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

Development of biocompatible system for introducing sensors and artificial materials into cells

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Project Information	Project Number : 25H00410　Project Period (FY) : 2025-2029 Keywords : injection, bio-compatibility, electrically-induced bubble, DNA-functionalized nanoparticle (DNA-NP) crystals, optical sensor

Purpose and Background of the Research

●Outline of the Research

In order to transmit information from within cells or living tissues, it is extremely important to embed sensors or artificial objects inside cells or tissues rather than on the surface of the tissue in order to accurately extract internal information. However, sensors and artificial objects embedded in living tissues or cells have issues with the weak signals they emit, low signal-to-noise ratios, and lack of biocompatibility to withstand long-term use. This research aims to solve these problems by developing a new minimally invasive introduction method and a new biocompatible sensor system that will function for long periods of time and perform monitoring. Specifically, 1. Using a microfluidic chip, we will create nanostructures (crystals, etc.) with repeating structures in controllable sizes and shapes, 2. Inject them minimally invasively at targeted locations using electrically-induced bubbles, 3. Amplify external light signals and transmit information to the outside, and 4. Build a system for long-term monitoring. The important question of this research is what kind of system is needed to enable artificial sensors embedded in biological tissues and cells to function for long periods of time.

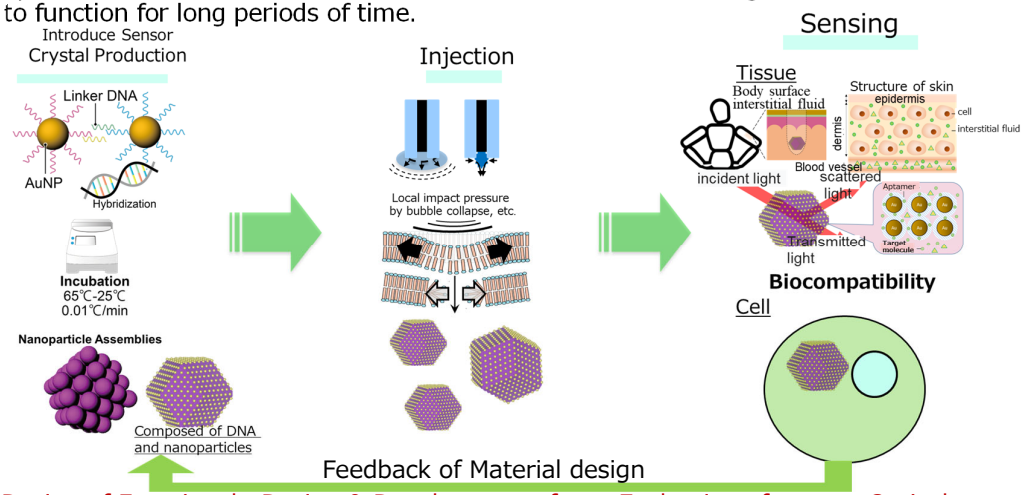

Figure 1.　Overview of this research

●High-throughput crystal growth technology using microfluidic chips

We have the technology to grow DNA-functionalized nanoparticle (DNA-NP) crystals that function as sensors in a microfluidic chip as designed, and the technology to produce them at high throughput. Furthermore, we can also perform solution replacement to place the DNA-functionalized nanoparticle crystals in a biocompatible solution environment for use in vivo.

●Features of this research

- A unique, minimally invasive injection method using electrically-induced bubbles that can accommodate a wide dynamic range from the cellular to tissue levels.
- DNA-functionalized nanoparticle (DNA-NP) crystals have a high degree of freedom in design, allowing a variety of crystal structures to be created using nanoparticles of various compositions, sizes, and shapes. The binding ability of DNA can be utilized to modify and deliver a variety of molecules to targets. The repeating structure of the DNA nanoparticles allows the return of enhanced optical sensing data.
- By combining the electrically-induced bubbles and DNA-functionalized nanoparticle (DNA-NP) crystals, they aim to construct an interface between technological and biological information transmission means in a wide dynamic range, and to extract biological information in time and space.

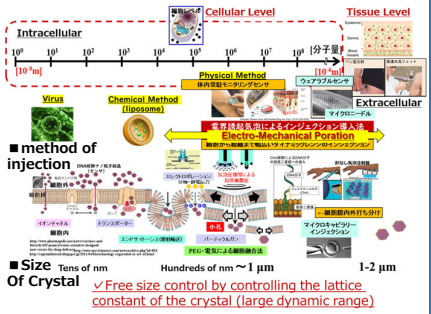

Figure 2. Novel transfection method that supports a wide dynamic range from cells to tissues

Expected Research Achievements

●Purpose and how to proceed our research

In this study, we aim to construct a system that enables artificial sensors embedded in biological tissues and cells to function for long periods of time while maintaining the viability of the cells and organisms, and to identify, weight, and understand the effective parameters in biology and engineering by mapping the improvement of the introduction rate and survival rate when introducing artificial objects for each target cell type and artificial object to be introduced.

We believe that constructing a robust information embedding system that can be implemented in any target will lead to a new academic trend that treats robotics (artificial objects) and living organisms as one unit and smoothly connects the mechanisms of artificial information transmission with those of living organisms.

In this research, we will first construct an artificial object, a highly sensitive sensing technology that amplifies and extracts optical information obtained from the repeating structure and controllability of lattice constants of DNA-functionalized nanoparticle (DNA-NP) crystals, outside the cell.

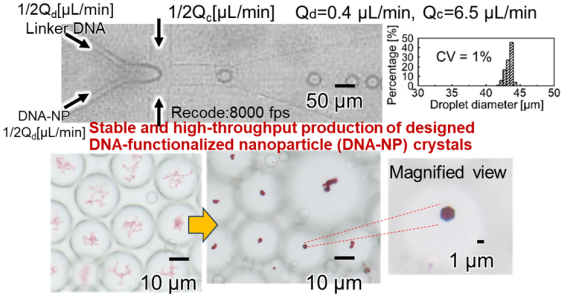

Figure 3. High through-put production of DNA-functionalized nanoparticle (DNA-NP) crystals using microfluidic channels

Introduction of DNA-functionalized nanoparticle (DNA-NP) crystals (size: about 1 μm) into cells (UMR-106) (under conditions where a thickening agent was added)

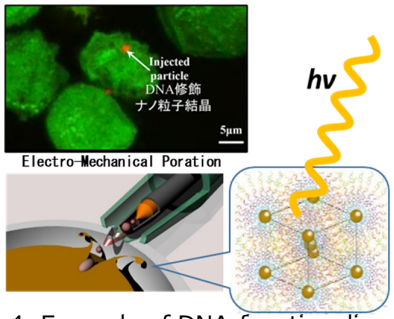

Figure 4. Example of DNA-functionalized nanoparticle (DNA-NP) crystals introduction to cells using electric field-induced bubbles

Homepage Address, etc.	Biomedical Microfluidics Lab, Kyushu University https://bmf.mech.kyushu-u.ac.jp/