Microbiology

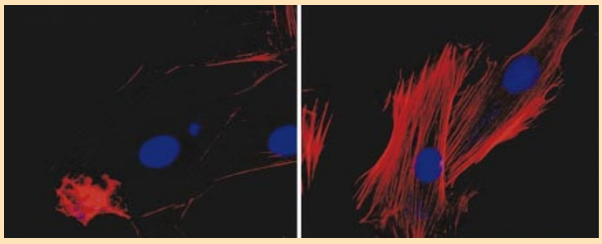
Destructive approach

In the latest example of the wiliness of infectious bacteria, Tomoko Kubori and Jorge E. Galán have shown that *Salmonella typhimurium* exploits its host's protein-degradation machinery in order to reverse the substantial cellular reorganization that allows the bacterium to gain entry (*Cell* **115,** 333–342; 2003).

A common cause of food poisoning in humans, *S. typhimurium* eases its passage into intestinal cells by injecting various proteins into them, including one called SopE. This protein causes rearrangements in the cell's actin filaments — part of the intracellular 'skeleton' — and ruffling of the cell membrane, events that enable the bacteria to gain entry. The left image here shows the rearranged actin filaments (red), along with internalized bacteria (blue). Shortly afterwards, another injected bacterial protein, SptP, counters these effects, restoring the status quo (right-hand image).

So how does *S. typhimurium* ensure that these events happen in the right order? One possibility is that it injects SopE first and SptP later. But Kubori and Galán rule out that idea: they show that SptP is present at the same levels as SopE within about 15 minutes of infection — just after the first evidence of actin rearrangement is seen. This also shows that SopE can produce these rearrangements even when SptP is about.

The authors find that levels of SopE subside later in the infection, when the actin reorganization ceases. But SptP is still easily detected. What causes the difference? Again, the authors eliminate the possibility that the proteins are produced to different extents in the infected cell. So they



looked at whether differential degradation might be the key. They find that it is. The main cellular machinery for chewing up unwanted or damaged proteins is the proteasome; when a proteasome inhibitor is added to infected cells, the levels of SopE remain high.

Why is SopE destroyed so quickly after infection whereas SptP is not? Kubori and Galán find that this is not due to the presence of other bacterial factors, so it must be determined by something intrinsic to the proteins themselves. Previous work led the authors to suspect that a particular region of each protein, known as the secretion and translocation domain, controls their degradation. To test this, they swapped these portions of the proteins. The result was that SopE was treated like SptP, and vice versa — the actin rearrangements were not reversed in either case, because SptP was degraded quickly, and SopE was not. So what's the difference between these regions of each protein? That's a question for the future. **Amanda Tromans**

was first described as the 'Coolidge effect'[13] after US President Calvin Coolidge, who, while visiting a government farm, professed amazement at the prolific frequency of one cockerel's mating — until he was informed that each mating took place with a new female. The Coolidge effect has previously been documented only as a re-initiation of sexual behaviour[14]. Pizzari *et al.* show that new females resuscitate both mating behaviour and ejaculate size.

Pizzari and colleagues' results[4] illustrate the selective forces that could be driving the evolution of male strategies for winning sperm competitions. However, it will be important to quantify the actual fertilization and reproductive rates of competing males — to see whether the 'spend-and-save' strategy is truly adaptive, translating into long-term or lifetime reproductive success. We also need more detailed information on the energetic and reproductive costs of producing sperm. Another question, given that the probability of encountering future receptive females is implicit in prudent sperm-investment strategies, is whether (as would be predicted) males show sensitivity to local cues of the abundance of receptive females when mating.

