【Grant-in-Aid for Transformative Research Areas（B）】

Smart nanoparticle photonics

Principal Investigator	Kyushu University, Faculty of Science, Professor HIRAMATSU Kotaro	Researcher Number : 60783561
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Purpose and Background of the Research

●Outline of the Research

To detect diseases early or understand how life works at the molecular level, we need technologies that let us observe what's happening inside living cells in real time. This is the goal of bioimaging, and many light-responsive materials—like fluorescent proteins, organic dyes, and quantum dots—have been developed for this purpose.

In recent years, advances in nanotechnology have led to the creation of a wide variety of nanoparticles made from metals and semiconductors. These tiny particles, just billionths of a meter in size, can strongly interact with light and are often biocompatible, making them promising tools for imaging. However, their full potential hasn't yet been fully realized. Most nanoparticles used today simply glow when exposed to light, but they don't provide detailed information about their surroundings.

In this research, we introduce the concept of "smart nanoparticles." These are not just light-emitting particles—they respond strongly to near-infrared (NIR) light, which can pass through biological tissue safely. What's unique is that their shape directly affects how they scatter light, allowing us to "read" information about their local environment.

We focus on ultrathin gold nanorods, only a few nanometers wide and 5–100 nanometers long. We aim to develop new ways to synthesize and measure these particles, and to apply them in living cells. Their shape and light response can reveal changes in cellular structure or molecular interactions.

As NIR light is gentle and penetrates deeply into tissue, these smart nanoparticles could enable non-invasive imaging inside living organisms. We hope this technology will become a new platform for early disease detection, advanced medical diagnostics, and nanoscale biological studies.

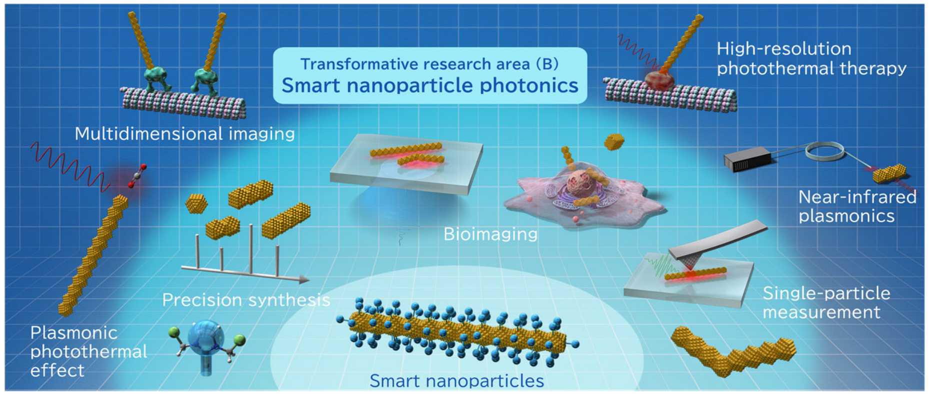

Figure 1 Overview and future prospects of smart nanoparticle photonics

●Future prospects

Our project aims to bridge medicine, life science, and materials research through smart nanoparticles. Specifically, we plan to enhance bioimaging using smart nanoparticles to visualize cell structures and molecular interactions in greater detail. We also envision using smart nanoparticles for targeted photothermal therapy and precise cell control, by modifying their surfaces with different molecules. Beyond biology, they could be applied to optical devices like plasmonic waveguides and to environmental uses such as CO_2 reduction through light-based reactions. We aim to build a collaborative framework with industry and government partners, turning these scientific advances into practical technologies for medicine, energy, and beyond.

Expected Research Achievements

●Research objectives

This project aims to develop next-generation bioimaging technologies using smart nanoparticles—light-responsive nanostructures with unique optical properties. We focus on ultrathin gold nanostructures with few-atom wide to visualize structures and molecular movements inside cells that were previously difficult to detect.

Our research is organized into three teams, A01, B01, and C01. A01 will develop reliable synthesis methods for smart nanoparticles, enabling the stable production of nanoparticles with highly uniform sizes and shapes. This will lay the groundwork for precisely correlating the shape of each particle with its optical response and extracting structural information at the nanoscale.

B01 will establish high-resolution spectroscopic techniques capable of measuring the near-infrared plasmon resonance spectra of individual particles. This will allow us to visualize how composition, shape, and local environments affect the particles' optical signatures, forming a basis for interpreting their behavior inside biological systems.

C01 will develop bioimaging technologies that use smart nanoparticles inside living cells, enabling real-time, non-invasive observation of structural changes and molecular interactions. This approach will make it possible to spatially and temporally resolve phenomena such as cytoskeletal deformation, molecular dynamics, local viscosity, and electric fields at the single-particle level.

Rather than simply marking target molecules, we aim to fully utilize the small size and anisotropy of smart nanoparticles to extract multi-dimensional biological information. These advances are expected to impact not only early cancer detection and personalized medicine, but also new optical therapies and nanoscale material science.

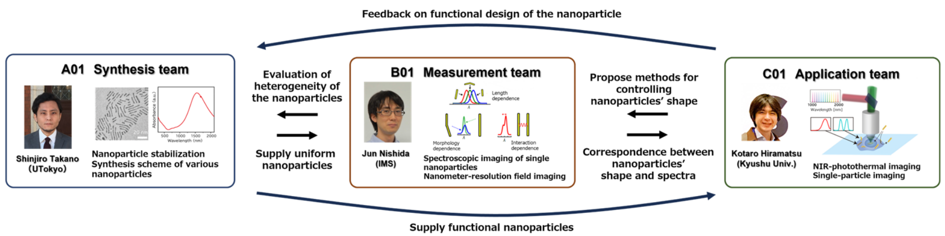

Figure 2 Project team structure of smart nanoparticle photonics.

Homepage Address, etc.	https://smart-nanoparticles.jp