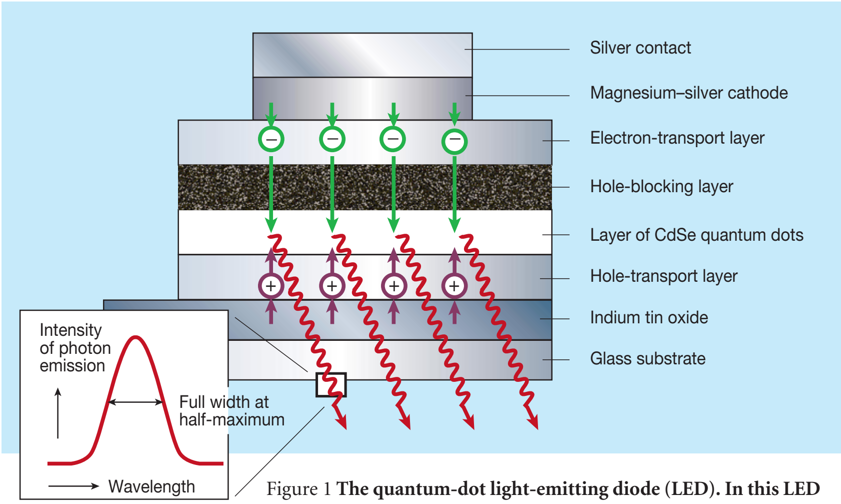


Figure 1 **The quantum-dot light-emitting diode (LED). In this LED made by Coe *et al.*[1], a layer of cadmium–selenium nanocrystals, or quantum dots, is sandwiched between layers of electron-transporting and hole-transporting organic materials. An applied electric field causes electrons and holes to move into the nanocrystal layer, where they are captured in the quantum dots and recombine, emitting photons. The spectrum of photon emission is narrow, characterized by its full width at half the maximum value.**

layered inorganic–organic perovskite compounds. But these LEDs have not achieved the emission efficiency or device durability needed for practical display applications[2,3].

Some inorganic nanocrystals emit visible light with sharp emission spectra that are less than 30 nm FWHM. The nanocrystals are in effect quantum dots and confine charge so well within their small volume that a high quantum efficiency, exceeding 50%, is possible. It might be expected, then, that quantum dots incorporated in organic LEDs would make excellent emission centres[4]. In fact, electroluminescence has been observed by simply mixing inorganic nanocrystals with π-conjugated polymers, but the emission efficiency was far lower than that of conventional polymer LEDs[5,6].

Coe *et al.*[1] have fabricated an organic LED with a single layer of CdSe quantum dots sandwiched between organic thin films (Fig. 1). Remarkably, the efficiency of their device is about 25 times higher than that achieved so far with quantum-dot LEDs. Thinking ahead to the design of device architectures, there are two noteworthy aspects here: the structure of this quantum-dot LED is already close to that for an optimum device and the process of fabricating a layer of quantum dots is simple.

For the structure of LEDs, one of the most challenging design aspects is how to bring electrons and holes together in small regions so that they recombine efficiently to emit photons without escaping or dissipating. The favoured structure is made of three layers: a thin emissive layer sandwiched between a hole-transport layer (HTL) and an electron-transport layer (ETL). If the emissive layer is thick, electrons and holes must be injected into it and transported; the emissive layer must then have the capabilities of both the ETL and the HTL, which is not ideal. If instead the emissive layer consists of a single layer of molecules, electrons and holes may be transferred directly from the surfaces of the ETL and the HTL, and high recombination efficiency is expected. At least two examples of organic LEDs with a molecular-size emissive layer have been reported: a molecular bilayer of cyanine dyes[7], and a rubrene dye layer[8], each sandwiched between an ETL and HTL of 50-nm thickness.

The design of Coe and colleagues' LEDs follows this lead (Fig. 1). The emissive layer in their quantum-dot LED is only a few nanometres thick, consisting of uniformly distributed single nanocrystals, each about 3 nm in diameter. The array of quantum dots was easily prepared by self-assembly in a process known as spin-casting: a solution of nanocrystals in an organic material is poured onto a substrate, which is then set spinning to spread the solution evenly. There is then a spontaneous phase segregation, as the nanocrystals pop up onto the top of the organic layer.

Coe *et al.*[1] propose that electrons and holes are captured directly at the surfaces of the CdSe nanocrystals — into discrete

Plant science

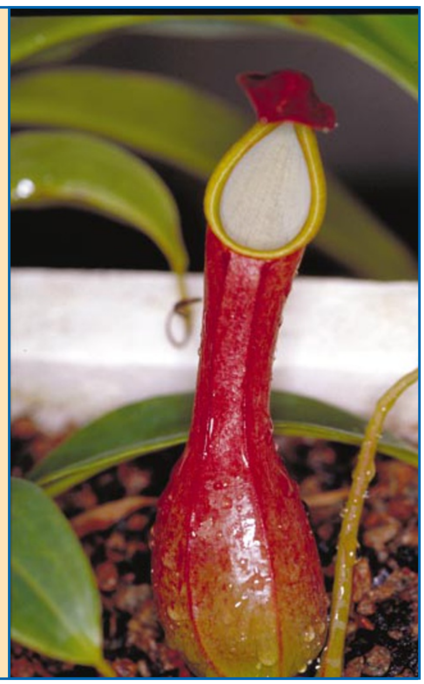
On the slide

The pitcher plant *Nepenthes alata*, which inhabits the forests of Indonesia, has one of the most dramatic organs of any carnivorous plant, as the picture here attests. In this month's *New Phytologist* (**156,** 479–489; 2002), Laurence Gaume and colleagues describe their investigations of the features that make this vessel so efficient at trapping insects.

Gaume *et al.* tested the ability of *N. alata* to capture ants and a flightless strain of fruitfly. Victims were placed on the pitcher's ridged rim. Few escaped, because any insects that stepped onto the waxy zone covering half of the pitcher's inner surface almost inevitably fell to their doom. Ants managed to hang on to the waxy zone slightly longer than flies, and rather than fall straight into the pool of digestive fluid at the bottom of the pitcher, some landed on the layer of glandular cells that coat the bottom half of the pitcher wall. But the cells secrete a viscous substance that prevented these ants, or the few that managed to clamber out of the digestive pool, from escaping their fate as insect stew.

Electron-microscopic investigation of the surfaces provided clues to their properties. In the case of the waxy layer, the covering is flaky and so breaks off easily — explaining why flies, which can normally cling tenaciously to a smooth surface, fell from it faster than ants. But that cannot be the whole story, as ants still had difficulty climbing surfaces from which wax had been removed with chloroform.

This study illuminates how the cunning adaptations of *N. alata*'s epidermal surfaces make the plant deadly to almost every insect that strays under its pitcher's lid. It might also inspire chemists to consider uses for materials with similarly exotic surface properties. **Christopher Surridge**



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