【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project： **Molecular electron microscopy for dynamic studies on molecules and their assemblies**

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Keyword：Structural analysis, Electron microscopy, Microanalysis, Organic chemistry

【Purpose and Background of the Research】

Video imaging of the dynamic behavior of a single organic molecule captured by high-resolution electron microscopy was reported first in 2007 (Single Molecule Atomic-resolution Real-Time Electron Microscopy, SMART-EM), linking organic chemistry to EM that had then focused largely on analysis of periodic structures and solid samples in biological and materials research. With a recently acquired state-of-the-art EM equipped with an ultrafast camera, we will capture high-speed two-dimensional videos at millisecond, and also acquire nano level three-dimensional information. Our purpose is to establish a new experimental method to be called "molecular electron microscopy" for studying the dynamic behavior of molecules and molecular assemblies.

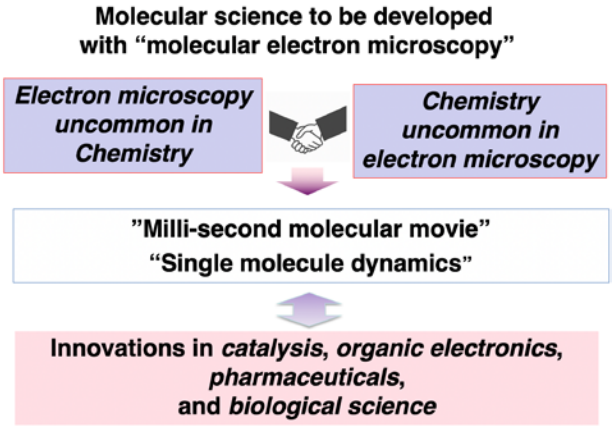

Figure. Research overview

【Research Methods】

SMART-EM is an imaging method fundamentally different from "cryo-EM" and "micro electron diffraction (ED)" in that it provides real time images of the dynamic behavior of a single molecule, enabling video imaging of single molecules and linking them to the understanding of macroscopic physicochemical properties and reactivities. The method will open up an experimental approach previously considered impossible, such as isolation and structure determination of a single molecule in a reaction mixture, and in situ observation of the time course of chemical reaction events.

It has been a chemists' dream to see in situ and at atomic resolution a molecule that changes its shape and reacts. The most advanced camera can capture 1,600 electron microscopic images per second. Through software development such as denoising and automatic video analysis, high-speed imaging of molecular motions and reactions will be achieved, providing hitherto unavailable basic knowledges in molecular science.

【Expected Research Achievements and Scientific Significance】

This research aims for the development of a variety of electron microscopic techniques centering on the SMART-EM method and solving problems in catalysis, organic electronics, pharmaceuticals, and life sciences. Elucidation of the dynamic behavior of molecular species, which cannot be studied by previously known methods, will be made possible by capturing and identifying a molecular amount of reaction intermediates and analyzing amorphous organic aggregates.

This study will realize a dream of people since Dalton's atomic theory in the 19th century, that is, seeing in situ the motions and reactions of the single molecules as they happen. By sharing such experience with young people, we will be able to make the world of atoms and molecules more familiar to people at large.

【Publications Relevant to the Project】

・M. Koshino, T. Tanaka, N. Solin, K. Suenaga, H. Isobe, E. Nakamura, Imaging of Single Organic Molecules in Motion, *Science*, **316**, 853, (2007).
・E. Nakamura, K. Harano, Chemical Kinetics Study through Observation of Individual Reaction Events with Atomic-Resolution Electron Microscopy, *Proc. Jpn. Acad., Ser. B*, **94**, 428-440, (2018).

【Term of Project】 FY2019-2023

【Budget Allocation】 475,200 Thousand Yen

【Homepage Address and Other Contact Information】

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