S. Kitagawa

*The author presented on this page has recently published his **25th article** since 2000 in Angewandte Chemie*: "Bidirectional Chemo-Switching of Spin State in a Microporous Framework": M. Ohba, K. Yoneda, G. Agustí, M. C. Muñoz, A. B. Gaspar, J. A. Real, M. Yamasaki, H. Ando, Y. Nakao, S. Sakaki, S. Kitagawa, *Angew. Chem.* **2009**, *121*, 4861 – 4865; *Angew. Chem. Int. Ed.* **2009**, *48*, 4767 – 4771.

Susumu Kitagawa

Date of birth:	July 4, 1951
Position:	Deputy Director, Institute for Integrated Cell-Material Sciences, Kyoto University (Japan) Professor, Department of Synthetic Chemistry and Biological Chemistry, Kyoto University
Education:	1974 BA degree, Kyoto University 1975–1979 PhD with T. Yonezawa and I. Morishima, Graduate School of Engineering, Kyoto University
Professional associations:	1979–1983 Assistant Professor, Department of Chemistry, Kinki University (Osaka) 1983–1988 Lecturer, Department of Chemistry, Kinki University 1986–1987 Visiting Scientist, F. A. Cotton Laboratory, Department of Chemistry, Texas A and M University (USA) 1988–1992 Associate Professor, Department of Chemistry, Kinki University 1992–1998 Professor, Department of Chemistry, Tokyo Metropolitan University (Tokyo) 1998–Present Professor, Department of Synthetic Chemistry and Biological Chemistry, Kyoto University 2007–Present Deputy Director, Institute for Integrated Cell-Material Sciences, Kyoto University
Recent awards:	**2001**: The Chemical Society of Japan Award for Creative Work; **2007**: Earl L. Muetterties Memorial Lectureship, University of California, Berkeley (USA); **2007**: The Japan Society of Coordination Chemistry Award; **2008**: Humboldt Research Award (Germany); **2009**: The Chemical Society of Japan Award
Current research interests:	Coordination chemistry with focus on the chemistry of organic–inorganic hybrid compounds, particularly the chemical and physical properties of porous coordination polymers from which "function-integrated pores" may be developed in the near future Developing a new field, "the chemistry of coordination space", which promotes the design of new substances involving dynamic electronic and spatial structure, and the creation of materials utilizing nanovoids, nonlinear phenomena, and quantum size effects
Hobbies:	bicycle riding

When I was eighteen I wanted to be … an architect.

The biggest challenge facing scientists is … to prepare organic compounds such as amino acids from air.

When I wake up I … like to hear the twittering of birds.

The biggest problem that scientists face is … that the economic status of the world influences possible research subjects.

My favorite piece of research is … frontier orbital theory.

If I could be anyone for a day, I would be … Antonio Gaudí.

If I could have dinner with three famous scientists from history, they would be … Erwin Schrödinger, Shin'ichiro Tomonagawa, and Ilya Prigogine.

I chose chemistry as a career because … chemists understand the difference between ethanol and methanol.

My biggest inspiration is … "reality is that the only constant is change".

My most exciting discovery to date has been … soft porous coordination polymer crystals (soft porous crystals).

My biggest motivation is … understanding and controlling the role of nanospace.

My work is significant because … of the great contribution it makes to low-energy processes in industry.

In my spare time I … read classical literature.

The secret of being a successful scientist is … as a painter improves his art by looking at great paintings, so you should interact with many great scientists.

The best advice I have ever been given is … "If it is not published, it is not finished" by Al Cotton.

How is chemistry research different now than it was at the beginning of your career?

As a graduate student, the use of X-ray crystallography to determine the structure of molecules was purely the realm of specialists, and it was unthinkable that a synthetic chemist could collect data and solve structures with the ease with which he could analyze infrared absorption spectra. After becoming a professor, we installed an X-ray crystallographic diffractometer in the lab, and it became possible to perform structural analysis in house. Such improvements in computing power, software, and analytical machines have all been quantum leaps. It is now possible to use a synchrotron radiation beam in X-ray structural analysis, and to collect X-ray data together with UV/Vis excitation and Raman spectra simultaneously for the same sample point on the crystal, and we are in an era when we can expect to see new material states (both in ground and excited states) as well as analyze data and discover and design new materials based on the obtained results.

Has your approach to chemistry research changed since the start of your career?

