Author Profile

A. K. Cheetham

The author presented on this page has recently published his ***10th article*** *since 2000 in Angewandte Chemie:* "Rapid Room-Temperature Synthesis of Zeolitic Imidazolate Frameworks by Using Mechanochemistry": P. J. Beldon, L. Fábián, R. S. Stein, A. Thirumurugan, A. K. Cheetham, T. Friščić, *Angew. Chem.* **2010**, *122*, 9834–9837; *Angew. Chem. Int. Ed.* **2010**, *49*, 9640–9643.

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Education: 1965–1969 Undergraduate Studies of Chemistry, University of Oxford (UK)
1969–1971 PhD in Chemistry with Prof. Sir Brian Fender, University of Oxford
1971–1974 E.P.A. Cephalosporin Research Fellow under Prof. Sir Brian Fender and Prof. Bertram T. M. Willis, University of Oxford and AERE, Harwell (UK)

Awards: **1982** Corday-Morgan Medal of the Royal Society of Chemistry; **1994** Elected Fellow of the Royal Society London; **1997–1999** Chaire Internationale de Recherche, Blaise-Pascal, Paris; **2001** Elected Honorary Fellow of the Indian Academy of Sciences; **2003** Humphry Davy Lecture of the Royal Society; **2007–2012** Royal Society Wolfson Research Merit Award; **2008** Royal Society Leverhulme Medal; **2008–2013** European Research Council Advanced Investigator Award; **2009** Elected Member of the Academia Europaea

Current research interests: In 1998, I moved into the emerging area of inorganic–organic framework materials, and since my move to Cambridge in 2007 this has become the primary focus of my research. In addition to open-framework hybrids (metal-organic frameworks, MOFs), which are a natural extension of my zeolite and phosphate work, I have a strong program in the area of dense hybrids that show striking analogies to conventional inorganic solids. Recent highlights of the hybrid work include the elucidation of the factors that control dimensionality in hybrid frameworks, the discovery of an amorphous metal-organic framework with a silica-related structure, multiferroic behavior in a metal-organic framework, and in-depth studies of the mechanical properties of hybrid frameworks. In addition, I am continuing to work on purely inorganic materials, especially in the fields of up-conversion and down-conversion phosphors for solid-state lighting and other applications.

Hobbies: I have a long-standing interest in international affairs, especially science in the developing world, and I enjoy traveling. I am also interested in sport, especially soccer, golf, and cricket. Finally, I am actively involved in the venture capital world and other investment activities.

My favorite subject at school was … chemistry, though I was not particularly good at it at the time!

My greatest achievement has been … mentoring a large number of very successful young scientists.

The biggest problem that scientists face is … to explain what they do to the general public and those who pay for our research.

If I could be anyone for a day, I would be … the Secretary-General of the United Nations (Ban Ki-Moon).

The three qualities that make a good scientist are … patience, determination, and creativity.

Chemistry is fun because … we have the opportunity to make compounds and materials that have never existed before in the history of man. Sometimes they turn out to be really useful!

If I won the lottery I would … set up my own research institute near Lake Como in Italy.

If I could have dinner with three famous scientists from history, they would be … Michael Faraday, Dmitri Mendeleev, and Linus Pauling.

The three things I would take to a desert island would be … my laptop, some fine wine, and my golf clubs.

A good work day begins with … a nice cup of tea and the acceptance of one of our papers for publication.

My favorite food is … Indian, though I also love French, Italian, and Japanese.

If I could be described as an animal it would be … a dog (since I am well known for my barking imitations!).

Young people should study chemistry because … they enjoy it; otherwise they should do something else that involves less work and pays better.

How is chemistry research different now than it was at the beginning of your career?

The greatest change in the field of materials chemistry has been the development of more sophisticated tools for structural and chemical characterization. For example, there have been dramatic advances in areas such as high-resolution electron microscopy, atomic force microscopy, synchrotron X-ray methods, and solid-state NMR spectroscopy, which were just emerging when I began my research career 40 years ago. There have also been remarkable advances in the power of computational methods, especially density functional theory.

Has your approach to chemistry research changed since the start of your career?

