

Impact case study (REF3b)

Institution: University College London
Unit of Assessment: 8 - Chemistry
Title of case study: Increasing public understanding of chemistry
1. Summary of the impact The UCL Department of Chemistry has for many years run a far-reaching programme of outreach and public engagement that has deep roots in the department's research programme. Its schools outreach work has promoted chemistry and science among secondary school children, while contributions to blogs, newspapers, radio, and television have engaged diverse audiences from primary school children to the elderly. Millions of people have viewed television contributions, while tens of thousands have been reached in theatres and science fairs, with positive reviews and feedback confirming a stimulation of public interest in, and understanding of, chemistry.
2. Underpinning research The impact of the Chemistry Department's school outreach work and public engagement activities is underpinned by research carried out in the department by a number of academic staff. One strand has examined important phenomena in surface-, materials- and nano-science. Since 2006, researchers have used concepts from quantum to statistical mechanics to apply and develop methods and computer simulations to study, for instance, chemical reactions at surfaces and processes of environmental relevance. Much of this research is carried out with leading experimentalists across the world, and in recent years water and ice have been a major focus of the work. Breakthroughs in this area include the discovery of the first extended ice-like structure built exclusively from water pentagons (in collaboration with colleagues at the University of Liverpool) [1], and theoretical studies of new phases of ice [2]. Professor Sella (Professor of Chemistry, at UCL since 1990) has worked on the synthesis of molecular rare earth complexes and their electronic structure [3]. His expertise in synthesis of air sensitive complexes has led to collaborative projects with Professor McMillan on tetrelide systems and their behaviour under high pressure. These systems have led to the preparation of amorphous phases of the group 4 elements, work that has uncovered superconductivity in germanium at high pressure [4]. For this, the synthesis and initial high-pressure studies were carried out at UCL, with the measurement of conductivity done by collaborators in Russia. In 2007, Sella was awarded an EPSRC Senior Media Fellowship – awarded to enable leading academic researchers to advance public engagement with the physical science – to be a champion for chemistry nationally, with a focus on energy issues; this was extended in 2010. Another aspect of UCL's research, led by Dr Rowley (Senior Lecturer) since 1998, has focused on studying fundamental gas phase free radical reactions. These reactions have potential impact on atmospheric composition and therefore environmental effects including ozone depletion, air quality and global warming. Specifically, reactions of peroxy radicals and the unexpected effects of water vapour on reactions of these species have been elucidated, giving a better description of atmospheric oxidation and therefore pollutant removal mechanisms [5]. In addition, reactions of chlorine and bromine monoxide species have been characterised, which has led to a better quantitative understanding of halogen mediated atmospheric ozone loss. The work of Professor Catlow and Dr Lewis [6] uses computational methods to understand the structure and synthesis of complex materials, and to subsequently synthesise new materials with specific properties. The research covers a range of solids with application as catalysts, sensors and ceramics; the present focus is on microporous materials. Dr Hirjibehedin's research at UCL since 2007 centres on understanding the electronic and magnetic properties of nanoscale structures. It explores how they might be used to make the smallest possible devices for information processing, data storage, and sensing using low-temperature scanning tunnelling microscopes [7]. STM is used to image individual atoms and molecules on surfaces; to probe structural, electronic, and magnetic properties; and even to arrange atoms and molecules into new configurations. Further research on the structure of surfaces has established a new scale of superhydrophobicity. This is based simply upon the number of times water droplets bounce on the surface which is dependent on the surfaces microstructure [8]. Work has also focused on the use of CVD to create TiO ₂ layers doped with nano-particles for photocatalytic water reduction and oxidation [9].
3. References to the research References [1], [3] and [6] best demonstrate the research quality.