Yes, a great deal from physical chemistry to synthetic chemistry. However, this experience has been useful for my present work. I started my career studying the chemistry of iron porphyrins to elucidate the relationship between their structures and properties. I relied on paramagnetic NMR spectroscopy, which allowed me to investigate apical ligand binding through chemical shifts and relaxation times. After graduation, I changed my focus to synthetic copper(I) chemistry, which is directly connected to the present chemistry of porous coordination polymers. As the structural chemistry of porous coordination compounds has been well developed, I am particularly focusing on their electronic properties. My research style has come full circle, returning to what I did in graduate school by using NMR and other spectoroscopic techiniques in addition to theoretical calculations.

Has your approach to publishing your results changed since the start of your career?

In graduate school we wrote articles debating the nature of molecular systems based on spectroscopic observation data, whereas today we first synthesize new metal complexes, the properties of which we then discuss in our papers. In other words, we now create new materials, analyze them, and make discoveries, all of which allow us to fully enjoy doing chemistry while presenting our results to the world.

What do you think the future holds for your field of research?

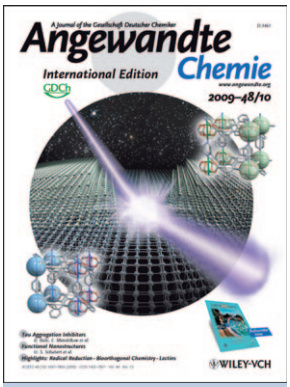
"Structures" are very important, but their meaning is changing from static and rigid to dynamic, flexible, or soft (spatiotemporal structures). The relationship between function and structure will be highly important. This is a big change from statically cooled aesthetic aspects to flexible and responsive ones. To investigate this, we need to develop new analytical methods because the current spectroscopic methods are not good enough to understand spatiotemporal phenomena. This is crucial because we need to focus on structures around the meso regime in which molecules and ions are assembled by various interactions ranging from strong to weak.

Have you changed the main focus of your research throughout your career and if so why?

As a graduate student, my focus was on the dynamic aspect of metal complexes through ^{1}H and ^{13}C NMR spectroscopic relaxation times. Tridentate amino acids are coordinated to Co^{II} ions resulting in bis-ligand cobalt complexes, in which the three functional groups behave differently from coordination depending on pH and temperature. However, at that time I could not discern the unique properties of the dynamic structure. Since then I have always tried to consider this aspect, although static exact structures are still important. I learned a great deal about crystallography through its applicability to crystal-structure-based systematic chemistry. I learned a lot from Al Cotton when I was in his laboratory. Crystallography is especially important in the inorganic field, for without it we would not be able to expand our chemistry. By taking advantage of crystallography, I was able to discover the interesting structures and properties of the extended system, which we now call coordination polymers.

What has been your biggest influence/motivation?

The ancient Chinese philosopher Chuang Tsu referred to "The usefulness of the useless". This may be difficult to grasp from a practically oriented, Western point of view, but I think it really rings true. When you change your point of view, it is often the case that something that seems useful at one moment suddenly loses its utility in the next. As a graduate student I read the physics Nobel laureate (1949) Hideki Yukawa's work "The World of Genius (*Tensai no Sekai*)," in which he introduced this expression of Chuang Tsu as a favorite of his. It immediately struck a chord with me for its applicability to the world of chemistry. Material and life sciences have significantly contributed to human well-being and prosperity, and atoms and molecules play a central role in all of this. The synthesis of molecules is one of the major themes of



S. Kitagawa has featured on the cover of Angewandte Chemie:
"Heterogeneously Hybridized Porous Coordination Polymer Crystals: Fabrication of Heterometallic Core-Shell Single Crystals with an In-Plane Rotational Epitaxial Relationship": S. Furukawa, K. Hirai, K. Nakagawa, Y. Takashima, R. Matsuda, T. Tsuruoka, M. Kondo, R. Haruki, D. Tanaka, H. Sakamoto, S. Shimomura, Osami Sakata, S. Kitagawa, *Angew. Chem.* **2009**, *121*, 1798–1802; *Angew. Chem. Int. Ed.* **2009**, *48*, 1766–1770.

the previous century. In addition to framework entities, the space surrounding and partitioned by atoms and molecules could represent another world of science, in a sense turning the "useless" of the 20th Century into the "useful" of the 21st. If we build nanosized spaces at will, what sorts of materials could be created and what discoveries about molecules in the space could be made? In a nanosized space world, walls, which are composed of atoms and molecules and apportioned space, have a considerable effect on the orientation, correlation, and assembled structures of guest molecules. We can, therefore, control the states of guest molecules in a space by changing the shapes and materials of surrounding walls. Knowing this is my motivation.

