cells[11], which has hampered efforts to develop small-animal models of HIV-1 infection. Even in human cells, Vpu might not always be able to overcome the powerful effect of tetherin, as the release of infectious Vpu-positive HIV-1 can be inhibited with high doses of interferon-α (ref. 5). Thus, an understanding of how tetherin works, and how Vpu fends it off, could lead to strategies to limit the spread of HIV-1 and other viruses that target humans. ■

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MATERIALS SCIENCE

Lilliputian light sticks

Melissa Fardy and Peidong Yang

Building two different fluorescing dyes into a composite organic nanocrystal makes a tunable light generator. At just the right dye proportions, a low-cost, highly efficient source of white light is the result.

If you have ever wondered what makes that ghostly colour in the light sticks used by trick-or-treaters on a Hallowe'en night, wonder no more: a typical answer might be a fluorescing organic molecule such as 5,6,11,12-tetraphenyltetracene, also known as rubrene. Writing in *Advanced Materials*, Zhao *et al.*[1] describe how they used such organic molecules to make white-light-emitting composite nanocrystals that are visible only under a microscope. Cute as these lilliputian light sticks are, they might also point the way to a new generation of light sources.

A typical light stick contains two chemicals: hydrogen peroxide and a phenyl oxalate ester. When these two substances are mixed, energy is released. That energy excites a suitable fluorescent dye, causing it to emit a photon. The wavelength of the photon, and so the colour of the emitted light, depends on the structure of the dye (Fig. 1a). Rubrene, for example, is an orange-emitter; the related molecule 1,3,5-triphenyl-2-pyrazoline (TPP) is blue.

Zhao *et al.*[1] use a process called physical vapour deposition, which is a common way of making organic nanocrystals, to co-evaporate rubrene and TPP at 200–300 °C and condense them onto a substrate at a lower temperature. The result is a collection of uniform organic nanorods with diameters of hundreds of nanometres and lengths of several micrometres (Fig. 1b). Each nanorod functions as a tiny light stick, with its colour determined by the molecular ratio of the two organic dyes.

The energy-transfer mechanism in these nanorods is known as intermolecular fluorescence resonance energy transfer (IFRET), and is fundamentally different from that of a typical light stick. In a typical IFRET process[2], energy is absorbed by one fluorescent molecule (blue-emitting TPP in Zhao and colleagues' case), and transferred non-radiatively to another fluorescent molecule (orange-emitting rubrene). Consequently, the emission of the first molecule is quenched, and the emission of the second is enhanced. The efficiency of this process depends sensitively on the degree of electronic coupling between the two molecules. In an amorphous thin film, for example, where TPP and rubrene molecules are intimately mixed, the emission of TPP can be almost completely quenched with a very small amount of rubrene.

The nanorods prepared by Zhao *et al.* show an intermediate degree of IFRET owing to an unusual structural feature: as X-ray diffraction studies reveal, the rubrene nanocrystals are uniformly embedded in a crystalline TPP matrix. This results in incomplete quenching of the blue emission from TPP, even with decent levels of rubrene 'doping', leading to colour mixing of the orange and blue emissions. Importantly, at the proper molecular ratio, it becomes possible to generate stable white light.

Among researchers investigating comparable lighting devices based on inorganic semiconductors, this kind of colour tunability is often achieved by using homogeneous mixtures of different compounds. A good example is recent research into indium gallium nitride (InGaN) materials, which are considered excellent candidates for solid-state lighting applications. Here, a mixture of indium nitride and gallium nitride is used to systematically shift the emission of the materials from ultraviolet wavelengths to the near-infrared[3]. Similarly, doping has commonly been used in organic light-emitting diodes (OLEDs), both to tune their emission colour and to improve their luminescence efficiency[4].

Many of these doping studies have used amorphous thin films, in which charge carriers have low mobility. Zhao and colleagues' composite organic nanorods not only represent an unusual source of stable white light, but, because of their ordered crystalline natures, should offer better transport properties, and hence better optoelectronic performance. Single crystalline nanowires of the aromatic hydrocarbon hexathiapentacene have been shown to have charge-carrier mobilities almost ten times those of more disordered thin-film structures[5]. To sound a note of caution, however, the emission efficiency of these composite nanorods has yet to be determined. Their integration into a functional electroluminescent device must also be demonstrated.