- [1] **A one-dimensional ice structure built from pentagons**, J. Carrasco, A. Michaelides, M. Forster, S. Haq, R. Raval and A. Hodgson, *Nature Mater.* 8, 427-431 (2009). [doi.org/bmw9jq](https://doi.org/10.1038/nmat2614)
- [2] **Proton ordering in cubic ice and hexagonal ice; a potential new ice phase—Xlc**, Z. Raza, D. Alfè, C. G. Salzmann, J. Klimeš, A. Michaelides and B. Slater, *Phys. Chem. Chem. Phys.*, 13, 19788-19795 (2011). [doi.org/fjirv6](https://doi.org/10.1039/c1cp21827a)
- [3] **(PhTe)₃⁻: The Anionic Tellurium Analogue of I₃⁻** A. C. Hillier, S. Liu, A. Sella and M. R. J. Elsegood, *Angew. Chem. Int. Ed.* 38, 2745-2747 (1999). [doi.org/bsfdxb](https://doi.org/10.1002/ange.199903827)
- [4] **Pressure-induced transformations and superconductivity of amorphous germanium**, O. I. Barkalov, V. G. Tissen, P. F. McMillan, M. Wilson, A. Sella and M. V. Nefedova, *Phys. Rev. B*, 82, 020507 (2010). [doi.org/fvthph](https://doi.org/10.1103/PhysRevB.82.020507)
- [5] **Ab initio investigations of the potential energy surfaces of the XO+HO₂ reaction (X=chlorine or bromine)**, N. Kaltsoyannis and D. M. Rowley, *Phys. Chem. Chem. Phys.*, 4, 419-427 (2002). [doi.org/cb5hgd](https://doi.org/10.1039/b1cp00001a)
- [6] **De novo design of structure-directing agents for the synthesis of microporous solids**, D. W. Lewis, D. J. Willock, C. R. A. Catlow, J. M. Thomas and G. J. Hutchings, *Nature*, 382, 604-607 (1996). [doi.org/dqqdhf](https://doi.org/10.1038/382604a)
- [7] **Quantum engineering at the silicon surface using dangling bonds**, S. R. Schofield, P. Studer, C. F. Hirjibehedin, N. J. Curson, G. Aeppli, D. R. Bowler, *Nature Communications*, 4, 1649, (2013). [doi.org/pt5](https://doi.org/10.1038/ncomms2515)
- [8] **Water droplet bouncing – a definition for superhydrophobic surfaces**, C. R. Crick, I. P. Parkin, *Chem. Commun.*, 47, 12059-12061 (2011). [doi.org/b8dtsj](https://doi.org/10.1039/c1cc11827a)
- [9] **An investigation into the effect of thickness of titanium dioxide and gold-silver nanoparticle titanium dioxide composite thin-films on photocatalytic activity and photo-induced oxygen production in a sacrificial system**, S. Kundu, A. Kafizas, G. Hyett, A. Mills, J. Darr, I. P. Parkin, *J. Mater. Chem.*, 21, 6854-6863 (2011). [doi.org/fmjisdv](https://doi.org/10.1039/c1jm10001a)

4. Details of the impact

The Chemistry Department's outreach and public engagement activities are strongly connected to its exceptional research. Almost all academic staff have an accessible talk on their research suitable for a range of audiences. Public lectures introduce audiences to the fundamental ideas of chemistry in engaging ways, in an effort to reduce the marginalisation of chemistry within society and promote general public interest in chemistry. UCL researchers' ability to engage non-specialist audiences in their research has led to further invitations to present on chemistry more broadly.

Promotion of chemistry to school pupils: The department has been extensively involved in The Training Partnership's A-level student lecture programme. Since 2008, 15 sell-out lectures, on topics such as atmospheric and ice chemistry, have been given to nearly 14,000 pupils (underpinned by, for example, outputs 1,2,5). The Training Partnership said: "*The fact that UCL speakers have taken part on several, and in numerous cases many, occasions indicates a high level of approval from students and teachers... [The] chemistry department has performed a service of inestimable value not just to chemistry but ultimately to developing the nation's skill base and potential for knowledge-driven growth.*" [a]

The Chemistry Department regularly holds lectures for schools attracting 400 pupils per year from more than 45 schools. Since 2008, this series has included lectures to inform pupils about its research on atmospheric chemistry (Rowley, output 5), nanomaterials (e.g. output 9), and materials design and prediction (Catlow, Lewis, output 6). Eight schools have found the talks so useful that they have attended more than four lectures. Talks have also regularly been delivered to A-level students through the UCL Science Centre, with 16 such talks each delivered to between 300-500 students in the REF period. Talks to individual schools, often demonstration lectures, are increasingly done by postgraduate students speaking about research in their supervisor's area. This provides pupils with the chance to talk to real researchers of a similar age to their own.

