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Special Topics : Mesoporous Materials : Galen Stucky - Special Topic of Mesoporous Materials

AUTHOR COMMENTARIES - From Special Topics

Mesoporous Materials - June 2008

Interview Date: November 2008



Dr. Galen Stucky

From the Special Topic of **Mesoporous Materials**

In our June 2008 Special Topic on mesoporous materials, the work of Dr. Galen Stucky ranked at #2 by total citations, #7 by total papers, and #1 by cites/paper, based on 61 papers cited a total of 9,833 times. Seven of these papers ranked in the list of the 20 most-cited over the past decade.

According to **Essential Science IndicatorsSM** from **Thomson Reuters**, Dr. Stucky's citation record includes 243 papers, the majority of which are classified in either **Chemistry** or **Materials Science**, cited a total of 17,296 times between January 1, 1998 and August 31, 2008. He is also a **Highly Cited Researcher** in the field of **Materials Science**.

Dr. Stucky hails from the University of California, Santa Barbara, where he is the E. Khashoggi Industries, LLC Professor in Letters and Science, as well as Professor in the Department of Chemistry & Biochemistry, Professor in the Materials Department, and a member of the Interdepartmental Program in Biochemistry and Molecular Biology. He is also an Honorary Professor at Fudan University in Shanghai, China, and a Visiting Professor at Peking University in Beijing. He has received numerous awards for his work and sits on the editorial boards of multiple journals.

In the interview below, he talks with ScienceWatch.com correspondent Gary Taubes about his work in mesoporous materials.

SW: What factors or circumstances led you to your work?

A key point is that the research we're discussing is an offshoot of work that was published five years earlier. In 1993, we published a paper in *Science* (Monnier A, *et al.*, "Cooperative formation of inorganic-organic interfaces in the synthesis of silicate mesostructures," 261[5126]: 1299-1303, 3 September 1993), which had to do with the cooperative formation of inorganic/organic interfaces in the synthesis of silicate mesostructures. In that paper we developed a concept that, as far as I know, was unique and new. It had to do with considering the assembly as a cooperative process. This was using charged surfactants and thinking about it collectively, in terms of all the species present, and doing so not only in the context of the thermodynamics but also in the context of the kinetics of the assembly of these species. It was a systems synthesis approach.

Alain Monnier was the lead author and he was more of a physicist. Ferdie Schüth was involved; he's now vice president of the German equivalent of our NSF. Quisheng Huo was on that paper. He was a brilliant postdoc of mine. The idea we

had there was that when you're trying to make domains of organics and domains of inorganics, the challenges are preventing phase separation and defining the interface between organic and inorganic to make this happen. And what we said was that you can't do it considering thermodynamics alone—you also have to consider kinetics.

The really key breakthrough, though, was the paper that is now listed as my fifth most-cited. It was published in 1994 in *Nature*: "Generalized synthesis of periodic surfactant inorganic composite materials," (Huo Q, *et al.*, 368[6469]: 317-21, 24 March 1994). The first author there was Quisheng Huo, then David Margolies, and another postdoc, Ulrike Ciesla. What we developed in that paper was a way to use the isoelectric point of the inorganic—the point at which the inorganic species has a zero charge—as the basis for creating organized inorganic/organic interfaces and structures. That was a new strategy. No mesostructure had ever been made under those conditions.

Since that time, all subsequent work, including my two most-cited papers in your analysis, has really just been extensions of this earlier *Nature* paper. It turned out that the strategy we presented in that *Nature* paper was just a very effective way to create mesostructured materials. And we showed you could make different kinds of structures, shapes, and forms. Those two papers—the '93 *Science* paper and the '94 *Nature* paper—were the foundation of everything that followed.

"Once you get into these kinds of polymers, there are all kinds of variations and you definitely open up a big area of research and applications."

SW: What made the 1998 *Science* paper (Zhao DY, *et al.* "Triblock copolymer synthesis of mesoporous silica with periodic 50 to 300 Angstrom probes," 279[5350]: 548-52, 23 January 1998) so special?

The 1998 work was all done with neutral, triblock polymers—nonionic, neutral polymers. From a practical point of view, that's a very good way to go. These were cheaper than anything we were using before; they're more environmentally compatible. They don't have any quaternary ammoniums, which makes the EPA happy.

SW: Why do you think it garnered nearly 2,500 references in a decade? That's quite a remarkable number.

Well, we showed several key things in that paper. First, it is a very, very simple preparation. Simple in the sense that if you took the chemistry described in the 1994 *Nature* paper and added triblock to it, you got the product. It's that simple. And triblock is an inexpensive polymer. So this work in '98 extended this whole thing to polymers, and particularly to cheap, accessible polymers that can be made in large bulk quantities. And they have no environmental hang-ups, so it opens up the field of potential applications a great deal. The other aspect is that we're going from charged to uncharged materials. So the interactions are much more direct in this case. You do away with the anion you carry along as extra baggage in the previous approach.

SW: Was there any element of serendipity to this work?

