A Place in the "X-ray" Sun

At Vanguard of Science

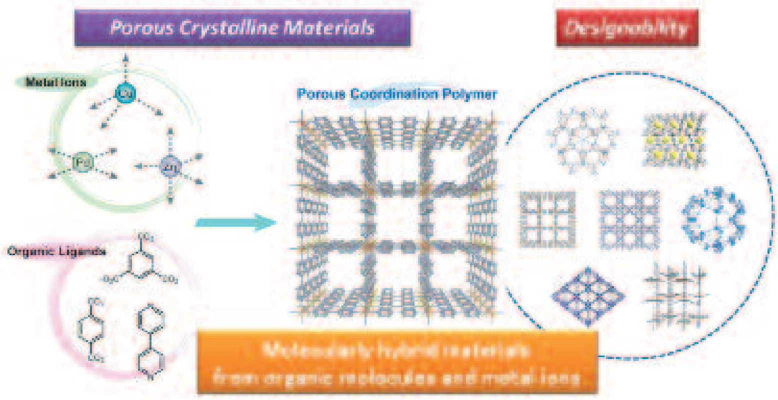
Photon Science, now, contributes to improve the quality of life in our society by tackling the reduction of carbon dioxide problem, healthcare problem, energy problem, etc. Described here are three scientists in chemical science, materials science, medical science and technology who assume the problem-solving leaderships in photon science at SPring-8.

Wizard of Nano Coordination Space
Susumu KITAGAWA

"Structural Chemistry of Coordination Nanospace" is an exciting research field at SPring-8 developed by Professor Susumu Kitagawa of Kyoto University, who has been managing atoms and molecules and fabricating various porous materials since the early 1990s. His magic of self-organizing synthesis of porous crystalline compounds created a new concept, "*coordination space*", where the coordination bond plays an important role in the formation of spatial structures. The novel materials he synthesized are now well known as porous coordination polymers (PCPs) or metal-organic frameworks (MOFs). Because of the chemistry of coordination space, PCPs have advanced extensively, affording various functional architectures, which are constructed from a variety of molecular building blocks with different interactions between them. Professor Kitagawa is the first scientist in the world to have synthesized a novel PCP relevant to the gas storage of supercritical gases such as methane at ambient temperature, and to develop its functions not only for gas storage but also for separation and catalysis with higher capacity than conventional materials. Low molecular weight molecules, such as O_2, N_2, CO_2, CH_4, and alkanes (C_2 - C_3) are important gases for human life, since they are associated not only with energy sources, but also with global environmental issues.

In 2002, by MEM (Maximum Entropy Method)/ Rietveld structure determination via *in situ* synchrotron radiation powder diffraction experiment at BL02B2, Prof. Kitagawa discovered a one-dimensional (1D) regular assembly of adsorbed dioxygen molecules in *coordination space* that cannot be realized under normal conditions [1]. This finding opened the door for long-term research targets in chemistry and physics, i.e., low-dimensionality magnetism and photo-physical properties. The use of a uniform nanosized channel in a microporous compound, i.e., *coordination space*, became a promising approach to forming a 1D-specific assembly of molecules. His discovery of a 1D ladder structure of O_2 aligned to the host channel has provided better understanding of adsorption phenomena in a nanochannel and led to novel nanotechnologies. Molecular arrays for other gases,

Porous coordination polymers (PCPs)
Metal-organic frameworks (MOFs)



Coordination Space Synthesis

Susumu Kitagawa

namely, N_2, H_2, Ar, and CH_4 have also been determined, indicating that guest molecules are confined to forming crystalline-like regular ordered arrays in a linear fashion, in contrast to the situation in the gas and liquid states, even at temperatures above the boiling point.

For the latest global issues on energy and the environment, low molecular weight molecules, such as carbon dioxide (CO_2), methane (CH_4), acetylene (C_2H_2), and alkanes (C_2 - C_3) are gases important for human life. Acetylene is one of the key molecules used as a starting material for many chemical and electric materials. To obtain highly pure C_2H_2 for the preparation of these materials, the separation of C_2H_2 from a gas mixture containing carbon dioxide (CO_2) impurities without a large expenditure of energy is crucial. In addition, acetylene is well known to be a highly reactive molecule; therefore, it cannot be compressed above 0.2 MPa, otherwise, it will explode without oxygen, even at room temperature. With this background, more feasible and safe materials for C_2H_2 separation/storage are required. Professor Kitagawa attained extremely high levels of selective sorption of acetylene molecules onto the functionalized surface of porous coordination polymers, compared with a very similar molecule, carbon dioxide. This permits stable storage of acetylene at a density 200 times higher than the safe compression limit of free acetylene at room temperature [2].

