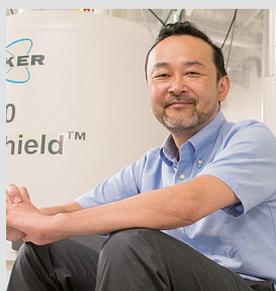


Solid-State NMR for Molecular Science

Department of Materials Molecular Science
Division of Molecular Functions

NISHIMURA, Katsuyuki
Associate Professor
[nishimur@ims.ac.jp]

Education

1994 B.S. Himeji Institute of Technology (University of Hyogo)
1999 Ph.D. Himeji Institute of Technology (University of Hyogo)

Professional Employment

1999 Postdoctoral Fellow, National High Magnetic Field Laboratory, Florida State University
2001 Assistant Professor, Yokohama National University
2006 Associate Professor, Institute for Molecular Science
Associate Professor, The Graduate University for Advanced Studies

Award

2002 The Young Scientist Poster Award, The Nuclear Magnetic Resonance Society of Japan

Member
Secretary
YOKOTA, Mitsuyo

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In order to elucidate functions of molecules, characterization of the molecule is the first step. There is a variety of important molecules, which are insoluble in any solvents and functional at amorphous state. Solid-state NMR enables us to obtain a variety of information at atomic resolution without damage to molecules and significant restrictions. Thus, solid-state NMR is one of the essential tools for the characterizations of those molecules.

We have been working on methodology and hardware developments of solid-state NMR and their application to structural biology and materials science. We study characterizations of membrane proteins and peptides, organic materials, natural products and synthetic polymers. Characterization of those molecules based on solid-state NMR is underway through collaborations with several research groups.

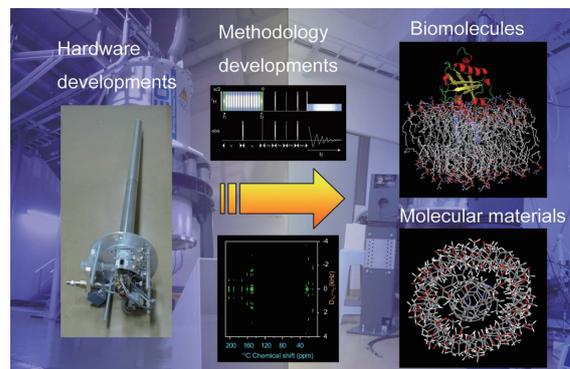


Figure 1. Outline of our studies.

Selected Publications

- M. Tanio and K. Nishimura, "Intramolecular Allosteric Interaction in the Phospholipase C- δ 1 Pleckstrin Homology Domain," *Biochim. Biophys. Acta, Proteins Proteomics* **1834**, 1034–1043 (2013).
- T. Asakura, T. Ohata, S. Kametani, K. Okushita, K. Yazawa, Y. Nishiyama, K. Nishimura, A. Aoki, F. Suzuki, H. Kaji, A. Ulrich and M. Williamson, "Intermolecular Packing in B. Mori Silk Fibroin: Multinuclear NMR Study of the Model Peptide (Ala-Gly)₁₅ Defines a Heterogeneous Antiparallel Antipolar Mode of Assembly in the Silk II Form," *Macromolecules* **48**, 28–36 (2015).
- M. Yagi-Utsumi, K. Kato and K. Nishimura, "Membrane-Induced Dichotomous Conformation of Amyloid β with the Disordered N-Terminal Segment Followed by the Stable C-Terminal β Structure," *PLoS One* **11**, 0146405 (10 pages) (2016).
- N. Huang, L. Zhai, D. E. Coupry, M. A. Addicoat, K. Okushita, K. Nishimura, T. Heine and D. Jiang, "Multi-Component Covalent Organic Frameworks," *Nat. Comm.* **7**, 12325 (12 pages) (2016).
- N. Ousaka, F. Mamiya, Y. Iwata, K. Nishimura and E. Yashima, "'Helix-in-Helix' Superstructure Formation through Encapsulation of Fullerene-Bound Helical Peptides within a Helical Poly(methyl methacrylate) Cavity," *Angew. Chem., Int. Ed.* **56**, 791–795 (2017).
- M. Yagi-Utsumi, S. G. Itoh, H. Okumura, K. Yanagisawa, K. Kato and K. Nishimura, "The Double-Layered Structure of Amyloid- β Assemblage on GM1-Containing Membranes Catalytically Promotes Fibrillization," *ACS Chem. Neurosci.* **14**, 2648–2657 (2023).