Finally, future research might also explore the mechanisms behind the modulation of ejaculate size. Physiological work on the promiscuous rodent *Peromyscus maniculatus* shows that muscular contractility of the vasa deferentia is directly sensitive to opioid hormones[15]. The vasa deferentia transport sperm to the site of ejaculation, and opioid hormones are secreted during male–male interactions as direct cues of sperm competition. It seems logical that a similar kind of mechanism might operate in fowl, too. ■

Matthew J. G. Gage is in the School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, UK.
e-mail: m.gage@uea.ac.uk

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Femtophysics

Birth of a quasiparticle

Alfred Leitenstorfer

As electronic devices shrink, the interaction between electrons and the silicon crystal lattice, described in terms of 'quasiparticles', is a central issue. Ultrashort laser pulses can track the birth of such a quasiparticle.

With few exceptions, electronic devices are based on silicon: using this semiconductor material, an extremely high density of basic switching elements (transistors) can be incorporated in complex circuits. Soon the size of transistors on commercial silicon chips might drop below 10 nanometres[1]. At this level of integration, the physical dimensions of each element are similar to the distance between atoms in the material, and the conventional description of charge flow in electronic devices breaks down. On page 51 of this issue, Hase *et al.*[2] present an experiment that gives a flavour of the colourful dynamics that might be expected under such conditions.

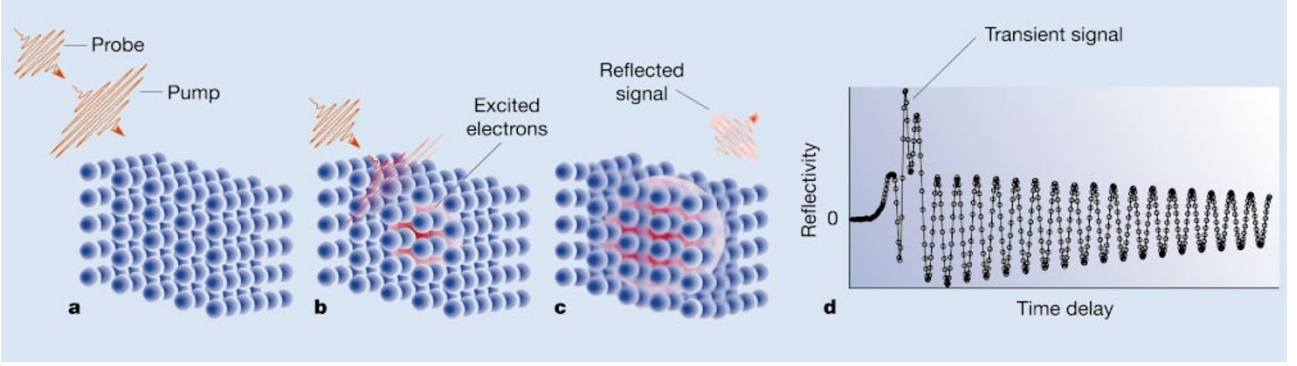

Figure 1 **Caught in the act.** a, **Before excitation by a short, intense laser pulse (the pump), a pure silicon crystal contains few free electrons, and the atoms in the crystal lattice (blue) are virtually at rest.** b, **The pump hits the sample and creates a localized cloud of excited electrons, which interacts with the surrounding crystal lattice and causes characteristic vibrations. This process is described in terms of the generation of quasiparticles and is analogous to the abrupt injection of electrons into a nanometre-size transistor.** c, **A delayed test pulse (the probe) is reflected from the sample surface and modified according to the instantaneous electronic conditions at the surface.** d, **By varying the time delay between pump and probe pulses, Hase *et al.*[2] have mapped out the excitation dynamics at the femtosecond timescale. The measured surface reflectivity shows a damped oscillation, and a transient signal lasting around 50 femtoseconds.**

In a material such as silicon, the motion of electrons is influenced by the surrounding ion cores of the crystal lattice. These processes are complicated; but, on time and length scales that are much larger than molecular ones, they may be described in a straightforward way by assuming that the electron mass is altered and that its specific state of motion has a finite lifetime. In the language of condensed-matter physics, the electrons are 'renormalized' by the surrounding matrix, becoming 'dressed' as 'quasiparticles'. Until now, microelectronics engineers could quietly assume that interactions between these quasiparticles and their matrix occur instantaneously — that when an electron bumps against the ion lattice, there is a sudden change in its kinetic energy and momentum. But at nanometre scales, where this semiclassical picture is no longer applicable and quantum effects become relevant, it is not clear at present how to model the electron behaviour.

