

[ScienceWatch Home](#)
[Interviews](#)
[Featured Interviews](#)
[Author Commentaries](#)
[Institutional Interviews](#)
[Journal Interviews](#)
[Podcasts](#)
[Analyses](#)
[Featured Analyses](#)
[What's Hot In...](#)
[Special Topics](#)
[Data & Rankings](#)
[Sci-Bytes](#)
[Fast Breaking Papers](#)
[New Hot Papers](#)
[Emerging Research Fronts](#)
[Fast Moving Fronts](#)
[Research Front Maps](#)
[Current Classics](#)
[Top Topics](#)
[Rising Stars](#)
[New Entrants](#)
[Country Profiles](#)
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[Archives](#)
[Contact Us](#)
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Special Topics : Mesoporous Materials : Dr. Bao-Lian Su - Special Topic of Mesoporous Materials

## AUTHOR COMMENTARIES - From Special Topics

### Mesoporous Materials - June 2008

Interview Date: August 2008



#### Dr. Bao-Lian Su

 From the Special Topic of [Mesoporous Materials](#)

*In our Special Topics analysis of mesoporous materials research over the past decade, Dr. Bao-Lian Su ranks at #8 by number of papers, with 61 papers cited a total of 660 times. According to [Essential Science Indicators](#)<sup>SM</sup> from Thomson Reuters, Dr. Su's work includes 169 papers, the majority of which are in the field of Chemistry, cited a total of 1,802 times between January 1, 1998 and April 30, 2008.*

*Dr. Su is a Full Professor in Inorganic and Materials Chemistry at the University of Namur, Belgium, where he is also the Director of the Laboratory of Inorganic Materials Chemistry. He is on the Editorial Board of Nanopages: An Interdisciplinary Journal of Nano Science and Technology. In 2007, he was named the A. Wetrems Prize Laureate by the Royal Academy of Sciences.*

*In the interview below, ScienceWatch.com talks with Dr. Su about his research.*

#### **SW:** Would you tell us a bit about your educational background and research experiences?

I received my Bachelor's degree from Liaoning University, China, in 1983, my Master's degree from Chendu Institute of Organic Chemistry, Chinese Academy of Sciences, in 1986, and in 1992 I earned my doctorate from the Université de Pierre et Marie Curie, Paris, France.

From 1986-1989, I was a Research Engineer at the Research Institute of Petroleum Processing in Beijing, China. I did a post-doc from 1993-1995 at the Laboratory of Catalysis of the University of Namur, under the supervision of Prof. E.G. Derouane. From January to September of 1995, I was a Research Scientist-Project leader at Catalytica in Mountain View, California, USA.

I went back to the University of Namur in September of 1995, where I was an Associate Professor and named Director of the newly created Laboratory of Inorganic Materials Chemistry (CMI). In September of 2002, I was appointed Professor of Chemistry, and in September of 2004, Full Professor (promoted exceptionally). I was also appointed the Director of the Research Centre for Nanomaterials Chemistry (CNANO).

#### **SW:** What would you say is the main focus of your research?

Design, modeling, property study, fundamentals, and the molecular engineering of organized, hierarchically porous and bio-inspired materials and nanostructures for nanotechnology, biotechnology, information technology, and biomedical applications.