1. Developments of Solid-State-NMR Techniques

In rigid organic solids, it is not easy to achieve high resolution ^1H NMR spectra in solid-state NMR spectroscopy due to the presence of strong ^1H homonuclear dipolar couplings which broaden ^1H signals. Therefore, ^1H homonuclear dipolar couplings must be decoupled efficiently by applying either magic angle spinning (MAS) at sufficiently high speed larger than 60 kHz or MAS at moderate speed in combination with multiple pulses (MPs). MAS and MPs give perturbations to spatial and spin parts of ^1H homonuclear dipolar coupling Hamiltonian, respectively. Furthermore, by using significantly high power radio frequency field (RF), it is still possible to apply MPs under ultra-high speed MAS in which require to keep short cycle time of MPs respect to the MAS period to avoid interference of time averaging effect between spatial and spin parts of ^1H homonuclear dipolar coupling Hamiltonian. Even under ultra-high speed MAS, applications of MPs improve spectral resolution furthermore. Therefore, methodology developments of MPs is still one of important research topics. ^1H spectral resolution depends on both the efficiency of decoupling and chemical shift scaling factor of MPs. The former factor can be improved through design of MPs enabling the removal of high order correction terms. On the other hand, the latter factor also depends on the design of MPs and larger scaling factor contributes better spectral resolution.

In the last report, we have reported the developed new MP sequence enabling removal of high order correction terms with moderate sequence length to realize efficient ^1H homonuclear dipolar decoupling. In this time, we have developed similar but new MPs possessing larger chemical shift scaling factors over previous one. However, the new MPs have twice length of previous one. Therefore, those are suitable to the conventional MAS up to 40 kHz. Such new sequences were evaluated theoretically and their performances will be demonstrated soon.

We have also designed two different types of modules to achieve heteronuclear dipolar recoupling with homonuclear decoupling of irradiated nuclei. The detail of those experiments will be reported. Such new sequences were evaluated theoretically and their performances will be demonstrated soon.

2. Developments of Core Technologies for Solid-State NMR Probes

We have been working on developments of totally original

solid-state NMR probes for a couple of years. The probe had been successfully built using originally designed parts except for a spinning module for 400MHz NMR. Then, we have been working on developments of original sample spinning modules for MAS solid-state NMR probes which are fully compatible with Bruker spectrometers and commercial sample tubes. The spinning modules have been designed to fit probes for narrow bore magnet with outer sleeve possessing 38 mm inner diameter. We started the design of a spinning module for a standard 4.0 mm sample tube. After several times of version up, our original spinning module significantly exceeded the spinning performance of the commercial one from Bruker.

The design and build of final version of the spinning module have been finished. Currently, it is under optimization of air bearing black to achieve sufficient stability of spinning at high spinning rate.

Furthermore, the design and build of final version of the original spinning module for 2.5mm sample tube have been finished and it is also optimization of air bearing black.

Currently, we are also working on the design and build of the original spinning module for 1.9 mm sample tube.

3. Characterization of Synthetic Molecules by Solid-State NMR¹⁾

Solid-state NMR is one of the efficient techniques to characterize amorphous samples such as synthetic molecules. We have collaborated with many research groups for the characterization of new synthetic molecules using solid-state NMR at the past. During couple of years, we have been collaborated with Associate Prof. Segawa group in IMS for the characterization of their newly developed synthetic molecules which are categorized to covalent organic frameworks (COFs).

Finally, ^{13}C signal solid-state NMR signal assignments had been successfully achieved for two of the new molecules. The obtained results from solid-state NMR together with other experimental data from other experiments sufficiently prove the achievement of the target molecular form of COFs for those samples. This project is also on the way.

Reference

- 1) K. Watanabe, J. Usuba, Y. Hijikata, T. Toya, Y. Toyota, Y. Kobayashi, R. Matsuda, K. Nishimura, H. Sugiyama and Y. Segawa, *Chem. Commun.* **61**, 2822–2825 (2025).