There's one thing: I was lucky enough to have brilliant people to work with. Dongyuan Zhao, the first author on the 1998 *Science* and *JACS* (Zhao DY, *et al.*, "Nonionic triblock and star diblock copolymer and oligomeric surfactant syntheses of highly ordered, hydrothermally stable, mesoporous silica structures," 120[24]: 6024-36, 24 June 1998) papers, was my postdoc. He was a physical chemist originally. When he got here, he joined up with Peidong Yang, another of my postdocs who is now at Berkeley. He's now very famous and has won many awards. Quisheng Huo was caught up in the tail end of that. Dave Margolies was with me as a graduate student and another co-author was one of my colleagues, Brad Chmelka. So things just kind of fell into place in that way; I happened to have very good people that got together at the right time in the right place. They knew what had to be done and how to do it. It was amazing how things were going at the time, just flying.

SW: Are you surprised by how influential the 1998 *Science* paper has been, or did you expect it?

"No mesostructure had ever been made under those conditions."

Well, for some very practical reasons this paper just took off. I would not have predicted it. I knew it was important; that's why we submitted it to *Science*. We thought it would have a major impact in the field, no question about that. Once you get into these kinds of polymers, there are all kinds of variations and you definitely open up a big area of research and applications. So I never meant to imply that the paper wasn't important, but it very much evolved out of that earlier work.

SW: Your critical papers seem to be pretty evenly divided between *Science* and *Nature*. How did you decide which one you would submit a particular

paper to?

In the old days, in the 1990s, if you wanted to reach as broad an audience as possible, your choices were pretty much *Science* or *Nature*. So I just went about 50-50. I knew the editors back then and I knew they had certain tastes regarding what they thought was right for their audience. I tried to submit papers to them that I felt would best fit into their agendas. Since then, of course, *Nature* has split up into *Nature Materials*, *Nature Biotech*, etc., and *Science* is definitely not as materials-oriented as it used to be. Now it's a much different game.

SW: So where do you go now for articles you think should be read widely?

I end up going to *Nature Materials* a fair amount. We're materials scientists, basically. So much of what we do falls into that category. I also publish in *PNAS* for high-impact articles.

SW: How has the research on mesostructured materials evolved since that flurry of influential papers in 1998?

One direction it's gone is to use these silica frameworks like three-dimensional lithography. This is an idea developed by Ryong Ryoo in Korea. You fill them up with other compositions, then dissolve the silica, and you have this mesostructured new material. If you fill them up with carbon and dissolve away the silica, you have a carbon mesostructure. You can fill them up with high-melting inorganics and grow crystals, things like that. Dongyuan Zhao, in particular, has really opened up the field in using molecular synthesis to make different compositions. He's explored many dimensions of these mesostructured materials.

Another direction came out of another very important paper we published back in 1998 in *Nature*, "Generalized syntheses of large-pore mesoporous metal oxides with semicrystalline frameworks," (Yang PD, et al., 396[6707]: 152-5, 12 November 1998). In that paper Peidong Yang figured out a way to make transition metal oxides that had semicrystalline walls, unlike silica, which is amorphous. The walls, in fact, were three dimensional, made of nanocrystals. In the last 10 years, there have been many variations made on this. Compositional control and structural control over these kinds of materials has really been developed superbly by various groups around the world for different purposes.

The potential applications have been evolving rapidly as well. A key point is that the pores in these materials are big enough to hold proteins. So you can now do size-selective protein separation. You can incorporate enzymes into these materials, and they'll still continue to function as enzymes, comparable to what they do in solution. You can use these enzymes as supports for catalysis, for biomolecules, things like that. So that's another direction that this field has gone. I should mention also that these pores are good for processing heavy crude oils. I'm not sure how much I should say about that, but I can say that these materials have definite potential for that application.

SW: Which of your professional achievements brings you the most satisfaction?

The papers I really feel good about are the one in *Nature* in 1994 and the one in *Science*, the year earlier. Those two. Because, in those papers, we really laid out the fundamentals of the science and how to make these materials. And those fundamentals have really held up quite well. They've been very useful to the science community and to the people who are making things out of these materials.

I have to explain how I think about this. When I work on a synthesis problem, I'm trying to make a platform. I want something on which I can create many different possibilities, many different possible products, or potential configurations of this synthesis process I'm developing. So say I want a magnetic mesostructure, or a mesostructure that can be used for a computer chip (which we published a paper about early on showing this would be a good idea), this is one way you can do this. And if you want to make a mesostructure out of iron, or you want it to contain titanium, this is how to do it. So what I feel good about is developing a fundamental approach that allows you to do all these things, to use it as a platform to create different compositions, different kinds of structures, different pore sizes, shapes, cages, channels, whatever you want. It's hugely flexible. That's what I feel very good about. ■

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Dr. Galen Stucky's current most-cited paper in *Essential Science Indicators*, with 2,487 cites:


Zhao DY, et al., "Triblock copolymer syntheses of mesoporous silica with periodic 50 to 300 angstrom pores," *Science* 279(5350): 548-52, 23 January 1998. Source: *Essential Science Indicators* from Thomson Reuters.

Additional Information:

[Galen Stucky](#) is featured in [ISIHighlyCited.com](#).

Keywords: mesoporous materials, inorganic/organic interfaces, silicate mesostructures, isoelectric point, triblock polymers, preparation methods, silica frameworks, transition metal oxides, nanocrystalline walls.

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