Because of the great tunability of both their crystal and their electronic structures, inorganic semiconductor nanowires have proved to be workhorses of nanoscale science and engineering[6], finding applications in various electronic, photonic and sensing devices.

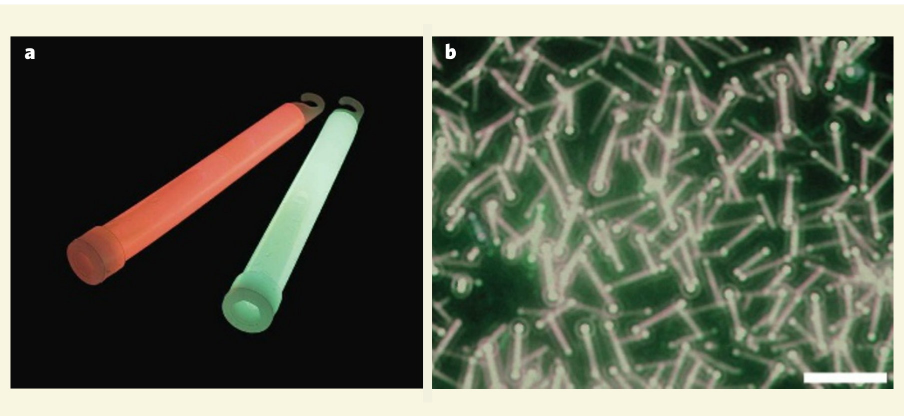

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Figure 1 | Great white hope. a, Commercial light sticks containing fluorescent dyes are available in various colours. **b**, Zhao *et al.*[1] engineer similar rods on a tiny scale (scale bar, 5 μm), incorporating two dyes, TPP and rubrene, so that the rods emit white light.

Considering the vast number of optically and electronically active organic molecules, the organic version of the nanowires could reasonably be expected to have similar potential — and indeed, they are already being considered for devices such as transistors, LEDs and photovoltaic cells. Their one-dimensional nanostructures offer the additional advantage of being mechanically flexible, making them particularly appealing for flexible optoelectronic applications: a hexathiapentacene nanowire transistor, for instance, suffers no significant loss in performance when placed under mechanical stress[5].

Just as with their inorganic counterparts, several important optical properties have already been demonstrated in organic nanowires, including lasing[7], waveguiding[8], nonlinear optical mixing[9] and polarized emission[10]. With Zhao *et al.*[1] adding colour tunability to the list, the nanowires seem to have a bright, white future ahead. ■

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PLANETARY SCIENCE

Under Jupiter's pulsing skin

Kunio M. Sayanagi

Fast jet streams blow along the hallmark coloured bands that engirdle Jupiter's surface. By observing how storms erupt in these jet streams and disturb them, we can penetrate deeper into what lies beneath.

Just as physicians use outward signs to diagnose the conditions inside their patients, so planetary scientists get beneath the skin of their equally dynamic subjects by looking at their surface appearances. Penetrating deep into Jupiter, the Solar System's largest planet, is especially difficult, as a thick cloud-deck keeps the lower levels of the atmosphere hidden from telescopic observations. Thus, Sánchez-Lavega *et al.* (page 437 of this issue)[1] study the behaviour of giant storms at Jupiter's visible surface to reveal the vertical wind and temperature structure in the atmosphere beneath.

The vivid stripes of Jupiter make the planet one of the most visually appealing objects in our Solar System. Observations by NASA's two Voyager spacecraft, which flew past in 1979, revealed that these bands of cloud are associated with atmospheric jet streams[2]. These jet streams are remarkably stable compared with their counterparts on Earth, which continually change course and vary in speed. Jupiter's jet streams, by contrast, flow essentially along lines of constant latitude. Measurements made by the Cassini probe[3], passing in 2000 on its way to Saturn, show no change in the jets' large-scale structure since the Voyager observations, and only minor differences in their locations and peak speeds.

