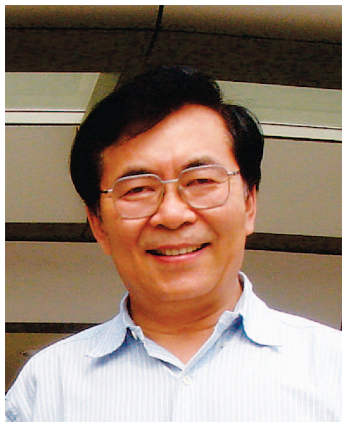
A Conversation with Dr. Chunli Bai: Champion of Chinese Nanoscience



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Dr. Chunli Bai at the Institute of Chemistry in Beijing.

I met with Dr. Chunli Bai at the Institute of Chemistry of the Chinese Academy of Science in Beijing during a visit last month. We discussed nanoscience in China and Dr. Bai's many roles in it.

PSW: What do you find exciting in nanoscience and nanotechnology? And how do you think advances in those areas will affect the world?

Chunli Bai: Originally, the driving force for nanoscience and nanotechnology was the electronics market, industry leaders trying to overcome Moore's Law. I think that Moore's Law can still be exciting for another ten years or so. I worry that what we can do in nanoelectronics is not clear.

I think the *foremost* area in nanoscience and nanotechnology is [at the interface] with the biosciences. I think that is most important. We can have a big impact on the human ability to survive.

PSW: What do you see for nanoscience in China?

Chunli Bai: The numbers of publications in nanoscience and nanotechnology by Chinese scientists have been increasing tremendously. If you look at the number of papers, China would be #2, just after the United States. But, I think the *quality* of the papers needs to be improved; the number of papers is only one indicator. The *impact* of the papers is more important. I have data for papers published by Chinese scientists in the field of nanoscience and nanotechnology; I think we are ranked #4 after the United States, Germany, and Japan. Some groups in China have very high numbers of citations, but the emphasis should be on the quality of the papers and not just on the number of papers.[1]

The second thing is patents; that is an indicator of innovation and potential for industrial application. The number of patents in the field is low compared to the United States, especially for patent applications in the United States or Europe. I know the number of nanoscience and nanotechnology patent applications within China has been growing over the past few years. I think international patents are more important, so I think we need more efforts in that regard.

PSW: Is there a strategy to do that?

Chunli Bai: The Ministry of Science and Technology and our Academy do not push, but we encourage scientists to consider applying for patents before they publish papers. Most scientists in China are not used to thinking about patents. They just want to publish papers, because when they seek promotion, they are asked, "How many papers have you published?" but not, "How many patents have you obtained?" In recent years, the situation has changed. Our Academy and even some agencies now evaluate the performance of universities or institutes based on the number of patent applications and patents issued.

PSW: Is nanoscience a particular focus area in China?

Chunli Bai: Yes. In China, the central government just issued the National Guideline on Medium- and Long-Term Program for Science and Technology Development (for 2006−2020).[2] The 16 big technological projects are national funding priorities (for example, moon probes, new aircraft, and high-speed computation facilities). Besides

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To hear Dr. Bai's advice to young scientists in English and Chinese, please visit us at the podcast page of http://www.ascnano.org/.

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those 16 big technology projects, we focus on four "basic research" areas. Nanoscience is one of those. The other three are developmental biology, protein science, and quantum modulation. Among these four areas of basic research, nanoscience occupies the largest portion of the budget.

Compared to the other three areas, the number of Chinese scientists and professors working in nanoscience is much, much larger. Based on incomplete statistics, we have at least 3000−5000 Chinese nanoscientists working in universities and institutes. More than 20 are nanoscience or nanotechnology research institutes in our Academy. More than 50 universities in China are working in nanoscience and nanotechnology because it is a multidisciplinary area and attracts those from other fields (professors in chemistry, physics, biology, and many other departments).[3] That is a lot of people! As more people become interested in nanoscience, more will work in this area.

In China, the earlier the scientists engage and involve themselves in nanoscience and nanotechnology, the more interdisciplinary they become. One example is the scanning probe microscope: in the mid-1980s, several Chinese groups started to work in this area. At that time, SPM [scanning probe microscopy] was not commercially available, so we had to design and to develop our own STMs [scanning tunneling microscopes] and AFMs [atomic force microscopes] in the laboratory, *starting* the work necessary to image surfaces and to correlate nanostructures. Chinese scientists, starting from these nanomaterials, later synthesized so-called ultrafine nanoparticles and nanotubes. More and more of the papers published by Chinese scientists in this area are on nanomaterials.

