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EDITORIAL

Nanotechnology in motion

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Microscopes provide tools of inimitable value for probing the building blocks of the world around us. The identity of the inventor of the first microscope remains under debate, but a name unequivocally linked with early developments in microscopy is Robert Hooke. His *Micrographia* published in 1665, was the first ever bestseller in science and brought topics in microscopy to the broader public eye with pages of detailed micrographs, most famously the fly's eye and plant cells. Since the first microscopes in the late 16th century, ingenious alternatives to the original optical microscopes have been developed to create images of the world at ever smaller dimensions. Innovations include scanning probe techniques such as the atomic force microscope [1]. As Toshio Ando describes in a review in this issue [2], these devices have also entered a new era in the past decade with the development of high-speed atomic force microscopy. Now, we can not only see the nanoscale components that make up the world around us, but we can watch them at work.

One of the first innovations in optical microscopy was the use of dyes. This principle first came into practice with the use of ultraviolet light to reveal previously indistinguishable features. As explained by a researcher in the early 1930s, 'It is obvious that if the dyes used for selective staining in ordinary microscopical work are supplemented by substances which cause a particular detail of the structure to fluoresce with a specific colour in ultraviolet light, then many strings will be added to the bow of the practical microscopist' [3]. More recently, emphasis on the role of plasmons—collective oscillations of electrons in nanoscale metal structures—has received considerable research attention. Plasmons enhance the local electromagnetic field and can lead to increased fluorescence rates from nearby fluorophores depending on the efficiency of the counteracting process, non-radiative transfer [4].

The 1930s also saw the development of the electron microscope, which aimed to exceed the resolving power of diffraction-limited optical microscopes. Since the diffraction limit is proportional to the incident wavelength, the shorter wavelength electron beam allows smaller features to be resolved than optical light. Ernst Ruska shared the Nobel Prize for Physics in 1986 for his work in developing the transmission electron microscope [5]. The technique continues to provide an invaluable tool in nanotechnology studies, as demonstrated recently by a collaboration of researchers in the US, Singapore and Korea used electron and atomic force microscopy in their investigation of the deposition of gold nanoparticles on graphene and the enhanced conductivity of the doped film [6]. The other half of the 1986 Nobel Prize was awarded jointly to Gerd Binnig and Heinrich Rohrer 'for their design of the scanning tunnelling microscope'. The scanning tunnelling microscope offered the first glimpses of atomic scale features, galvanizing research in nanoscale science and technology into a burst of fruitful activity that persists to this day.

Instead of using the diffraction and scattering of beams to 'see' nanoscale structures, the atomic force microscope developed by Binnig, Quate and Gerber in the 1980s [1] determines the surface topology 'by touch'. The device uses nanoscale changes in the forces exerted on a tip as it scans the sample surface to generate an image. As might be expected, innovations on the original atomic force microscope have now been developed achieving ever greater sensitivities for imaging soft matter without destroying it. Recent work by collaborators at the University of Bristol and the University of Glasgow used a cigar-shaped nanoparticle held in optical tweezers as the scanning tip. The technique is not diffraction limited, imparts less force on samples than contact scanning probe microscopy techniques, and allows highly curved and strongly scattering samples to be imaged [7].

In this issue, Toshio Ando from the University of Kanazawa provides an overview of developments that have allowed atomic force microscopy to move from rates of the order of one frame a minute to over a thousand frames per second in constant height mode, as reported by Mervyn Miles and colleagues at Bristol University and University College London [8]. Among the pioneers in the field, Ando's group demonstrated the ability to record the Brownian motion of myosin V molecules on mica with image capture rates of 100 x 100 pixels in 80 ms over a decade ago [9]. The developments unleash the potential of atomic force microscopy to observe the dynamics of biological and materials systems. If seeing is believing, the ability to present real motion pictures of the nanoworld cannot fail to capture the public imagination and stimulate burgeoning new avenues of scientific endeavour. Nearly 350 years on from the publication *Micrographia*, images in microscopy have moved from the page to the movies.

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