There is another complication too. In principle, it should take a finite amount of time to establish the quasiparticle in a non-equilibrium situation or to complete a scattering with the lattice. The typical timescale for this is given by the oscillation cycle of the lattice vibrations. These are quantized, and are given the name 'phonons'. As transistors shrink to nanoscale dimensions, they might respond so quickly to a pulse of electric current that their internal switching times approach this limiting timescale.

The build-up of quasiparticles has been observed[3] in compound semiconductors such as GaAs. But quantum kinetic processes have not previously been accessible in silicon. To measure them requires extremely high temporal resolution, which can currently only be achieved using ultrashort laser pulses, of a few femtoseconds duration ($1\,\mathrm{fs} = 10^{-15}\,\mathrm{s}$). However, the electrons moving inside silicon are typically of low energy and their coupling to the photons of the laser pulse is relatively complicated, so direct insight has been hampered.

Hase *et al.*[2] have worked around this problem by using femtosecond ultraviolet pulses first to excite the electrons to much higher energies, and then to probe the subsequent dynamics (Fig. 1). The absorption of high-energy photons by the electrons is a relatively simple process, and interpretation of these data is straightforward. The authors then trace what happens to the electrons using the electro-optic effect, which describes how the excited electrons and lattice vibrations change the optical properties of the material. These measurements are truly a *tour de force*: the electro-optic effect is absent in bulk silicon (because it is a centrosymmetric system); but Hase *et al.* have sampled reflected light from the silicon surface and show that it is modulated. Their apparatus needed to be a hundred times more sensitive than in previous experiments[4] (on polar materials), because only a few atomic layers at the surface contribute to the signal.

The time traces recorded by Hase *et al.* consist of two parts (Fig. 1). One is an exponentially damped oscillation, which originates from the interactions of lattice phonons and the photo-generated electrons. The other is an aperiodic, transient signal from the electrons themselves that appears only for 50 fs. Other researchers might have been content to focus on the phonon oscillations alone. But with an experiment capable of 10-fs time resolution, Hase *et al.* realized that the electronic response does not simply follow the excitation pulse. Instead, it contains more information on the build-up, or dressing, of the electronic quasiparticles. Cleverly, they transformed their time-dependent data into time–frequency space, creating a sequence of spectra defined by varying the delay between the application of the pump and the probe laser pulse. And there, they have found new physics.

Extremely close in time to the initial excitation, Hase *et al.* have uncovered signatures of the force exerted by the electronic charge on the lattice, and by the lattice on the developing quasiparticles. The most remarkable feature is a dip in their spectra where the electronic and lattice responses overlap in the time–frequency plane. The authors attribute this to a so-called Fano interaction[5], originating from a coherent superposition of phonons and the broad continuum of electronic excitations. Solid-state physicists talk about 'quantum correlations' in this context; researchers from the field of quantum optics might use the term 'entanglement'. In any case, Hase *et al.* have watched, step by step, the ultrafast birth of quasiparticles in silicon, as electrons are dressed by the lattice.

This paper[2] stimulates many fascinating questions, some general in nature, others specific to future research. For example, specialists might wonder how theory will succeed in explaining quantitatively the complicated phenomena that are seen in this experiment. Also, how closely does the behaviour of the very energetic electrons observed by Hase *et al.* mimic that of their lower-energy counterparts travelling through silicon chips? The day will come when quantum physics directly influences the functionality of computers and other electronic equipment that we use in everyday life — the question is, when? ■

Alfred Leitenstorfer is in the Department of Physics, University of Konstanz, PO Box M 695, D-78457 Konstanz, Germany.
e-mail: alfred.leitenstorfer@uni-konstanz.de

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