What advice would you give to up-and-coming scientists?

Sports and the arts have the power to move people emotionally. Even in the natural sciences, similar effects can be seen in reactions to revelations from mathematics or astronomy. It is in our power as chemists to unlock mysteries that likewise inspire feelings of wonder and passion. We must strive to uncover facts that turn conventional wisdom on its head and create a new chemistry.

What is the secret to publishing so many high-quality papers?

In graduate school I learned to write clear papers, free from inconsistencies, based on "solid" physical chemistry observation data. I also grasped how to write introductions that spark the reader's interest. Since that time I have occasionally had to work in research environments that were less than ideal, but through synthetic chemistry I have been able to make fresh discoveries that have brought me to where I am today. All of these experiences combined have given me the ability to publish high-quality papers. Even when co-authors are in a rush to publish, I always insist on taking the necessary time to be satisfied with the result. One last thing is that I always try to publish a review article on a topic or subject in which I am involved at that time. I think a review article is as important as an original paper, because a review gives you an opportunity to describe ideas and present your own world view of chemistry, declaring a challenge to develop a new field that represents a fusion of chemistry, physics, and biology.

My 5 top papers:

1. "Three-Dimensional Framework with Channeling Cavities for Small Molecules. $[M_2(4,4'\text{-bipyridine})_3(NO_3)_4 \cdot x H_2O]_n$ (M = Co, Ni, and Zn)": M. Kondo, T. Yoshitomi, H. Matsuzaka, S. Kitagawa, K. Seki, *Angew. Chem.* **1997**, *109*, 1844 – 1846; *Angew. Chem. Int. Ed. Engl.* **1997**, *36*, 1725 – 1727.
   We were the first in the world to synthesize a novel porous coordination polymer relevant to gas storage of supercritical gases at ambient temperature. Previously, conventional wisdom said that coordination polymers were always fragile and weak, but we turned this idea upside down, and as a result many researchers have become involved in this new field.
2. "Formation of a One-Dimensional Array of Oxygen in a Microporous Metal-Organic Solid": R. Kitaura, S. Kitagawa, Y. Kubota, T. C. Kobayashi, K. Kindo, Y. Mita, A. Matsuo, M. Kobayashi, H.-C. Chang, T. C. Ozawa, M. Suzuki, M. Sakata, M. Takata, *Science* **2002**, *298*, 2358 – 2361.
   We made the first observation of a detached oxygen molecule in a solid, a 1D ladder structure aligned to the host channel, which provided a better understanding of the adsorption phenomena in a nanochannel and led to novel nanotechnology.
3. "Porous Coordination-Polymer Crystals with Gated Channels Specific for Supercritical Gases": R. Kitaura, K. Seki, G. Akiyama, S. Kitagawa, *Angew. Chem.* **2003**, *115*, 444 – 447; *Angew. Chem. Int. Ed.* **2003**, *42*, 428 – 431.
   We discovered a soft porous coordination polymer showing gate-opening behavior for guest gases at ambient temperature, which will find applications in gas separation and sensors.
4. "Highly Controlled Acetylene Accommodation in a Metal–Organic Microporous Material": R. Matsuda, R. Kitaura, S. Kitagawa, Y. Kubota, R. V. Belosludov, T. C. Kobayashi, H. Sakamoto, T. Chiba, M. Takata, Y. Kawazoe and Y. Mita, *Nature* **2005**, *436*, 238 – 241.
   C_2H_2 is one of the key molecules used as a starting material for many chemical and electric materials. We attained extremely high levels of selective sorption of C_2H_2 molecules onto the functionalized surface of porous coordination polymers, which permits stable storage of acetylene at a density 200 times higher than the safe compression limit of free C_2H_2 at room temperature. We are now about to perform on-demand synthesis of functional pores by tuning size/shape and chemical properties.
5. "Functional Porous Coordination Polymers": S. Kitagawa, R. Kitaura, S.-i. Noro, *Angew. Chem.* **2004**, *116*, 2388 – 2430; *Angew. Chem. Int. Ed.* **2004**, *43*, 2334 – 2375.
   In 1998 I classified porous coordination polymers into the three categories (first, second, and third generations) predicting the presence and importance of flexible porous frameworks. I established a new field of porous materials by introducing the third-generation compounds, "soft porous crystals", and am developing their rational design/synthesis thanks to an understanding of sorption phenomena. I have published many instructive reviews on porous coordination polymers or MOFs, and I am in particularly proud of my article in *Angewandte Chemie*, which is one of the most cited reviews in this field.

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