I have noticed that I collaborate with other colleagues more than I did during the early part of my career. It used to be possible to publish a paper that describes the synthesis and crystal structure of a new material in a high-quality journal, but now the expectations are much higher. Referees and editors of the leading journals expect to see a more complete story, including chemical and physical properties, or computer simulations. Many of us have responded to this trend by engaging with more collaborators, which has been very rewarding. It means that our papers often have more authors, of course, but the final product is greatly enhanced.

Has your approach to publishing your results changed since the start of your career?

My publication strategy today is certainly quite different from the approach I adopted early in my career. The number of journals was then much smaller than it is today and, as a solid-state chemist, I was content to publish in the few journals that were willing to consider papers in this less popular area of chemistry. Today the field has morphed into materials chemistry and it has become very fashionable, leading to an abundance of new journals such as *Chemistry of Materials*, *Journal of Materials Chemistry*, and *Advanced Materials*. In addition, the Web of Science and h-indices did not exist 30–40 years ago, so our choice of journals was not influenced by citation impact as it is now. One thing has not changed, however: it still gives me the greatest pleasure to publish in the leading professional journals, such as *Angewandte Chemie*, *Journal of the American Chemical Society*, and *Physical Review Letters*.

What do you think the future holds for your field of research?

I am extremely bullish about the future of the chemistry of materials. While science in the second half of the twentieth century was dominated by remarkable advances in molecular biology, which led to important advances in medicine that have improved the quality and duration of our lives, I believe that the twenty-first century will increasingly focus on issues such as energy independence, sustainable development, security, water, and so on. The technical challenges in these areas will largely be solved with new materials, rather than molecular biology, so materials chemistry will play a central role. If I was starting my career again today, this is the field in which I would want to work.

Have you changed the main focus of your research throughout your career and if so why?

The focus of my research has certainly shifted regularly throughout my 40-year career. In my early days at Oxford I worked on the structural characterization of inorganic materials by powder diffraction using neutrons and, later, synchrotron X-rays. We demonstrated that unknown structures could be solved ab initio with powders rather than single crystals. In addition to diffraction methods, I explored the use of other emerging tools, in particular solid-state NMR spectroscopy, which we applied for the first time to paramagnetic systems. During the 80s I began to work on aluminosilicate zeolites and other classes of molecular sieves, taking advantage of my expertise in characterization methods, and this was my major interest for a decade after my move to the University of California, Santa Barbara in 1991. The zeolite work evolved naturally in the late 90s toward the emerging field of metal-organic frameworks, which remains a major passion at the present time. In parallel, however, I have continued to work on inorganic materials, especially mixed metal oxides for a variety of optical applications.

What has been your biggest influence/motivation?

I have most certainly been influenced at various times by particular individuals with whom I have worked or collaborated. My PhD mentor, Sir Brian Fender, gave me a great deal of freedom and I have tended to adopt his style of supervision with my own graduate students. Sir John Meurig Thomas persuaded me to work on zeolites in the early 80s, thereby influencing the direction of my work for many years afterwards. Then my old friend C. N. R. (Ram) Rao has been a major influence, encouraging me to collaborate with him in new areas such as colossal magnetoresistance and carbon nanotubes. I think that I have influenced his work, too, by stimulating an interest in inorganic framework structures and hybrid materials. We have published nearly 60 papers together and they have an h-index of 30. I must also mention Sir Harry Kroto, another old friend, with whom I have collaborated on both carbon nanotubes and, more recently, hybrid frameworks.

What advice would you give to up-and-coming scientists?

During my 40-year career I have mentored over 50 PhD students and 30 post-docs, many of whom have gone on to lead successful research careers of their own. I do not have a one-size-fits-all philosophy in terms of advising them. On the contrary, it strikes me that they each succeed in their own unique way, taking advantage of their individual strengths. I am pleased to say that most of them stay in touch regularly and approach me when they are making important decisions about their careers. One thing I have learned, however, which might be worth sharing, is that success rarely comes quickly in a scientific career. It is a long and slow process and one has to be prepared for disappointments and setbacks, as well as the moments of great pleasure and pride. One final point: the literature is now so vast that it is no longer sufficient to publish good work and expect that everyone else will be eager to read about it; it is equally important to promote your own work through attending conferences and giving lectures around the world.