Structural investigation using SPring-8 has performed crucial roles of his outstanding achievements described above. Every year, his paper regularly appears in our scientific highlights publications, "Research Frontiers". To date, many researchers have become involved in this new field. As a world leader in this field, Prof. Kitagawa is blazing a way to systemize the serendipity of porous material synthesis toward future gas storage/separation technology [3].

1) Formation of a One-Dimensional Array of Oxygen in a Microporous Metal-Organic Solid: *Science* 298 (2002) 2358.
2) Highly controlled acetylene accommodation in a metal-organic microporous material: *Nature* 436 (2005) 238.
3) Functional Porous Coordination Polymers: *Angew. Chem. Int. Ed.* (Review) 43 (2004) 2334.

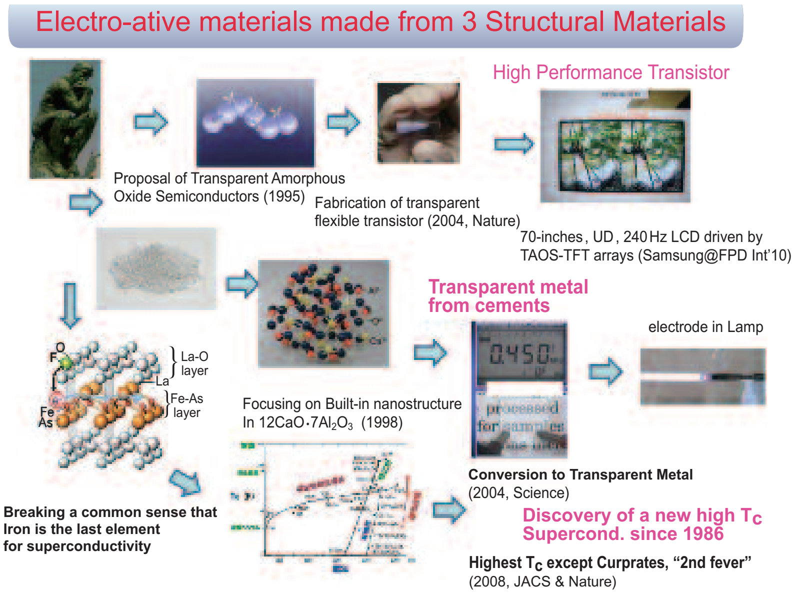
Maverick Hunter in Advanced Materials Science
Hideo HOSONO

Professor Hideo Hosono of Tokyo Institute of Technology is a maverick hunter of novel functional materials by applying his quite unique approaches. The inventions of the electroconductive cement as an alternative transparent oxide semiconductor [1] to ITO (indium tin oxide) and of transparent amorphous oxide semiconductors facilitating the industrialization of high-performance thin-film transistors for driving next-generation flat-panel displays [2] as well as of iron pnictide superconductors [3] have been a result of his wild Element Strategy.

In particular, the discovery of an iron-based superconductor, $LaO_{1-x}F_xFeAs$, rekindled the second wave of superconductor fever in materials science. 43 K, the superconducting temperature (T_c) of this material under high pressure, is the highest T_c of non-copper-based materials ever reported. People can expect to hear of yet higher transition temperatures since this type of complexity of material offers considerable flexibility for chemical modification. Professor Hosono's discovery of iron-based high-T_c superconductors ended the monopoly of CuO_2 for high T_c over the past two decades.

Professor Hosono and his research group are now frequent users of SPring-8 and have all the time trying out new functional materials using various measurement techniques.

