【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)

Title of Project : Innovation of structural materials science: Femtosecond time-resolved atomic imaging

Katsumi Tanimura
(Osaka University, The Institute of Scientific and Industrial Research, Professor)

Research Area : Solid state physics, Structural materials science
Keyword : Photoinduced phase transitions, Ultrafast time-resolved spectroscopy

【Purpose and Background of the Research】

In the last century, innovative progress in materials science has impacted chemistry, biology, solid-state physics and other related fields. Structures of molecules, proteins, and solids can be determined at the atomic level (1 Å resolution) in static experiments while ultrafast dynamics can be captured by optical spectroscopy in temporal domains as short as 10^{-13} s. However, despite such progress, simultaneous ultra-high spatial and temporal resolution is yet to be demonstrated.

The beginning of 21st century has become the starting point of the next innovation that leads to the realization of the "dream" of structural dynamics research: direct structural determination of materials in ultrafast processes. The main purpose of this project is to develop just such a femtosecond time-resolved electron microscope with 1-Å spatial resolution and with a single-shot imaging capability.

【Research Methods】

We renovate our single-shot transmission electron diffractometer with fs temporal resolution, shown in Fig.1, to establish the method for ultrafast atomic imaging. We will use this new time- resolved microscope to study structural dynamics in solids, such as photo-induced structural phase transitions, lattice instability in warm dense matter, and molecular reactions of photochromic organic crystals with ultimate spatial and temporal resolution.

Fig.1 Our time-resolved electron diffractometer

【Expected Research Achievements and Scientific Significance】

Ultrafast real-space imaging of atomic ensembles will provide the most direct and crucial information for dynamical mechanisms of many important processes in chemistry, solid-state physics, materials science, and biology. Our microscope will establish 10^{-13} s temporal resolution and 1-Å spatial resolution with a single-shot imaging capability; thus making it possible to study a broad variety of irreversible processes initiated by photoexcitation.

This innovation of knowledge on structural dynamics will greatly improve our understanding of the ultrafast cooperative interactions in condensed matters, and provides direct insight into the dynamical mechanism of phase transformation. By combining precise knowledge of structural dynamics with that of electronic relaxation, together with advanced theoretical analysis, we can elucidate the dynamical mechanism of many-body interaction from a microscopic perspective.

Ultrafast real-space imaging at the atomic level, will strongly impact other scientific fields, such as molecular science, chemistry, and biology, thus providing a break-through in the field of ultrafast structural dynamics research.

【Publications Relevant to the Project】

- Y. Murooka et al., Appl. Phys. Lett. **98**, 251903 (2011)
- J. Kanasaki et al., Phys. Rev. Lett. **102**, 087402 (2009).
- A. H. Zewail, Science, **328**, 187 (2010).

【Term of Project】 FY2012-2016

【Budget Allocation】 302,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.sanken.osaka-u.ac.jp/labs/aem/Projects.html