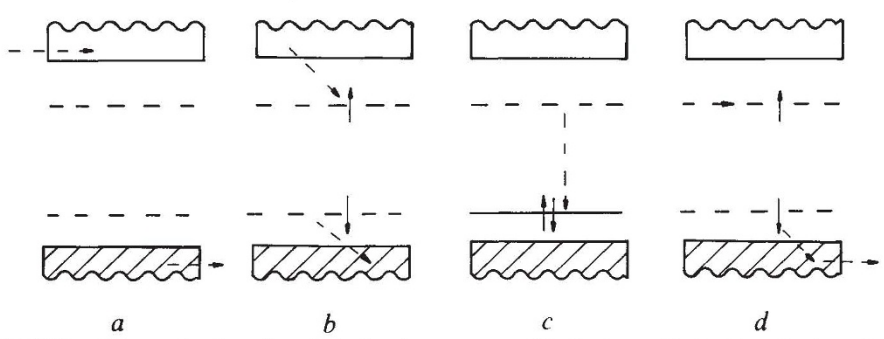

Fig. 2 Possible mechanisms for electroluminescence. *a*, Carrier tunnelling or thermionic emission into the conduction and valence bands. *b*, Formation of negative and positive polarons which combine to form a neutral polaron exciton. *c*, Emission by decay of excited polaron exciton. *d*, Direct injection of electrons to form negative polarons which combine with positive polarons followed by emission (as in *c*).

strates and the transistors produced are unaffected by bending. So, the way is open to large-area, conformable device arrays.

Although metal–insulator–semiconductor structures comprising an oxidized silicon substate and a semiconducting polymer layer do not compete with silicon FETs, they offer new devices not possible with conventional semiconductors. When charges are induced in the polymer by applying a voltage to the silicon, partially filled states are created in the band gap of the polymer. The polymer can then absorb light at wavelengths to which it is normally transparent, by promoting electrons from the valence band to the mid-gap states or from the mid-gap states to the conduction band[5]. Because the silicon substrate is also transparent at these wavelengths, the whole device functions as an electro-optic modulator. Other unusual characteristics have been reported. Metal–polyalkythiophene Schottky-barrier diodes behave with a pronounced temperature dependence[6] acting as diodes at room temperature but not at 100 °C. Polymers have also been manipulated to produce multilayer structures analogous to inorganic semiconductor 'quantum well' structures[7]. The potential of such structures to be used in devices remains to be explored.

Light-emitting diodes and lasers based on III–V semiconductors provide sources in the green, orange, red and infrared spectral regions. Blue sources, though available, are less efficient. Organic materials fluorescing at short wavelengths are well known, but only in 1987 was electroluminescence of high intensity produced[8]. This device combined an emitter layer, in which electrons were able to move, with a hole (electron-vacancy) transport layer. Recombination of electrons and holes at the interface produces the electroluminescence. This concept has been extended by Saito and co-workers[9] to provide efficent organic light-emitting diodes with output running across the visible spectrum into the blue. At present the devices lack long-term stability, but they are easy to prepare.

A parallel, more dramatic advance has been the observation of electroluminescence from semiconducting polymer diodes. This was first reported for polyparaphenylene[10], another polymer prepared by a precursor route. Polyparaphenylene was sandwiched between a positive electrode of oxidized aluminium, gold or indium oxide and a negative electrode of aluminium, magnesium silver alloy or silicon hydrogen alloy. The devices were made by spin coating the precursor polymer, which was thermally converted to the semiconducting form before the second electrode was applied. Similar results have been obtained with a soluble semiconducting polymer, poly-2-methoxy-5-(2-ethylhexoxy)-1,4-phenylene vinylene[11], although this was less efficient.

The exact mechanism of the electroluminescence in these materials is unclear. The charge carriers normally encountered in polyparaphenylene vinylene are bipolarons (paired charges) with low mobility. These are unlikely to contribute to the electroluminescence. Two possibilities are either that electrons tunnel to band states and relax to the final emissive exciton states (bound electron–hole states) via mobile polarons, or that they tunnel directly to the exciton levels (Fig. 2). These preliminary results are encouraging as control of polymer structure and micromorphology is likely to lead to improved device performance.

Progress since 1988 has been rapid and if the rate of progress is maintained practical polymer-based devices are likely to emerge. However, greater long-term

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RÉSUMÉ

Splice after splice

A GENE in the *Euglena gracilis* chloroplast contains an intron within an intron. This is the surprising conclusion of D. W. Copertino and R. B. Hallick (*EMBO J.* **10**, 434–442; 1991) who show that the internal intron is excised while the external intron is still in place. Splicing out of the larger intron then produces the mature form of the RNA. Evolutionary considerations suggest that intron addition to chloroplast genes in *Euglena* is not uncommon, but it is unclear why the 'twintron' is processed in two separate splicing reactions. An intriguing possibility is that we may be seeing a primitive form of alternative splicing, a mechanism by which eukaryotes can use a single gene to produce related but distinct proteins, often with significantly different properties.

Radical prospects

AN international clinical trial holds out the promise that recombinant interferon-γ may be a safe and effective treatment for the rare inherited disorder chronic granulomatous disease (J. Gallin *et al. New Engl. J. Med.* **324**, 509–516; 1991). The disease, which exists in more than one form, affects the production of oxygen free radicals by phagocytes, diminishing the cells' ability to kill ingested bacteria. Only 14 out of 63 patients receiving interferon-γ experienced a serious infection, compared with 30 out of 65 who were given a placebo. The total number of serious infections was also reduced, yet phagocyte function was unchanged and so the mechanism of interferon action is unclear. However, if interferon can act in an oxygen-independent way, it may help not only those suffering from chronic granulomatous disease but also in the treatment of infectious ailments such as leprosy and leishmaniasis.

Strong stuff

NEUTRON stars may preserve their magnetic fields for 10^{18} years — an eternity on the timescale of the age of the Universe — according to calculations by E. Harrison (*Mon. Not. R. astr.Soc.* **248**, 419–423; 1991). The powerful fields are swept through space as the neutron star rotates, and are the source of the radio and optical pulses we recognize as pulsars. Curiously, pulsars seem to turn off after about 5 million years, when their rotation has slowed to around a cycle per second. One possibility proposed was that because the neutron stars have a superfluid and superconducting interior, the magnetic flux lines could effectively float out of the pulsar, which would consequently fade from view. Harrison now shows that the electromagnetic forces set up by the migration of the flux lines would completely negate any 'buoyancy' they may have. Another mechanism must silence the pulsars.