【Grant-in-Aid for Scientific Research (S)】

Implantable Optoelectronic Devices for Unified Early Diagnosis and Treatment: Toward Creation of Optoelectronic Pharmacolog

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Purpose and Background of the Research

●Outline of the Research

Our bodies are lined with various nervous systems, which exchange information with each other using electrical signals. Therefore, it is possible to measure and modulate the functions of the nervous system of a living body using electricity, and diagnosis and treatment of diseases using electricity are widely used in medical equipment. In recent years, electroceuticals, miniaturized devices that perform electrical stimulation and measurement and are implanted in the body to diagnose and treat diseases locally, have been attracting attention.

Light has little effect on living organisms in contrast to electricity, and luminescence from living organisms is seen in only a few organisms, such as fireflies. However, recent advances in genetic engineering have made it possible to measure and modulate the activity of specific functions of the nervous system (e.g., the dopamine nervous system) using light. In this study, we propose for the first time the use of photoceuticals (optoelectronic medicine) for diagnosing and treating diseases, similar to the electroceuticals described above, by specifically measuring and controlling biological functions using light.

Generally, drugs used to treat diseases act on areas other than the diseased area after administration (non-local effects) and may cause side effects (nonspecific effects). Unlike the drug treatment (pharmaceuticals), the electroceuticals are implanted near the diseased area, so the effect is localized. Still, the body conducts electricity and stimulates all the nervous systems near the electrode, so they may cause side effects (nonspecific effects). On the other hand, the proposed photoceuticals can measure and control only the activity of a specific nervous system (specific action), and the effect is localized only in the vicinity of the implantation.

In this study, we will develop an ultra-compact optoelectronic device that can be implanted intravitreally to realize the unique features of photoceuticals that are not found in conventional therapies. This research is expected to be used as a treatment method for diseases that have been difficult to treat, such as pain and epilepsy.

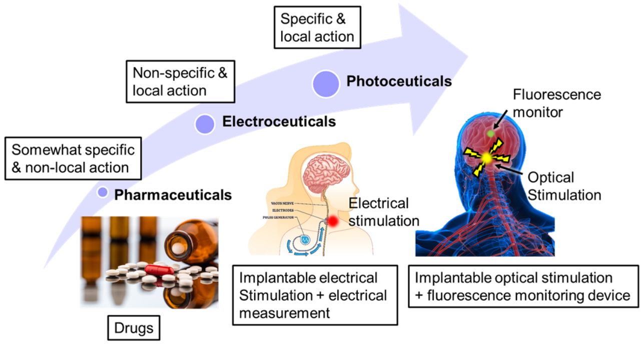

Figure 1. Concept of implantable optoelectronic devices for unified early diagnosis and treatment

●Ultra-compact optoelectronic devices and systems developed for in vivo implantation

We have developed devices implanted in the mouse brain to measure the activity of specific nervous systems (e.g., dopamine nervous system) using light and stimulate them with light (Figure 2). We have also developed a distributed system connecting many devices (Figure 3). These devices and methods are the basic technologies for photoceutical devices.

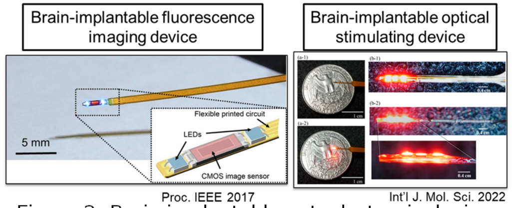

Figure 2. Brain implantable optoelectronic devices

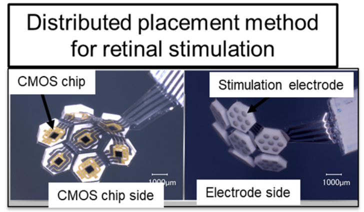

Figure 3. Distributed placement method

Expected Research Achievements

●Toward photoceutical devices

This research aims to develop an implantable device that integrates optical diagnosis and treatment in vivo. The plan involves three main steps: (1) Enhancing imaging and optical stimulation devices suitable for photoceutical applications, (2) Establishing a decentralized placement method for in vivo use, and (3) Testing the device on animal models to demonstrate its efficacy. The first step focuses on improving fluorescent imaging and optical stimulation devices for diagnostics and therapy. The second step involves developing a decentralized placement method that allows implantation in various body parts based on the disease and enables communication between devices. For instance, placing devices in central and peripheral regions enables closed-loop diagnosis and treatment of pain. The Principal Investigator's distributed placement method for artificial vision devices will be employed for efficient placement. Animal models of pain, depression, and epilepsy will be used to demonstrate the effectiveness of the prototype devices, including chronic implantation. Figure 4 illustrates the concept of distributed photocetutical devices in the brain, each with light stimulation and fluorescence measurement capabilities, and enabling control of multiple devices with minimal wiring. The successful development of a phototherapeutic device holds promise for treating depression, pain, epilepsy, and other challenging conditions unresponsive to traditional drugs and electrotherapeutic devices.

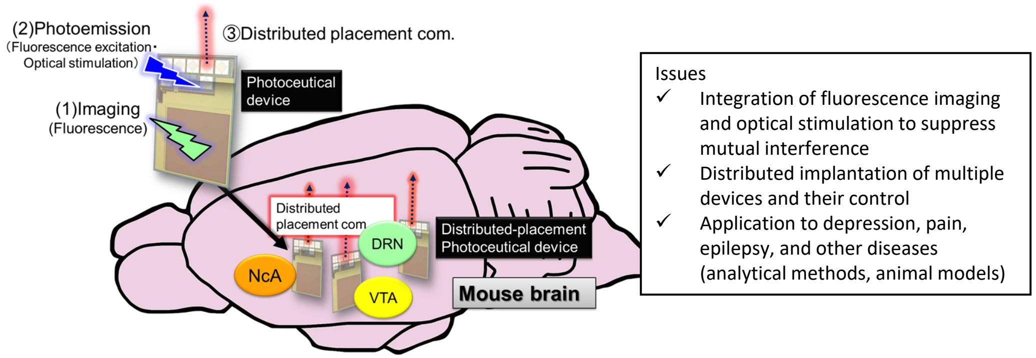

Figure 4. Concept and issues of photoceutical device

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