- 1) Synthesis, structure determination and theoretical simulation of new micro-, meso- and macro-porous systems and molecular sieves.
- 2) Theoretical and experimental study on molecular recognition effect in micro-, meso- and macro-porous systems and molecular sieves.
- 3) Conception and understanding at molecular and atomic level of hierarchically multimodal inorganic porous structures and nanostructures and application as catalysts, catalyst supports, adsorbents and drying agents in the petroleum processing, petrochemicals, chemicals, in hydrocarbons and gas separation processes and environmental protection. For example:
  - A. Development of new concepts "one-pot reactor" and "hierarchical chemistry and catalysis,"
  - B. Development of highly efficient self-cleaning surfaces (photocatalytic action, Lotus superhydrophobic effect, photosynthetic action, etc.)
  - C. Development of highly efficient energy conversion system (conversion of sun energy to chemical energy),
  - D. Biomimicking photosynthesis processes in porous media (see inside cover page: *J. Mater. Chem.* 2008, 18),
  - E. Development of the enzymatic catalysis in porous media,
- 4) New orientations are to use these novel porous and nanoparticle materials as a matrix for the encapsulation of organometallics, oxide and metallic nanoparticles and biological molecules and organisms, for the design of new catalysts, new drugs, energy storage agents and for the development of optical, electronic, random laser, and thermosensitive materials and nanobiosensors.
- 5) Development of highly advanced optical, photonic, electronic, and opto-electronic nanocomposites.

*"Hierarchical materials containing both interconnected macroporous and mesoporous structures have enhanced properties compared with single-sized pore materials due to increased mass transport through the material and maintenance of a specific surface area on the level of fine pore systems."*

**SW:** Your most-cited paper in our analysis is the 2001 *Chemistry of Materials* paper, "Well-ordered spherical mesoporous materials CMI-1 synthesized via an assembly of decaoxyethylene cetyl ether and TMOS." Would you walk our readers through this paper—its goals, findings, and significance?

This paper provided a comprehensive study on the synthesis mechanism of highly ordered mesoporous materials. This paper was one of first papers to use a special type of neutral surfactant molecule (polyoxyethylene alkyl ether) as a templating agent to tailor the organization of mesoporous materials.

Its goals: better understanding of the synthesis mechanism, showing how important the surfactant concentration in aqueous solution on the final organization of mesoporous materials is, and providing the first example of synthesizing mesoporous materials under very mild conditions by using this neutral surfactant and tetramethyl oxysilane (TMOS) as silica source.

Findings: the effect of the surfactant concentration on the final organization of mesoporous materials was evidenced; highly ordered mesoporous materials can be synthesized under very mild conditions; the morphologies of the final materials can be controlled, two synthesis mechanisms have been proposed for the synthesis of highly ordered CMI-1 and wormhole-like disordered mesoporous materials (DWM). It is evidenced that when the concentration of surfactant is less than 25%, the well-ordered CMI-1 is obtained while higher than 30%, and the DWM structure is obtained.

Significance: Synthesis of highly ordered mesoporous materials under very mild conditions, a better understanding on the synthesis mechanism, and the first example to control the morphogenesis of mesoporous materials.

**SW:** Several of your papers involve molecular sieves. Would you explain exactly what these are and how they are used?

Mesoporous materials can be considered as mesoporous molecular sieves although it is not exact since molecular sieves concern initially materials with a microporosity (pore size less than 2 nm) and a crystalline structure, while mesoporous framework is often amorphous.

**SW:** Another of your key papers is the 2000 *Stud. Surf. Sci. Catal.* paper, "New way to synthesize

**MCM-41 and MCM-48 materials with tailored pore sizes." Would you talk a little bit about this work?**

This is one of the first papers to use swelling agents (alcanes and trimethylbenzene) to control the pore size of mesoporous materials. The great importance of this paper is a new finding that we can also control the phase transition (from cubic to hexagonal, etc.). Unfortunately, we reported this in a meeting and the paper was generated by this meeting and published in a proceedings. The audience of this proceedings was not as broad as expected. Otherwise, this paper might have attracted much more attention.

*"Do as nature, work as nature, and produce as nature' is the only way to solve the problems of our humanity: energy, food, and environment."*

**SW: Is there any part of your work you feel is particularly exciting or rewarding?**

Yes; firstly, since 2003, I initiated a new research subject in the field of mesoporous materials by introduction of the new concept: hierarchically meso-macroporous materials. This means to generate materials with different porosities in different length scales integrated in one solid body. Hierarchical materials containing both interconnected macroporous and mesoporous structures have enhanced properties compared with single-sized pore materials due to increased mass transport through the material and maintenance of a specific surface area on the level of fine pore systems.