PSW: You had special roles in this?

Chunli Bai: I came back to China relatively early, as one of the pioneers, with the experience I gained in the United States. I studied in this area while in the United States [at Caltech]; that was a very good experience for me.

PSW: And now what are your nanoscience roles in the Academy and nationally?

Chunli Bai: As the Executive Vice President for the Chinese Academy of Sciences, I am responsible for many things, nanoscience/technology being one of them. You know, in China in 2002, we established a National Center for Nanoscience and Technology, which was founded on the basis of the nanoCenters of the Chinese Academy of Sciences, Peking University, and Tsinghua University. We merged those three centers together to form this national center, which was on the campus of the Institute of Chemistry and has now moved. This nanoCenter is co-organized by the Chinese Academy of Sciences and the Ministry of Education. I'm the founding director of this nanoCenter. The government is investing money for the infrastructure—new buildings, instruments, and facilities. So, this is one role I have served in for more than four years.

I also serve on the National Steering Committee for Nanoscience and Related Technology. I am Vice Director of this committee and Chief Scientist. The committee consists of 17 experts and administrators from the Ministry of Science and Technology, Ministry of Education, National Development and Reform Commission, Chinese Academy of Sciences, National Science Foundation of China, and also industry. We work together to discuss and to coordinate the national projects for how to support research and development in nanoscience and nanotechnology. We issued the national guidelines for the development of nanoscience and nanotechnology and coordinated several related national projects.

As a scientist, I have been invited to give lectures to important leaders, including the Premier, Vice Premier, and provincial governors discussing the importance of nanoscience. We wish for support in this area, so we seek support from the central government.

Also, we have made great efforts on the nano safety problem. We set up a Laboratory for Biological Effects of Nanomaterials and Nanosafety to research the impact of nanomaterials on the environment and to research nanotoxicology.

We have also set up two special committees: (1) the National Technical Committee on Nanotechnology Standardization—we have issued more than ten national standards for nanoproducts and nanomaterials, also nanoscience terminology—and (2) a special committee for laboratory accreditation. We want to compare laboratories based on standardized samples. We send samples to several laboratories; they compare results, and we see if each laboratory is qualified for our nano accreditation. This is basic work, but I think it is very important.

PSW: In addition to these roles in the Chinese Academy, nationally, you are the president of the Chinese Chemical Society, and internationally, a Bureau member of IUPAC, and editorial advisory board member of the *JACS* [*Journal of the American Chemical Society*], *Accounts of Chemical Research*, and *ACS Nano*. You run an active laboratory. How do you manage your time?

Chunli Bai: That is a very good question! I have been the Vice President of the Chinese Academy of Sciences for 12 years. About three and a half years ago, I was appointed as Executive Vice President. Our Academy is a pretty large organization. We have about 100 individual institutes and about 46,000 employees. There is a very heavy administrative load.

Before I was Executive Vice President, I worked on China's "basic research" programs (nanoscience and nanotechnology in China are classified as basic research). That is my field—I could combine my administrative work with my research. When I took care of the projects to set up the guidelines for nano research in our Academy, that was also very closely related to my work in the laboratory.

I'm no longer the Director of the laboratory; I just have some students in the laboratory. Starting three and a half years ago, when I was appointed Executive Vice President, I reduced the number of students that I have to only one student. That keeps my

connection with my laboratory and I still read papers.

International connections as the President of Chinese Chemical Society, being on the Bureau of IUPAC, and membership on the editorial advisory boards of international journals gives me a lot of opportunities to communicate with very famous and preeminent scientists in the field. I have access to information, and for scientific research, international collaboration is very important, especially for basic research. So, those positions give me a lot of opportunities to learn from those very famous scientists and also to encourage international cooperation between Chinese scientists and scientists in other countries.[4] So, I think that is very useful for my work.

You know, I have so many duties, I have almost no free evenings or weekends. I have a very full schedule![5]

PSW: Do you have an official governmental role by virtue of your position in the Chinese Academy?

Chunli Bai: It is something like this: the Chinese Academy of Sciences is not a governmental agency. However, the President or Vice President is responsible to the Premier.

We have two parts of the Academy. One is a research body comprising branch academies, scientists, and institutes.

