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Special Topics : Mesoporous Materials : Chung-Yuan Mou - Special Topic of Mesoporous Materials

AUTHOR COMMENTARIES - From Special Topics

Mesoporous Materials - June 2008 PDF

Dr. Chung-Yuan Mou
From the Special Topic of Mesoporous Materials

According to our Special Topic on mesoporous materials, Dr. Chung-Yuan Mou's work ranks at #5 by number of papers, with 68 qualifying papers cited a total of 1,003 times. Dr. Mou's record in Essential Science IndicatorsSM *from* Thomson Reuters *includes 176 papers cited a total of 2,021 times between January 1, 1998 and February 29, 2008, the bulk of which are found in the fields of Chemistry and Materials Science.*

Dr. Mou is a Professor in the Department of Chemistry and the Center of Condensed Matter Science at National Taiwan University in Taipei.

In the interview below, he talks with ScienceWatch.com *about his highly cited research on mesoporous materials.*

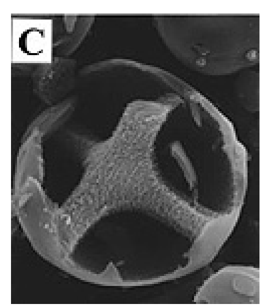
SW: Please tell us a little about your educational and research background.

I did my undergraduate study in chemistry at National Taiwan University. In graduate school, I was trained in theoretical chemistry; my Ph.D. thesis was on nucleation theory (Washington University in St Louis, 1976). After postdoctoral researches, I returned to teach in the department of chemistry of National Taiwan University in 1978, and have been here ever since.

Until 1992, my research activities were mainly in the statistical mechanics of electrolyte solution and non-equilibrium systems. In the early 1990s, I started seriously going into experimental materials chemistry, first in C60 and carbon nanotubes, and later in mesoporous silica materials.

SW: What drew your interest to materials science, and in particular meso/nanoporous materials?

Figure 1: + details



My theoretical background may seem to be an unusual starting point for getting into materials science. Actually in the late 1980s, I was paying close attention to the physical chemistry of self-assembly of amphiphiles in solution, both in theoretical and experimental sides. So when the first synthesis of MCM-41 by surfactant-templating was reported by Mobile researchers, I was able to move into the field with good understanding of its physical chemistry. Besides, at the time I was teaching undergraduate experimental physical chemistry course and writing a textbook for it. That helps me to learn many experimental techniques.

To me, mesoporous silica materials are an ideal playground for materials synthesis with wide possibilities of structure and morphology control and many chemical applications. My first paper on mesoporous silica was published in *Science* in 1996 (Lin HP, Mou CY, "'Tubules-within-a-tubule' hierarchical order of mesoporous molecular sieves in MCM-41," *Science* 273[5276]: 765-68, 9 August 1996). It is the first work on hierarchical organization of mesoporous silica from the point of view of soft matter physics. The success of that first paper led to many other ideas and I gradually gave up on theoretical work and focused on mesoporous materials.

SW: In our analysis, one of your highly cited papers is the 1998 *Chemistry of Materials* paper, "Hierarchical order in hollow spheres of mesoporous silicates," (Lin HP, Cheng YR, Mou CY, 10 [12]: 3772+, December 1998). Would you walk our readers through this paper—its aims, findings, and significance?

My 1998 *Chemistry of Materials* paper reports a morphosynthesis of mesoporous silica MCM-41 in an intricate morphology of pillar-within-sphere. Its micron scale structures consist of hollow spheres with a pillar, fork, or cross inside. This paper together with my 1996 science paper gave two early examples of building hierarchical structures of mesoporous silica. Also, they are the first two papers bringing together ideas in sol-gel synthesis and soft-matter physics to mesoporous materials.

We found there is organization in the micrometer scale on top of the nanometer structural order from self-assembly. The micron scale organization comes about through transformation of mesophases. Understanding hierarchical organization of matter is important for biomimic strategies of fabricating materials.

Anyway, the pillar-within-sphere organization is distinctly nature-like, a bit like the frustal of radiolaria and diatoms. The structure is beautiful in my view. Maybe one day, someone will be able to make intricate silica structures like diatoms in the laboratory—that would be most satisfying.

There are practical implications too. By learning to control the morphology during synthesis of mesoporous silica through understanding its physics of self-assembly, we later developed other morphologies such as thin films with vertical channels (for catalysis support) and mesoporous silica nanoparticles (for biomedical applications).

SW: Many of your papers in our analysis concern supercooled water confined in nanoporous silica. Would you talk a little bit about this aspect of your work?

Liquid water is a complex fluid with many abnormal properties not yet well understood. Its anomaly becomes more prominent in supercooled state and there are hints of thermodynamic singularity below –40°C. However, ice nucleation would take over at about –35°C for bulk water.

"... mesoporous silica materials are an ideal playground for materials synthesis with wide possibilities of structure and morphology control and many chemical applications."

In 2002, I discussed the possibility of avoiding freezing using mesopore-confined water with Prof. Sow-Hsin Chen of MIT, a leading expert in neutron scattering. Soon this was realized with specially designed mesoporous silica with small pores, and suddenly a whole range thermodynamic state of water became accessible.