Normally, to incorporate different porosities in one solid body, different synthesis strategies with different preparation steps and hard and soft templates have been developed. However, my group observed a new self-formation phenomenon of porous hierarchy. Without any external templating agents, by using the power of metal alkoxide chemistry, we can prepare materials with well-organized pores in different length scales. The method is quite simple and can be extended to other situations.

This phenomenon has been considered very important discovery to the porous materials community.

Here is an extract from one of my papers in *Chem. Mater.* 2007, 19, 3325- 3333:

"It has recently been reported that hierarchically structured meso-macroporous metal oxides (silicoaluminates,  $\text{Al}_2\text{O}_3$ ,  $\text{ZrO}_2$ ,  $\text{TiO}_2$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{Nb}_2\text{O}_5$ , and mixed oxides) possessing well ordered funnel-like macrochannels with mesoporous walls can be targeted via a "one-pot" self-formation process. Their synthesis is quite simple and is performed on the basis of the chemistry of metal alkoxides. A comprehensive study following the formation of the funnel-like macrochannels has recently been completed. Optical microscopy was used in situ to follow the reaction and has revealed that these hierarchically structured meso-macroporous metal oxides are produced by a self-formation mechanism. The key point of this novel synthesis process is the very high rate at which the metal alkoxides hydrolyzed undergo condensation reactions in aqueous solution. Alcohol molecules can be generated suddenly as soon as the metal alkoxide precursor is in contact with the water molecules. The molecules of alcohol will increase in quantity as the reaction progresses because one metal alkoxide molecule can produce at least two more alcohol molecules. These alcohol molecules can be considered as the 'porogene' in the generation of the funnel-like macrochannels with hierarchically mesostructured porous walls. This new process could be of great interest and is a significant advance toward the understanding of the formation mechanism of these hierarchically structured porous materials. This process could be adopted for the large scale funnel-like, straight macrochannels which interconnect with the mesoporous shell and pore walls. The process could be used to targeted new functional materials with very sophisticated architectures. Instead of alcohol molecules as the self-generated "porogene," it is possible to imagine other precursors which can generate and release "porogene molecules" in liquid and even in gas form. The formation mechanism of these meso-macroporous structures has been discussed in depth in recent papers. These metal oxides with a hierarchical meso-macroporous network have additional benefits as a result of the enhanced access to the mesopores by the regular macrochannel array."

Secondly, the immobilization of plant and animal cells and bacteria into biocompatible porous matrices is my recent exciting research field.

"Do as nature, work as nature, and produce as nature" is the only way to solve the problems of our humanity: energy, food, and environment.

My recent papers on this include:

- 1) *J. Mater. Chem.* (inside cover page): 2008, 18, 1333–1341: "Targeting photobioreactors: Immobilisation of cyanobacteria within porous silica gel using biocompatible methods"
- 2) *J. Mater. Chem* 2008, DOI: 10.1039/b802705f: "Photosynthesis within porous silica gel: viability and

activity of encapsulated cyanobacteria"

3) *Pure Appl. Chem.* (Invited review paper): "Energy from Photobioreactors: Bioencapsulation of Photosynthetically Active Molecules, Organelles and Whole Cells within Biologically Inert Matrices"

**SW:** What would you like the "take-away lesson" about your research to be?

To be creative, to be curious, to be perseverant, and work hard.■

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***Dr. Bao-Lian Su's most-cited paper with 82 cites to date:***

Yuan ZY and Su BL, "Titanium oxide nanotubes, nanofibers and nanowires," *Colloid Surface A* 241(1-3): 173-83, Sp. Iss. SI, 14 July 2004. Source: *Essential Science Indicators*<sup>SM</sup> from Thomson Reuters.

Keywords: mesoporous materials, bio-inspired materials, organized and hierarchically porous materials, molecular engineering, nanoparticle materials, mesoporous molecular sieves, tailored pore sizes.



PDF

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