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

Innovation in Medical and Engineering Measurement by Optical Condensation Proteomics

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Project Information	Project Number : 25H00421　　Project Period (FY) : 2025-2029 Keywords : Optical condensation, protein, medical engineering measurement, affinity

Purpose and Background of the Research

●Outline of the Research

We aim to construct an innovative measurement technology that controls the affinity of antigen-antibody reactions of proteins in complex biological systems by optical condensation (OC) and enables highly sensitive and rapid measurement of proteins, and to establish the science of "Optical condensation proteomics" by integrating photophysics, proteomics, and immunology. In particular, we will selectively measure specific proteins in liquids containing a large amount of foreign substances, such as blood, and clarify the correlation between the aggregation state and pathological conditions, thereby contributing to the expansion of the search space for new disease markers. Through these efforts, we will elucidate a new mechanism to induce trace markers into the measurement area by OC and detect them with high sensitivity, and work to build a foundation for innovation in medical engineering measurement.

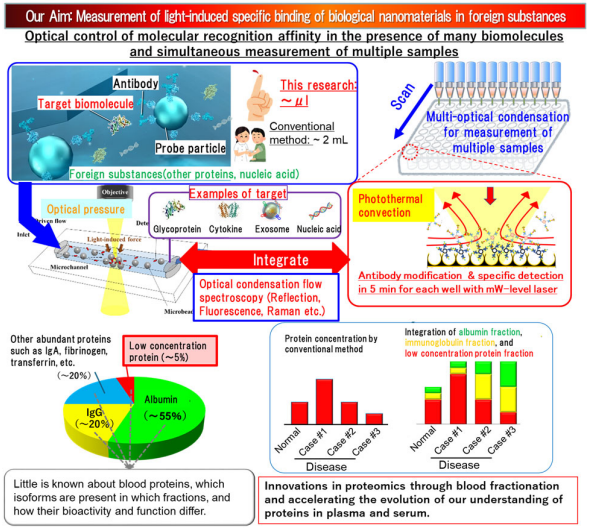
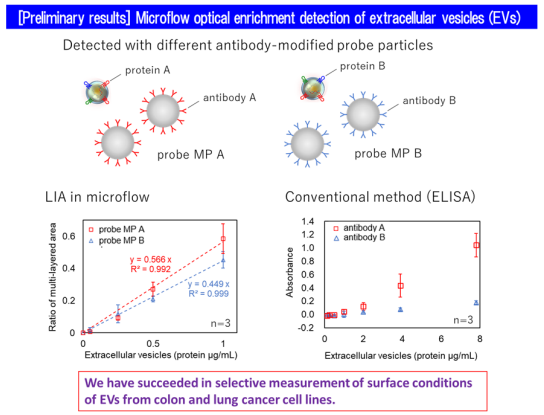


Figure 1　Concept of this research

●Preliminary results and purpose of this study

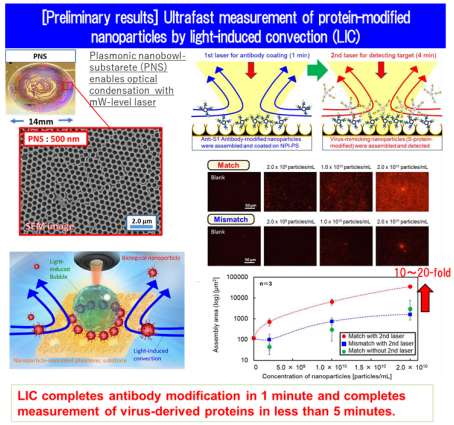
We have clarified the mechanism of OC by the synergistic effects of light-induced force and photothermal effect and have succeeded in light-induced acceleration of various biochemical reactions for the first time in the world. For example, we can selectively detect and quantitatively evaluate membrane proteins on the surface of extracellular vesicles (EVs) at low concentration ranges by optical pressure and fluidic pressure in microfluidic channels that cannot be measured by conventional immunoassay methods (Figure 2). Furthermore, the antibody modification, which required half a day by conventional methods, can be completed within one minute by light-induced convection, and nanoparticles modified with virus-derived proteins can be measured within five minutes with one to two orders of magnitude higher sensitivity (Fig. 3).

The purpose of this research is to expand the OC detection system to accommodate multiple samples by making full use of state-of-the-art photonics based on these preliminary results, and establish the principles of affinity analysis and control between biomolecules in blood and other body fluids containing rich foreign substances through interdisciplinary and collaborative research with the medical field.



Ref.) Nanoscale Horizons (2023)

Figure 2　Highly sensitive and selective measurement of membrane proteins by an acceleration mechanism of antigen-antibody reaction using micro-flow OC



Ref.) npj Biosensing (2024)

Figure 3　Rapid and sensitive measurement of proteins with low-power OC comparable to that of a laser pointer on a multi-pore OC-substrate

Expected Research Achievements

●Specific Research Items

(1)Elucidation of the control principle of affinity of biomolecules in the presence of foreign substances by light-induced acceleration (LIA) [Iida-Tokonami-Nakase G, Ito G].
(A) LIA of antigen-antibody reaction and affinity measurement in foreign substances
(B) Evaluation of effect of foreign substances on molecular recognition of a few molecules
(C) Construction of simultaneous OC measurement system for multiple markers

(2) Application of OC in cancer marker measurement [Taguchi G].
(A) Conventional measurement of existing markers in plasma (protein, nucleic acid)
(B) Search for new cancer markers by mass spectrometry

(3) Application of OC in the measurement of inflammation markers [Murakami G, Iwatani G].
(A) Measurement and analysis of cytokines in serum by conventional methods
(B) Search for inflammation markers inside and outside of EVs

(4) Application of OC in the measurement of dementia markers [Nagashima G].
(A) Conventional measurement and analysis of dementia markers
(B) Spectroscopy of nerve-related proteins and evaluation of structures obtained by OC

This research will establish a general-purpose multi-OC measurement methodology to elucidate the state of proteins in blood fractions, establish the science of "Optical condensation proteomics" to realize ultra-sensitive, rapid, and selective measurement from a small amounts of biological samples, and build a foundation for light-induced health monitoring not only in clinical site but also in everyday situations. Expected results will contribute to the health and longevity of humankind.

Homepage Address, etc.	Bio-photophysics Group: https://www.omu-lacsys.com/iidalab/e_index.html RILACS: https://www.omu-lacsys.com/LAC-SYS/e_index.html