A brief history of some landmark papers

Twenty years after spelling out IBM with atoms, the scanning tunnelling microscope is still going strong.

We are in the midst of a spate of anniversaries: December was the fiftieth anniversary of 'There's plenty of room at the bottom', and January was the tenth anniversary of the speech in which President Bill Clinton launched the National Nanotechnology Initiative in the US. The laser was invented 50 years ago, the discovery of C_{60} molecules was announced 25 years ago. Looking ahead, next year marks 100 years since the discovery of superconductivity and 20 years since Sumio Iijima's first paper on the carbon nanotube. And, as Chris Toumey reminds us on page 239, it is 20 years since researchers at IBM's Almaden Research Center in San Jose reported that they had used a scanning tunnelling microscope (STM) to write the name of their company on a nickel surface with 35 xenon atoms[1].

Until then the STM had been used to image surfaces, and atoms and molecules on surfaces, with atomic precision, but not to manipulate matter at the nanoscale. In less than three pages of *Nature*, and with just three figures and six references, Don Eigler and Erhard Schweizer (who was visiting from the Fritz Haber Institute in Berlin) reported that they had employed an STM to "fabricate rudimentary structures of our own design, atom by atom". They ended their first paragraph optimistically, stating that "the possibilities for perhaps the ultimate in device miniaturization are evident", although they added several notes of caution later in the paper, and concluded on a tentative note by saying "The prospect of atomic-scale logic circuits and other devices is a little less remote."

Eigler and Schweizer's 'IBM' paper capped a remarkable decade for the STM, which was invented by two other employees of the IBM Research Division — Gerd Binnig and Heinrich Rohrer of the company's Zürich Research Laboratory — and recognized with the Nobel Prize in Physics in 1986. The basic idea was simple: apply a voltage to a very sharp metal tip and then measure the current that tunnels from this tip as it is scanned over a surface to produce an atomic-scale image of the surface (or, alternatively, move the tip up and down to keep the tunnel current constant as the tip is scanned over the surface).

In their Nobel lecture[2], Binnig and Rohrer recall how they had no experience in microscopy or surface science: "This probably gave us the courage and light-heartedness to start something which should 'not have worked in principle,' as we were so often told." By January 1979, however, they were sure enough of their ideas to submit a patent disclosure, although they did not confirm that the tunnel current depended exponentially on the tip–surface separation — the piece of physics at the heart of the STM — until the night of 16 March 1981. After rejection by one prestigious physics journal, the paper reporting the invention of the STM, which was co-authored with Christoph Gerber and Edi Weibel, was accepted for publication by *Applied Physics Letters* on 4 November 1981[3]. Five years later the prodigious child of the STM — the atomic force microscope (AFM) — was invented by Binnig, Calvin Quate and Gerber[4].

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The enlightened attitudes in IBM's Research Division — which, for some reason, has never had the same lustre as Bell Laboratories — are evident in some of these papers. Binnig and Rohrer recall that they were "granted the necessary elbow-room to dream, to explore, and to make and correct mistakes" and the acknowledgements in the 'IBM' paper state that "This work would not have occurred were it not for the patient and visionary management of the IBM Research Division". Top-quality papers on nanotechnology continue to flow from Almaden and Zürich, and also from Yorktown Heights, although it is unusual for such fulsome acknowledgements to make it into print nowadays.

The 'IBM' paper has now been cited close to 1,500 times, almost twice as many as the paper reporting the invention of the STM, although another publication from the Zurich group[5] with the rather prosaic title 'Surface studies by scanning tunnelling microscopy' recently topped 2,400 citations (and the original AFM report had a staggering 6,295 citations at the time of writing). More importantly, however, the images in the 'IBM' paper brought the possibilities offered by nanotechnology to a broader audience than ever before and, 20 years later, they are probably still the most famous images in the history of the field. Moreover, the 'IBM' paper was also the first of a number of reports from Eigler and co-workers to combine STM images with stunning visual impact and new insights into fundamental phenomena in physics: check out the quantum corral[6] and the quantum mirage[7,8].

This spirit lives on today: on the cover of this issue is an STM image showing molecular chains formed by an organic charge-transfer salt. Scanning tunnelling spectroscopy reveals that chains containing just four molecules can be superconducting (page 261). Elsewhere, researchers have demonstrated the potential for an STM-based technique called quantum holography to reach unprecedented data-storage densities[9], and it comes as no surprise to find that an increasing number of research groups are using STMs to study a new family of insulating materials that support exotic metallic states on their surfaces[10]. Indeed, these topological insulators[11], which are probably the hottest topic in condensed-matter physics today, seem purpose-built for the scanning tunnelling microscope. ❐

References

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