Who invented nano?

THE NANOTECH PIONEERS BY STEVE EDWARDS

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The many breakthroughs in science and engineering made during the last century are well documented and there is a general consensus about who discovered what. It is widely agreed, for instance, that William Shockley, John Bardeen and Walter Brattain invented the first transistor in 1947. Such inventions and discoveries were based on research conducted by individuals or groups from similar technical backgrounds, and there was little cross-fertilization of ideas between the sciences. Matching people to inventions was easy in the twentieth century.

But connecting people and discoveries in the twenty-first century will be complicated by the increasingly multidisciplinary nature of research in general, and nanoscience and nanotechnology in particular. Who invented and/or discovered nanotechnology? In *The Nanotech Pioneers*, science writer and biologist Steven Edwards takes us behind the scenes for a closer look at the visionaries in the field, the fundamental concepts involved, the prospects for commercialization and the potential dangers of this all encompassing technology.

It is generally acknowledged that the term nanotechnology was first used by the late Professor Norio Taniguchi of the Tokyo Science University in a paper, "On the Basic Concept of 'Nanotechnology'", presented at a meeting of the Japan Society of Precision Engineering in 1974. In this paper, Taniguchi states that "Nano-technology mainly consists of the processing of separation, consolidation and deformation of materials by one atom or one molecule".

Edwards takes us back to Richard Feynman's famous 1959 lecture, "There's plenty of room at the bottom", which challenged engineers to write "the entire 24 volumes of the Encyclopedia Britannica on the head of a pin", inspiring a number of 'top-down' approaches to miniaturization; and forward to a highly imaginative paper by K. Eric Drexler, a Massachusetts Institute of Technology trained engineer, in which

he proposed building machines by a 'bottom-up' approach that used 'molecular assemblers' to manipulate individual atoms (*Proc. Natl Acad. Sci. USA* **78**, 5275–5278; 1981). The possibility of using molecular self-assembly to make functional nanoscale systems was a sign of things to come, including the need for a multidisciplinary approach to many problems. Some venture capital companies are developing tools called nanomanipulators to build Drexler's molecular assemblers, although nanorobots are a long way off.

Hardened engineers with a diminutive appetite for the politics of science will be intrigued by Edwards' description of Mike Roco's role in setting up the National Nanotechnology Initiative in the US. Roco's own research on nanoparticles convinced him of the need for a national effort to tackle problems at the nanoscale, and in 1996 he formed a think-tank consisting of academics, industrialists and scientists from various US laboratories to formulate a national strategy for nanotechnology. In March 1999, Roco was given his 'ten minutes of fame' to make a pitch to President Clinton's advisors. He succeeded — his proposal received \$490 million (only \$10 million less than he asked for), the Initiative was formally announced in January 2000, and the rest is history.

Edwards also addresses the major issues, imagined or otherwise, about the potential dangers of nanotechnology, including: environmental catastrophe due to self-replication of 'nanomachines'; inhalation and ingestion of nanoparticles; claims that only wealthy groups will benefit; the possibility of creating weapons of mass destruction; and fears that advances in technology might become uncontrollable (the 'singularity' idea first put forward by John von Neumann). Government regulation and potential applications as diverse as energy storage and generation, 'space elevators' and quantum computing are all discussed.

Moreover, the explanations of these ideas — and others like spintronics, nanomedicine, molecular biology, scanning probe microscopy and more — are clear and should be readily comprehensible to a general readership. This book also highlights the recent changes in attitudes of scientists and engineers towards multidisciplinary research, with groups of physicists, chemists, materials scientists, biologists, engineers, IT researchers, metrologists and others all joining forces for a common cause.

There are, however, some blind spots in the book, notably about nanotechnology in Asia. The carbon nanotube was discovered by Sumio Iijima at NEC in 1991, as Edwards reports, but what do Iijima and NEC think about the future of nanotubes? How will China's increasing investments in science and technology affect nanotechnology in the US and EU? And what impact will the increasing mobility of research and researchers have? It is worth noting that although the fundamental ideas leading to the invention of the transistor and integrated circuits were conceived in US laboratories, it is most unlikely that they would have had such an impact on our lives had it not been for Japanese engineers and companies.

Edwards hints at the need to take a step back when contemplating the wonders of nanotechnology. "There is something god-like about manipulating matter at its most basic level," he writes, "a certain amount of heady grandiosity, much of it warranted, can be perceived in some of the statements of the *Nanotech Pioneers*". Maybe, but in the era of convergence and multidisciplinary research, simply identifying the real pioneers will be a challenge.

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