Below this thick deck of cloud, however, observational records become scarce. The only direct measurements so far were made by the Galileo mission's entry probe[4,5] in 1995. This probe was designed to reach 140 kilometres below the clouds, but in fact entered a small, anomalously cloud-free region. Applying the information gleaned from this single *in situ* measurement to the rest of the planet is therefore not straightforward.

As part of a campaign of observations to coincide with the passing of NASA's Pluto mission New Horizons, which swung by Jupiter in early 2007, Sánchez-Lavega *et al.*[1] used the Hubble Space Telescope to monitor the Jupiter system. By chance, in late March 2007 they captured the onset of two large convective storms in a jovian jet stream at a latitude of 23° N. This jet stream is particularly notable because it is Jupiter's fastest, with a speed that has varied between 140 and 180 metres per second in recent years[6–8].

The authors monitored the development of the storms using various ground-based telescopes as well as Hubble. The motion of the clouds during the outbursts gives useful hints about the atmospheric structures that lie beneath. In analysing their images, the authors found that the convective plumes substantially overshot the tropopause, a horizontal boundary in the atmosphere located above most clouds that generally acts as a stable dynamical lid on weather phenomena. The storm plumes must be extremely energetic, as they seem to extend more than 100 kilometres vertically from the storm's base below the thick cloud-deck. Towers of cumulus cloud on Earth extend up to only about 10 kilometres or so in the vertical.

To explore this observation further, Sánchez-Lavega *et al.*[1] performed numerical simulations with various background thermal stratifications. They show that, for a storm to become as energetic as those observed, the temperatures below the tropopause must be 2–5 kelvin colder than those measured by the Cassini probe on its 2000 flyby[9]. It is as yet unclear whether this difference represents a local spatial variance or a change in the vertical temperature structure throughout the latitude band over time. But constraining the thermodynamic

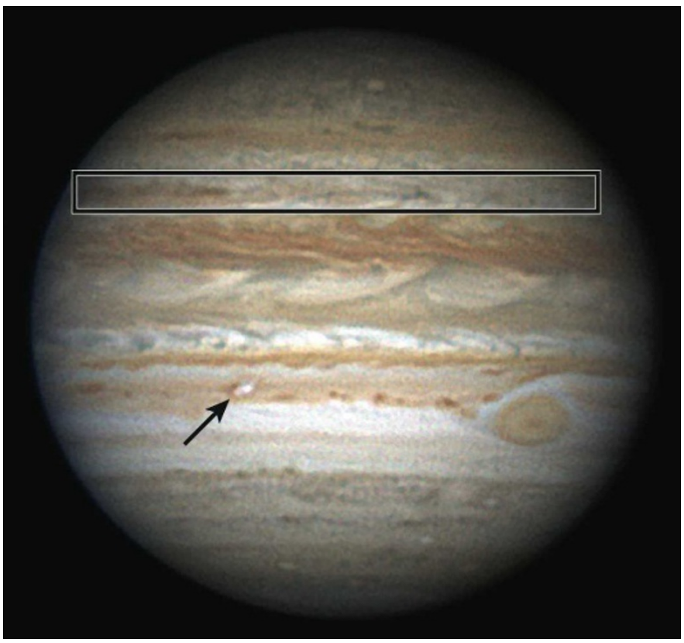

Figure 1 | Storm on camera. An image of Jupiter, obtained on 17 May 2007 from the island of Cebu in the Philippines by an amateur astronomer, shows the planet at the height of its global upheaval of that year. The box indicates the region of the 23° N jet, with the dark grey patches inside it representing the remnants of the disturbance triggered by the storms studied by Sánchez-Lavega and colleagues[1]. The bright spot indicated by the arrow is the onset of yet another storm. The frequency and flexibility of amateur observations, coupled with the ability to achieve spatial resolutions high enough to resolve many major atmospheric features, has made them an integral part of Jupiter observation campaigns. (Image courtesy of C. Go[1,13].)