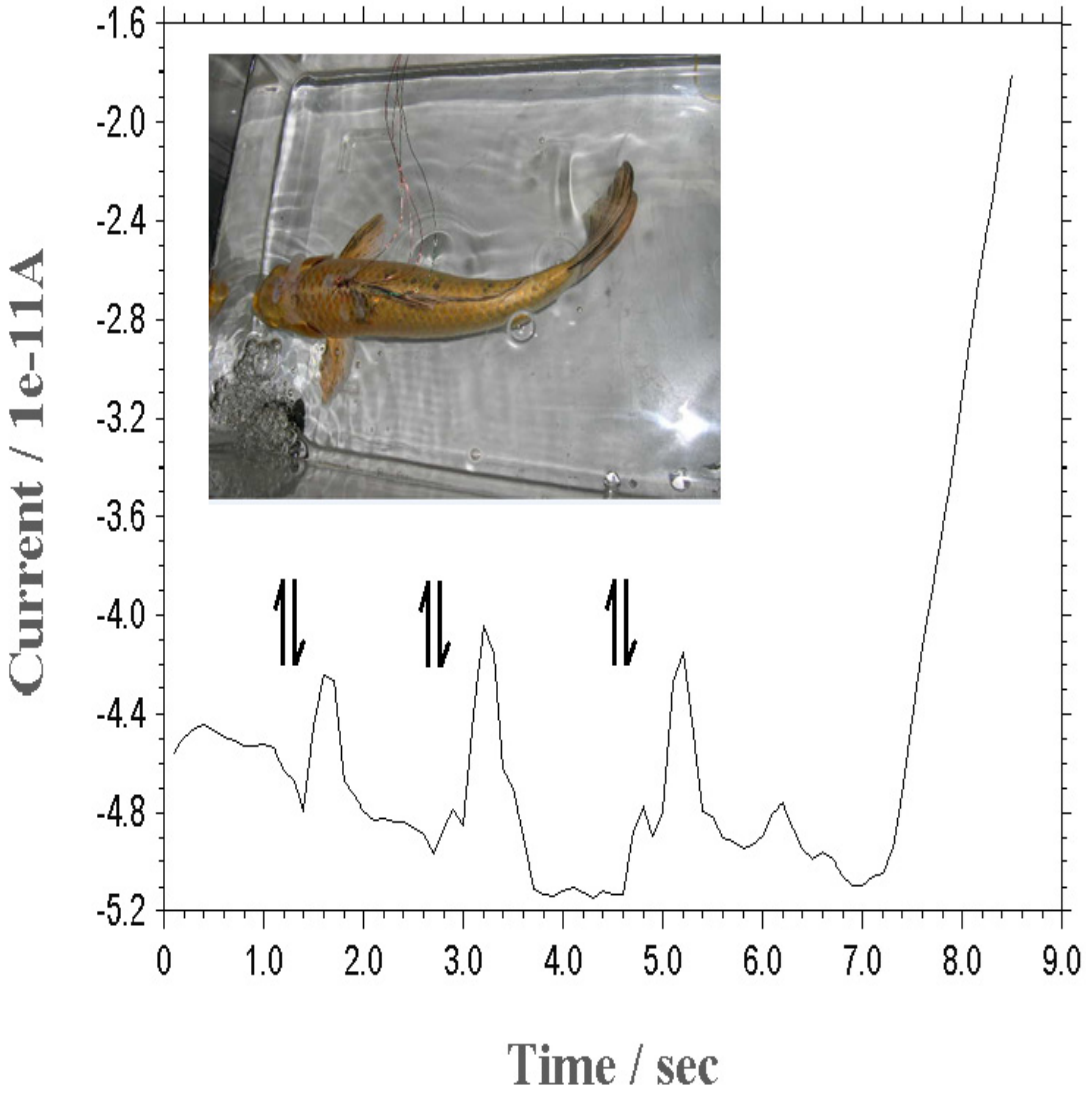
signal results were obtained, the proposed method can be used for extracellular, neuropsychiatric, and other types of neurocontrol.