What is the secret to publishing so many high-quality papers?

Most of the credit for publishing high-quality papers has to go to the co-workers who perform high-quality work. Without them, there would be nothing to write about. I like my co-workers to produce the first draft of our papers, but before doing so I like to discuss the "big picture" with them so that we all agree on the shape of the story that we are going to tell. This is an area wherein 40 years of experience can be very useful! One of the other lessons I have learnt is that we need to pick our problems carefully. There are so many interesting problems that we could tackle, but not all of them are important. The distinction between interesting and important in science should not be taken lightly.

My 5 top papers:

1. "Localizing active sites in zeolite catalysts: neutron powder profile analysis and computer simulation of deuteropyridine bound to gallozeolite-L": P. A. Wright, J. M. Thomas, A. K. Cheetham, A. Nowak, *Nature* **1985**, *318*, 611–614.
   This combined neutron diffraction and computer simulation study revealed the precise location of a hydrocarbon in a zeolite cavity. What pleased me at the time, and still does, is that the story made such good chemical sense. The nitrogen of the pyridine molecule coordinates to an extra-framework potassium ion while the aromatic ring rests on the van der Waals surface of the zeolite cavity. The agreement between experiment and calculation was also excellent. We were all thrilled because our beautiful illustration of the bound molecule in the zeolite channel was featured on the front cover of Nature just before Christmas 1985!
2. "Selective oxidation of methane to synthesis gas using transition metal catalysts": A. T. Ashcroft, A. K. Cheetham, J. S. Foord, M. L. H. Green, C. P. Grey, A. J. Murrell, P. D. F. Vernon, *Nature* **1990**, *344*, 319–321.
   I selected this paper for two reasons. Firstly, it had a major impact on research into natural gas conversion, drawing attention to the excellent thermodynamics of partial oxidation compared with steam reforming. Secondly, this breakthrough actually emerged from solid-state NMR spectroscopy work that my student Clare Grey was doing at the time on paramagnetic pyrochlores.
3. "Open Framework Inorganic Materials": A. K. Cheetham, G. Férey, T. Loiseau, *Angew. Chem.* **1999**, *111*, 3466–3492; *Angew. Chem. Int. Ed.* **1999**, *38*, 3268–3292.
   This review was written when I held a Chaire Blaise Pascal in Paris in the laboratory of Professor Gérard Férey. It covers the universe of open-framework solids, from aluminosilicate zeolites to metal-organic frameworks. The review proposed the notion that it should be possible to make open frameworks with virtually any chemistry, an idea that has since been confirmed in many different areas. I also chose this paper because it is my most-cited publication, with over 1500 citations.
4. "Open-Framework Nickel Succinate, $[Ni_7(C_4H_4O_4)_6(OH)_2(H_2O)_2]\cdot 2H_2O$: A New Hybrid Material with Three-Dimensional Ni–O–Ni Connectivity": P. M. Forster, A. K. Cheetham, *Angew. Chem.* **2002**, *114*, 475–477; *Angew. Chem. Int. Ed.* **2002**, *41*, 457–459.
   This striking paper with my student, Paul Forster, changed my view of chemistry. Not only was it clearly possible to make a metal-organic framework with a simple transition-metal salt such as nickel succinate, but the network that we discovered had three-dimensional nickel-oxygen-nickel connectivity, much as you might find in an oxide perovskite. The only disappointment was that it was not magnetically ordered at low temperatures, presumably because of frustration. We and other groups have since made many similar materials and I continue to be interested in their properties.
5. "Structural diversity and chemical trends in hybrid inorganic–organic framework materials": A. K. Cheetham, C. N. R. Rao, R. K. Feller, *Chem. Commun.* **2006**, 4780–4795.
   We wrote this Feature Article in spring 2006 during one of Ram Rao's annual visits to UC Santa Barbara. Our idea was to show the huge structural and chemical diversity of inorganic–organic frameworks, spanning both dense and porous systems as well as different dimensionalities with respect to inorganic and organic linkages. We also proposed a simple classification of hybrid frameworks that is now quite widely used.

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