The department's success in introducing its research in schools led to invitations to present on chemistry as a wider subject. For example, Sella's lecture, "How the Zebra got its Stripes", about the crucial role of chemical feedback mechanisms in natural pattern formation that also asks profound questions about faith, has been given to over 38,000 GCSE students at 26 GCSE ScienceLive events held since December 2008. GCSE ScienceLive, which takes place across the UK, is a day-long event consisting of talks from the country's most prestigious scientists to inspire

GCSE students to continue to study science. Participant feedback includes: “*Before I had attended Science Live I had only chosen to attend for the chance to miss a day of school (...) I also had no idea what career path I was going to choose. But after your words on why I should become a scientist (which shook my religious beliefs, which I adhere [to] with conviction) I’ve decided that you are right, and consequently for work experience placements I am visiting both Norwich University Hospital and hopefully something else science-related. Thank you so, so much.*” [b]

Stimulation of public interest and engagement in science: Sella has spearheaded much of the outreach work, with the EPSRC awards specifically enabling him to promote chemistry and establish himself as the UK’s foremost public exponent of chemistry. The success of Sella’s fellowship is highlighted by an article in *New Scientist*: “It has often been said that chemistry needs a champion in the mould of Brian Cox or Richard Dawkins. That is starting to happen with the arrival of such popularisers as Andrea Sella of University College London” [n]. As a result, he has not simply presented science directly related to his own research (e.g. a video on didymium, which is composed of rare earth metals, has been watched over 21,000 times since December 2012 [c]), but because of this underpinning research he has also been instrumental in bringing a broad range of the department’s chemistry to a wider audience, through regular radio and TV appearances.

The department’s research on thermodynamic properties of matter including phase diagrams [output 4] led to Sella contributing to BBC Four’s *The Secret Life of Ice* in October 2011, which had 0.47m viewers in the UK [j]. It also aired in 8 countries, including the USA, Canada and Australia, helping promote chemistry among a global public audience. In late 2012, this contribution was developed into a demonstration lecture called *Strange Ice*, which has been delivered to 2,700 sixth-form pupils through the Training Partnership’s “Chemistry in Action” events, and audiences at Cambridge, Cheltenham and Edinburgh Science festivals. The Training Partnership stated “the feedback on the most recent UCL presenter, Sella in autumn 2012 and spring 2013 for ‘Strange Ice’, ranged from ‘outstanding’ to ‘motivating’ and ‘exceptional’” [a].

The platform created by presenting departmental research, combined with Sella’s ability to translate complex subjects for the public, led to repeat invitations to act as consultant and contributor on major television and radio productions. This has included ongoing collaboration with, among others, the BBC. For example, he acted as consultant and recorded demonstrations for the award-winning documentary *The Secret Life of Chaos*, again utilising his expertise in thermodynamics [output 4], presented by Jim Al-Khalili and first broadcast on BBC Four in Jan 2010 (0.53m viewers [j]). The programme won the Best Film prize at the International Science Film Festival 2010 and the Association of British Science Writers’ best scripted television programme award [d]. A senior BBC producer confirms Sella’s important contribution to programmes across the entire spectrum of BBC broadcasting: “He is terrific at translating the complex and intangible into focused, accessible information which can be incorporated into science programmes to make them multi-textured, fascinating and entertaining to a wide variety of audiences.” [i]

Sella also contributed to and appeared on the BBC Four 3-part series *Chemistry: A Volatile History* in January 2010, which he ensured contained an appropriate mixture of historical context and scientific rigour. This series holds the record for the highest audience of any science series on BBC Four and was consistently one of the channel’s top 2 broadcasts throughout the series, demonstrating that the public engaged with the topic (0.74m viewers tuned in to the first episode) [j]. It was nominated for a 2010 Specialist Factual BAFTA [h]. It also aired in the USA. Online comments were positive, including: “*I learnt more in these 4 viewings than during 3 years of weekly chemistry lessons at college*”; “*Superb. The opening episode of this series was simply excellent, with an engaging presenter, well demonstrated experiments and evocative locations*”, and “*If only all chemistry lessons were this good at school, we’d all become scientists*” [f]. His other work has included contributions to the BBC Four 2-part series *Everything and Nothing* (March 2011, 0.43m viewers); the 3-part *Science and Islam* (Jan 2009, up to 0.42m viewers per episode); the BBC Two 6-parter *The Story of Science: Power, Proof and Passion* (May 2010, 1.56–2.25m viewers per episode); and Channel 4’s *Heston’s Tudor Feast* (March 2009, 2.6m viewers) [j]. A BBC presenter noted that without Sella’s “fundamental” input, many science series “wouldn’t make it to screen” and was a crucial source for promoting science to young children: without it, “there would be little chemistry and much smaller audiences on [CBBC]” [o].