We have an educational function, as we have a university; we are not research-only. The University of Science and Technology of China was founded by and is affiliated with our Academy. I often talk about education in China. We have a graduate school, which now has 32,000 students. About half of them are studying for Ph.D. degrees, half for master's degrees. They spend the first year in courses, then they do research in the institutes of our Academy.

The other part is made up of the academic divisions. In these, we have a membership division where we elect outstanding Chinese scientists in universities and other institutes as members; we also elect foreign members. The function is to give advice to the government, especially on national science/technology projects before launch. They ask for our opinion because our Academy is the largest research organization in China.

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Frequently, the State Council asks for our advice about development of science and technology in China. So, we can also play an important role in this regard.

PSW: So it is a role akin to the US National Academy of Sciences, which was set up by Abraham Lincoln as an advisory body to the government

Chunli Bai: Yes, an advisory body to the government. I also sometimes participate in State Council meetings when they are talking about affairs related to science and technology.

PSW: Is that a formal role?

Chunli Bai: Yes, that is a formal role. The government pays great attention to science and education in China.

PSW: Is there a special respect for science in China?

Chunli Bai: Scientists and professors are highly respected in China. In Western countries the younger generation may not be inclined toward science. They want to become a lawyer, dentist, or doctor to make big money. But in China, the situation is pretty good. There are more young talented students wanting to study science and technology—physics, chemistry, and mathematics—because those careers are highly respected. They look up to scientists and professors.

PSW: There is a growing population of students in China. What are the challenges associated with expansion of Chinese universities?

Chunli Bai: Starting six or seven years ago, the government wanted to expand the size of the universities because more people want higher education. In the past few years, most Chinese universities have expanded in terms of the number of students. But still, some universities want to remain smaller in size in order to emphasize quality; one of them is the University of Science and Technology of China, which is affiliated with our Academy. During the past few years, it has only expanded a little bit, without many new students. They thought that the quality of the students is more important.

The other limitation is infrastructure - classrooms and experimental facilities. In China, it is different from Western countries; usually, the university has to provide dormitories. If they do not have enough dorms for students, it may be a problem because the housing market is not well developed in China. It is not easy for us to get housing off-campus; that is another problem.

Recently, the expansion of universities has been limited and not as fast. The central government thinks university infrastructure is something they want to continue to expand in upcoming years only according to the ability of the university. If they can get more students, they can; otherwise, they do not have to expand.

To answer one of your questions, there are still positions in universities, research institutes, and even companies in China open to those very young, brilliant scientists and engineers from abroad ["young talents"]. The government and leaders of universities and our Academy pay great attention to the training and recruitment of brilliant young talents from abroad. For example, in our Academy, we have the Hundred Talents Program [also known as the CAS Bairen Program]. We recruit young talents from abroad. When they come back to our Academy, we provide 2,000,000 yuan [~$300,000 USD for three years of research funding] for each of them.[6] We started in 1992, and at

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that time 2,000,000 yuan was quite a lot of money! We can increase their salary. We help them set up a laboratory. We can give them students, and can help them set up in China. You can see that many of the directors of our institutes came back from abroad through this program. This project is very successful and will continue over the next several years.

There are still open positions in this young talents program, but it is more and more competitive. It is not easy for common people, but if you have done exciting work and you are well qualified, through evaluation by a special committee, we will offer a position.

I also know that the central government is going to set up a special program for recruiting more young people from abroad, not only for work in university research institutions, but perhaps half of them for working in industry. If they want to set up their *own* companies in China, maybe we can also give them special help.

PSW: With all the people coming back, is there more grant pressure? Is there enough support for those groups that have been successful? Do you find lower acceptance rates for funding?

Chunli Bai: The funding for science and technology in China has been increasing tremendously in the past few years. I remember five years ago, R&D, as a fraction of our GDP, was only ~0.5%. Now, it is 1.3% or 1.4%, which is a tremendous increase.[1] If you are good enough, you can get money for research in China. I think for most people who have come back here, obtaining funding is not a big problem. It is very competitive in China, so it is not very easy, but if you have good, creative ideas, it is okay.

I know some young scientists feel some pressure. "I have to spend a lot of time applying for funding. I cannot focus all my time on research. There are too many meetings." I think there, we should do something as administrative officers, not schedule too many meetings or have too many evaluations.

For some young scientists, there is a difference in maturity. Some of them, when abroad at a university in the United States, were students; others were postdocs. They were not group leaders, and they do not know how much time is needed to apply for money in the United States. When they come back, they are the boss! They have to run the group and plan finances. Compared to the time they spent applying in the United States, "Oh, it's a problem!"