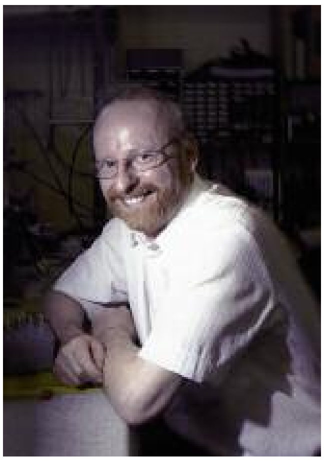
Hideo Hosono



Three functional materials created by Prof. Hosono

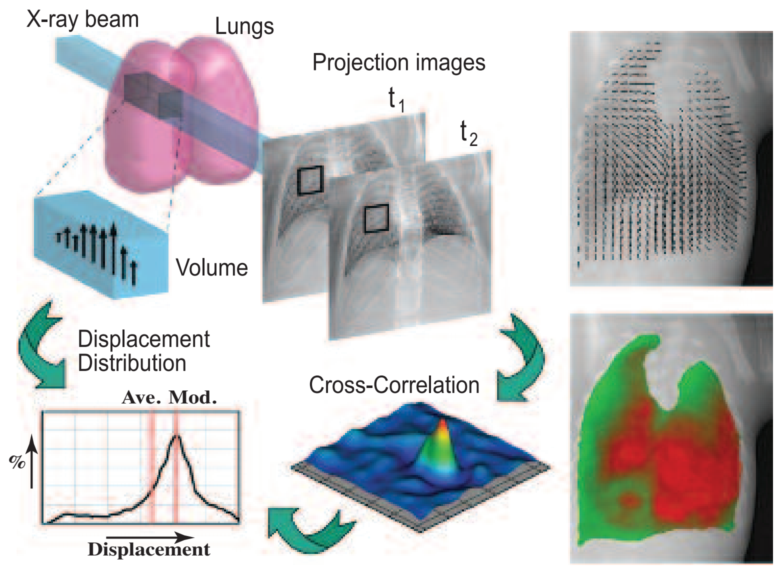
1) Light-induced conversion of an insulating refractory oxide into a persistent electronic conductor: *Nature* 419 (2002) 462.
2) Room-temperature fabrication of transparent flexible transistors using amorphous oxide semiconductors: *Nature* 432 (2004) 488.
3) Superconductivity at 43 K in an iron-based layered compound $LaO_{1-x}F_xFeAs$: *Nature* 453 (2008) 376.

Pioneer in Catching Breath via Biomedical Imaging Rob LEWIS

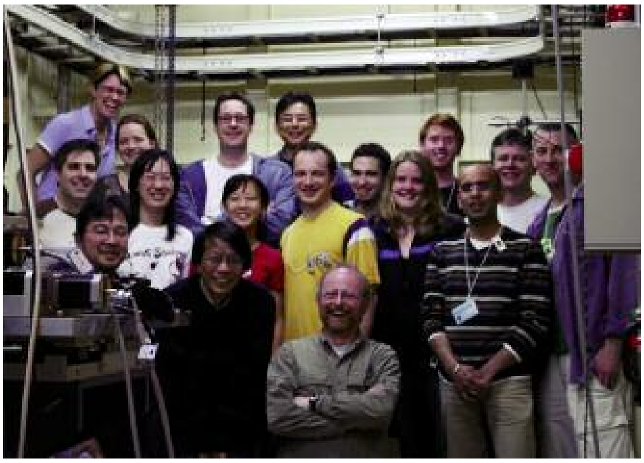


Rob Lewis

Professor Rob Lewis of Monash University, Australia is a world-leading key scientist in the medical applications of synchrotrons. His research achievements based on high-resolution medical imaging at SPring-8 have assisted in the development of new diagnostic and therapeutic techniques. He and his research colleagues particularly physiologist, Professor Stuart Hooper (Monash University) have been conducting long-term program utilization at SPring-8



Catching Lung Motion by PIV



Rob & his team

to develop phase contrast imaging techniques using live rabbits and mice. Their strikingly clear images and movies visualizing lung aeration in newborn rabbits have provided new insights into the mechanism of lung liquid clearance at birth and how lungs can be injured during mechanical ventilation. The results of their work have been used to assist in training new clinical medical staff who are called upon to resuscitate very premature infants, immediately after birth. In the research program, the team recognized that the lungs can be clearly visualized throughout the full breath cycle, allowing lung motion to be studied at a level of detail sufficient to see small airways and even the alveoli. Such imaging quality has never been achieved and has only been possible using the outstanding phase contrast capabilities of the wide beam at BL20B2.

Professor Lewis said, "Most medical problems are problems of function. Static images, even in 3D, tell us little about function. Breathing is a dynamic process and so we had to develop methods to record movies so that we could see what was happening. To do that, we had to pull together a large multidisciplinary team that includes physicists, physiologists, engineers and medical doctors. Without all of them, it would have been impossible".

The first step was to develop methods of extracting reliable information about the volume of air in the lungs from phase contrast movies. The team then studied how different types of ventilation and gestational age affect the degree and uniformity of air distribution in the lung.

The second step was to try to use these techniques to study lung diseases such as asthma, fibrosis, and emphysema, as well as their treatments. A major step forward came by combining an engineering technique, i.e., Particle Image Velocimetry (PIV) used to study fluid motion, with synchrotron imaging. The groundbreaking methodology of quantitatively analyzing the motion of the lungs was developed by Dr. Andreas Fouras (Monash University). The team has succeeded in detecting the speed and direction of lung (particle) motion from the phase contrast movies obtained at SPring-8, and is now embarking on the application of their technical achievements to examine how normal lung motion is altered by diseases and subsequent pharmacological treatments, starting with asthma.

by Masaki Takata