Presentations to general audiences: Sella’s engagement activities extend beyond his media outreach, with talks to the general public, such as contributions to the Cheltenham Science

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Festival. Between 2008 and 2013, he delivered 24 presentations and 4 discussions to audiences of up to 600 members of the public per session. These talks consistently drew on departmental research; for example he curated a discussion between Dr Lewis and architect Magnus Larsson to draw attention to the parallels between deliberate design of porous structures such as zeolites and the design of large-scale structures in which bacteria transform sand into sandstone. He brought superhydrophobic surfaces [output 8], supercooled water [outputs 1,2], phase diagrams and high-pressure science [output 4] to this and other Science Festivals, as part of presentations including the *Overambitious Demo Challenge*, *Molecular Mastery*, *The Science of Cocktails*, and *Mercury: Window on the Invisible*. His talk *Chemistry and Architecture* was underpinned by Catlow and Lewis's work into computer-aided materials design [output 6]. A Festival organiser confirms that Sella's events "all received good feedback from members of the audience... The comments included how enthusiastic Andrea is and how it has motivated them to learn more or increased their understanding of the topic. The style of his events, which often include demonstrations, also helps to draw in audiences that might not want to attend debate or lecture style events" [g].

Since 2009 UCL researchers have been involved in Bright Club, a monthly comedy event based on the participants' research (including the work of Rowley and Parkin), run by the UCL Public Engagement Unit. Bright Club brings researchers to a new audience: 20-50 year olds who have no existing relationship with academia. The reach of these events is increased further by free podcasts available on iTunes. Sella has also played an important part in the science-based comedy event Festival of the Spoken Nerd (FoTSN), performing to over 1,200 people over the past three years. One of the organisers of FoTSN says: "The chemistry demos are without a doubt the most talked-about part of the show on the night, on social media, and for days afterwards." [e]

Online outreach activities: The department has also undertaken a number of online activities to engage the public with its research, helping reach a far wider, international audience. For example, a 2009 collaboration with Sciencefilms and Labreporter led to the development of six "Lab Report" short videos on CVD, atmospheric chemistry and carbon-carbon bonds. These videos were posted on YouTube and had, as of 31 July 2013, been viewed some 25,000 times [m]. Meanwhile, Hirjibehedin instituted a citizens' science project titled *Feynman's Flowers*, which uses online participatory methods to educate the public about molecular spintronics; the project webpage received around 1,800 unique visitor hits from almost 80 countries since Sept 2012 [k].

The interfaces, catalytic and environmental group's exhibit on the properties of water at the nanoscale, at the 2010 Royal Society Summer Science Exhibition, included a free iPhone game called Waterfall that users in 73 countries downloaded 4,265 times. During the impact period, the 25+ videos on the group's YouTube channel were collectively viewed 110,000 times [l].

5. Sources to corroborate the impact

- [a] For corroboration of the impact of the A-level lecture series, see the statement from the Training Partnership. Available upon request.
- [b] A compilation of feedback from members of the public corroborates that demonstrations stimulated public interest is available on request.
- [c] Royal Institution Didymium video received 21,000 views between Dec 2012 and 31 July 2013: <http://youtu.be/6UI8CmUkO4E>
- [d] *The Secret Life of Chaos*, winner of Best Film at the International Science Film Festival, 2010, <http://bit.ly/1akaMbO>, and Association of British Science Writers award: <http://bit.ly/17nyio2>
- [e] FoTSN statement confirms Sella's work stimulated public interest in chemistry. Copy available.
- [f] Positive reviews of Chemistry: A Volatile History, <http://bit.ly/1atf6BM>
- [g] Statement from Cheltenham Science Festival Assistant confirms that festival audiences have commented how Sella's demonstrations increased their understanding. Available on request.
- [h] 2010 Specialist Factual Bafta Award nomination for Chemistry: A Volatile History: <http://awards.bafta.org/award/2010/television/specialist-factual>
- [i] A statement from a Senior BBC Producer corroborates Sella's contribution to programmes across the BBC for a range of audiences. Available on request.
- [j] Viewing figures for all TV programmes from BARB. Available on request.
- [k] Feynman's flowers <http://bit.ly/1eZr355>. Usage data, Google Analytics. Available on request.
- [l] Viewing figures for ICE YouTube page from YouTube. <http://www.youtube.com/icelcn>
- [m] Lab Report videos on YouTube: <http://www.youtube.com/sciencefilms>
- [n] RSC President quote in New Scientist, 24 January 2012, <http://bit.ly/1hFQnlt>