I think in the United States you have to spend a lot of time applying for money, right?

PSW: And meetings too! We always wondered what our professors did, and now—in some sense, unfortunately—we know how they spent all of their time!
How do you differentiate between chemistry and nanoscience?

Chunli Bai: That is a very good question. In China, at early stages, there were not many chemists involved in nanoscience. The STM and AFM were invented by physicists; they thought because nanoscience and nanotechnology deal with quantum effects, nanoscience belonged to the field of physics. Those ideas are not typical now.

In China, many scientists work in nanomaterials, so more and more chemists are involved. I can tell you that, in China, of the number of scientists who claim they are working in nanoscience, chemists comprise the largest percentage, over 50%.

We had lunch together today with professors from Peking University and Tsinghua University. Most of them are from chemistry departments, but only one of them is from physics. I think chemists have a very close relation to nanoscience and nanotechnology.

There are many, many people working on nanomaterials. An understanding of materials chemistry is needed to learn how to synthesize nanomaterials. If they want to characterize the chemical and physical properties of the materials, they use very technical instruments that physical chemists usually use. Chemists can do a lot of work in nanoscience, even in nanoelectronics, nanobiology, drug delivery, materials, and especially self-assembly.

I know many chemists working in the field of nanoscience. Sometimes they use the term "nanochemistry", but it is hard to designate what can be classified as nanochemistry.

Nanoscience is a truly multidisciplinary field, but chemistry occupies a big portion—that is what I believe. *ACS Nano* should grow rapidly, and be very exciting!

PSW: Could you tell us what you learned from your time at Caltech, and also your later visit to Tohoku University?

Chunli Bai: I was an X-ray crystallographer when I was a graduate student. I used X-ray diffraction to determine molecular structures at Peking University. While a Ph.D. student, I also worked in EXAFS [extended X-ray absorption fine structure].

I did a postdoc at Caltech and at that time I started working in scanning tunneling microscopy with Prof. John Baldeschwieler. I loved that. I think John Baldeschwieler was the first chemist working in STM—I'm so lucky to have started with STM studies there in his laboratory.

At that time, we designed and constructed an early ultrahigh vacuum STM. I wrote the software for data collection and image processing.

I learned a lot at Caltech, and that helped me start my new research group [Nano-Youth Laboratory of the Chinese Academy of Sciences, now CAS Key Laboratory of Molecular Nanostructure and Nanotechnology] when I came back to China. That makes me one of the pio-

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neers in the field of nanoscience here in China. When I recall the time spent in the United States at Caltech, I appreciate it very much. Also, during that time, I made a connection with the outside world; that was my first time abroad.

During 1991−92, I spent a half-year at Tohoku University, Institute for Materials Research. That Institute is very good in the field of materials science, not only in Japan but in the world. I worked on STM as a visiting professor, researching Na adsorption on Si and GaAs surfaces.

During that half-year, I wrote a book titled *Scanning Tunneling Microscopy and its Application*.[7] I spent some of the time in Japan working on the book, published by Springer. That book took about two years [to write].

I think that Japanese scientists were engaged in nanoscience and nanotechnology from very early on. There was an atmosphere there for nanoscience.

PSW: Do you have advice for young scientists?

Chunli Bai: I think for young scientists—first, you have to work hard. If you want success, you have to spend the time. There's no simple way. I'm not very smart. Maybe you are very smart, maybe you do not have to spend time doing hard work, but you have to be hard working. You have to concentrate on your studies; you have to be devoted to your studies. If your research work is just to make some money—*just* for work—maybe you will not have big achievements. You have to *love* your research. Do not prioritize something else besides your research. You have to concentrate on and be interested in what you study. Devotion and hard work—this is what I say.

Second, you should pay attention to new phenomena that you may not be able to explain easily.[8] Perhaps you cannot find the reason or the driving force, but do not just say, "I don't know that, so I'll just pass over it." That is not good. You have to examine carefully, to check what new phenomena you find in your experiments. Maybe it is some new discovery you find in the course of your work; it is very important to be attentive.

In China, we have a saying, "*zhòng guā dòu*". Literally, it might translate, "If you plant some watermelon, but you get beans, grow beans!" Maybe your first aim was to get one thing, but you got something else instead. But that something else could be more important. If you miss the new phenomena, maybe you will also miss your success.

[Literature citations and figures were added after our conversation to assist and to direct the reader to relevant publications.]

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