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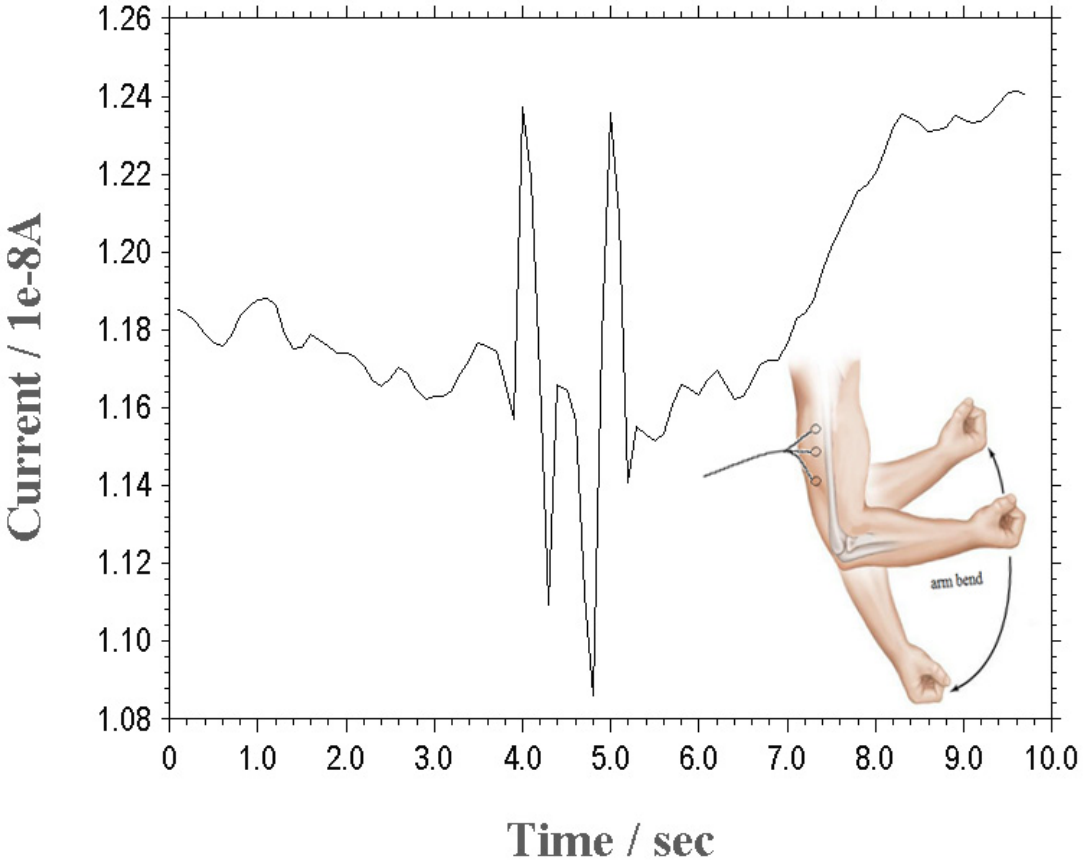

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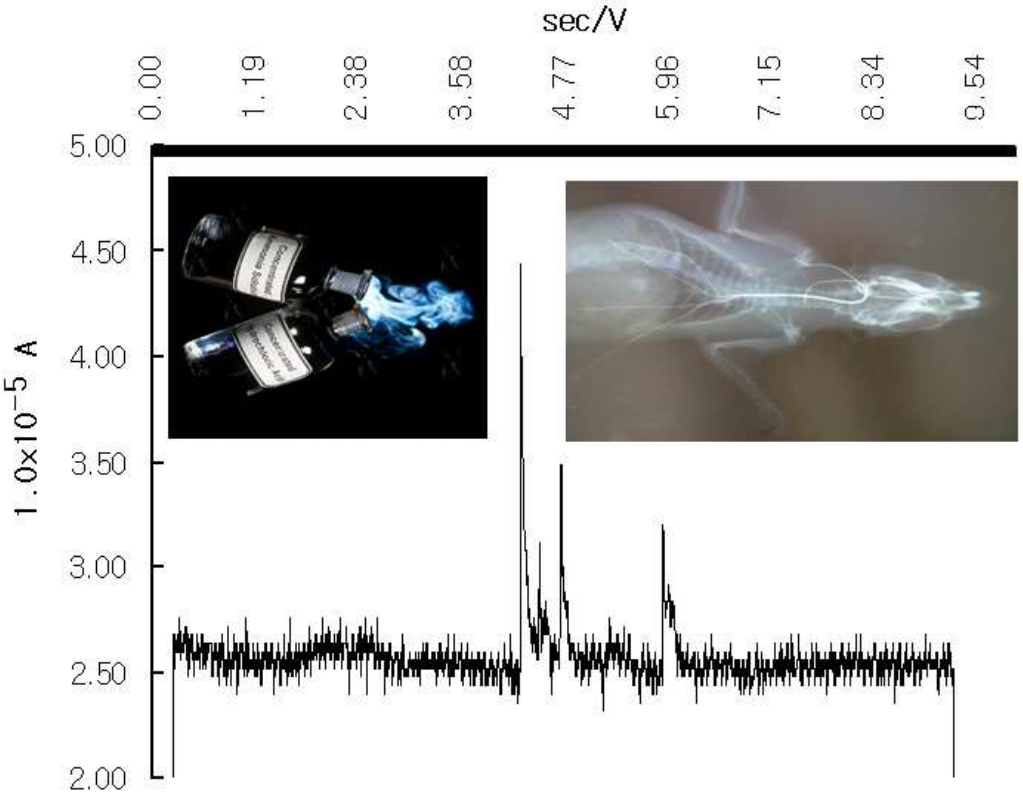

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Figure 3. (A) $1.0x10^{-5}$ A chronoamperometric sensitivity at the forehead cutis, with three-point muscular action. (B) $1.0x10^{-5}$ A chronoamperometric sensitivity at the arm elbow, with three-point muscular action. (C) *In-vivo* current in the mouse brain core, using a smell signal for an ammonium concentrate solution.

Conclusions

Electrochemical neuro sensing were sought using a voltammetric bio circuit, and a microprobe was directly implanted into the bran systems. The optimum diagnostic conditions were set at 30 s accumulation time, 2.0 V initial potential, -2.0 V switching potential on CV, and -0.3 or 0.3 V chronoamperometric potential, under the optimized potential can be attained to nano working current. Here, an eye action of muscular current was obtained, and the implanted *in-vivo* probe was activated to the five-sensing neuro assay. The results can be applied to brain sensing and to any other field requiring mammalian extracellular nerve analysis or real time *in-vivo* electro physiologic assay.

Authors' contributions: This idea from **Suw Young Ly**, All authors read and approved the final manuscript.

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Declarations Ethics approval and consent to participate: All experiments were performed according to established guidelines for the ethical use.

Consent for publication: Not applicable.

Data Availability Statement: All materials are available by the corresponding author.

Conflicts of Interest: declare no conflict of interest.

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