Since then, a series of publications (including four *PNAS* and one *Physical Review Letters* paper) with Chen and Francesco Mallamace (University of Messina) followed, reporting many significant discoveries about supercooled water. We found a fragile-to-strong dynamical transition at low temperature. Recently, for the first time we discovered a density minimum of D2O at 210 K by SANS, in addition to the well-known density maximum. (Liu D, *et al*., "Observation of the density minimum in deeply supercooled confined water," *PNAS* 104[23]: 9570-4, 5 June 2007). This discovery is highly significant in our fundamental understandings about the structure of water.

This whole series of works have attracted a lot of attention from physicists, chemists, and biologists. Our 2005 *Physical Review Letters* paper (Liu L, *et al*., "Pressure dependence of fragile-to-strong transition and a possible second critical point in supercooled confined water," *Phys. Rev. Lett*. 95[11]: Art. no. 117802, 9 September 2005) has been highly cited, and was recently listed in the Research Front rankings of *Essential Science Indicators*.

SW: Are there any other papers, regardless of citations, you would like to highlight and discuss their importance?

Our 2005 *Chemistry of Materials* paper on "Well-ordered mesoporous silica nanoparticles (MSN) as cell markers" (Lin YS, *et al., Chem. Mater*. 17[18]:4570-3, 6 September 2005) is the first report of making well-suspended nanoparticles of mesoporous silica with a fluorescence agent as the cell marker. This work has led to developing MSN as a multi-functional, contrast-enhancing, and drug-delivery agent, which combines organic/inorganic and diagnostic/therapeutic components within a nanoscaled delivery agent. The pores may be used for delivering drugs, enzymes, DNA, or RNA.

At present, many types of nanoparticles, such as quantum dots and metals, are being developed as cell-tracking/delivery agents. However, metals and Q-dots are toxic. Our silica materials, however, are quite safe. Therefore, we envision its development for clinical use in cell tracking, drug delivery, and gene therapy. We are making long-term collaborations between biologists, clinical doctors, and chemists. It is challenging.

SW: What are the practical applications (or potential applications) of these materials?

The field of mesoporous materials is expanding into many major applications. These include catalyst support, biomedical tracking/delivery platform, and as an adsorption/separation agent. I foresee many new applications in the years to come.

What should the "take-away lesson" be about your work?

Materials science is truly interdisciplinary. Scientists from different backgrounds can make good contributions. However, there is a need to integrate "vertically," particularly in nanomaterials. Too often, we see fabrication of intricate materials without the follow-up of applications. Using mesopore as a nano-reactor, the selectivity and activities of many reactions can be changed and exploited. The physics of small systems can be studied creatively by confining matter within. Hierarchical materials of a mesoporous nature can be built to satisfy various applications in biomedicine and engineering.

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Dr. Chung-Yuan Mou's most-cited paper with 95 cites to date:

Lin HP, Cheng YR, Mou CY, "Hierarchical order in hollow spheres of mesoporous silicates," *Chem. Mater.* 10(12): 3772-+, December 1998. Source: *Essential Science Indicators* from Thomson Reuters.

Keywords: mesoporous silicates, mesoporous materials, materials synthesis, supercooled water, cell marker, drug delivery, gene therapy applications.

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AUTHOR COMMENTARIES - From Special Topics

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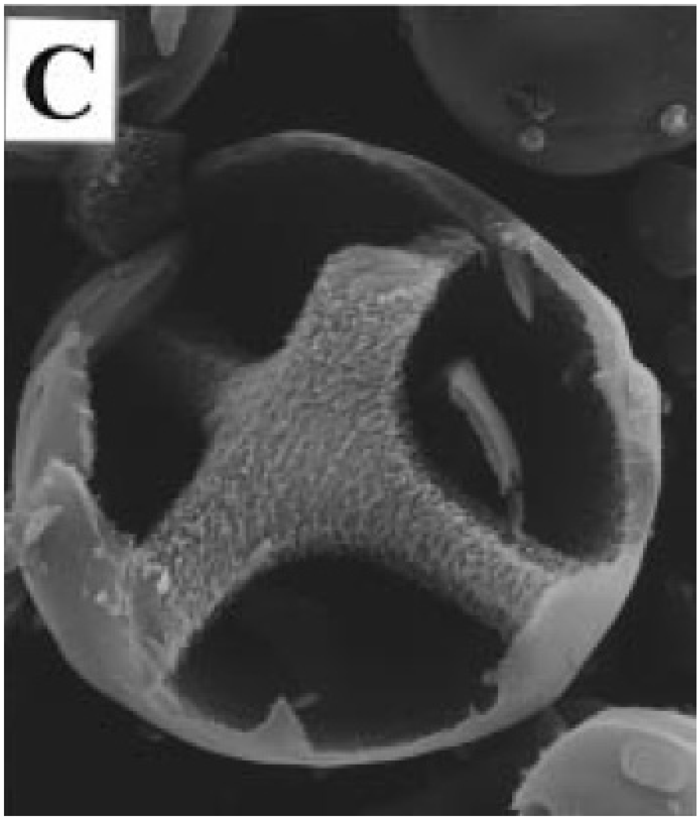

Figure 1: Pillar-within-spheres hierarchical organization of mesoporous silica.

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