Everyone wants affordable flat screen TVs and computer monitors but which technology will they be based on?
One of the hottest markets driving physics research is the demand for a perfect visual display. People want, for example, large, thin, lightweight screens for high-definition TV and outside displays, very high-resolution flat computer monitors that are robust and use little power, and mobile phones with colourful micro-displays that are ‘bistable’ – which means they remain visible when switched off. Several types of flat display are competing for these applications – a market currently worth about $20 billion a year but expected to double in the next five years. Not surprisingly, the research departments of universities and the big electronics companies around the world are bustling with exciting ideas and developments, of which just a few are mentioned here. Many new devices are being developed by new university spin-out companies.

### Liquid crystal displays

Even the liquid crystal display (LCD) which has 85 per cent of the flat-screen market, is still a young technology and the subject of very active research. LCDs depend on arrays of cells (pixels) containing a thin layer of molecules which naturally line up (liquid crystals); their orientation can be altered by applying a voltage so as to control the amount of light passing through. Their main drawbacks have been poor viewing characteristics when seen from the side and in bright light, and a switching speed too slow for video. However, new materials and novel device concepts are continually emerging. For example, electrically sensitive materials called ferroelectric and antiferroelectric liquid crystals show potential. These work slightly differently and are bistable so should use less power. They can respond 100 to 1000 times faster than current displays, and should give brighter images from all angles.

ZBD Displays based at Malvern Science Park (from QinetiQ) offers a bistable device based on traditional liquid crystals which uses a type of holographic structure similar to that found on your credit card to store the image. One solution to the drawbacks of LCDs is to combine them with another technology. Indeed, the latest, high quality LCDs on the market incorporate a tiny electronic switch (a thin film transistor, TFT) in each pixel to drive the display. Sony and Sharp are also working on ‘plasma addressed’ LCDs in which the TFTs are replaced with an array of plasma channels (containing ionised gas) that switch the liquid crystal state. An interesting hybrid approach has been developed by Professor Bill Crossland and colleagues at Cambridge, and commercialised by ScreenTechnology Ltd. UV light is shone through an LCD panel (which controls the light) onto a pixelated phosphor screen which then emits red, green and blue light – as from a TV screen.

However, there are many other exciting developments in the LCD field, such as reflective colour displays for electronic games, high-resolution micro-displays used for projection onto a screen, and ferroelectric liquid crystals placed directly on a silicon integrated circuit.

### Plasma displays

Although LCDs up to a 42-inch diagonal have been demonstrated, for larger flat TV screens, companies have instead turned to plasma display panels. These employ gas discharges (as in a fluorescent tube) controlled by an electrical signal. The ionised gas, or plasma, emits ultraviolet light which stimulates red, green and blue phosphors inside each pixel making up the display panel to produce coloured light. The images on the latest displays are very clear and bright. Unfortunately they are still expensive (£5000-10,000). As

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with LCDs, researchers continue to refine their understanding of the basic physics and engineering of plasma displays leading to improvements in characteristics such as lifetime and image quality.

**Electroluminescent displays**

One of the most promising emerging display technologies exploits ultrathin films of organic compounds, either small molecules or polymers, which emit light (luminescence) when subjected to a voltage. These organic light-emitting diodes (OLEDs) produce bright, lightweight displays. A number of small independent firms in Europe and the US have been developing devices based on various luminescent molecules. For example, in the UK, Cambridge Display Technology (CDT), from Cambridge University, has successfully developed light-emitting polymers which can be built up into a device using simple ink-jet printing technology. These might be used to create huge flexible displays. In collaboration with Epson-Seiko (above), CDT recently demonstrated a mobile phone colour display with an acceptable lifetime. Another company, this time from Oxford University, called Opsys, has synthesised phosphors based on heavy metal-organic compounds which have the potential to produce very pure colour displays (front cover).

**Field emission displays**

The other major technology competing for the flat screen market is the field emission display. This works a bit like a cathode-ray tube, except that electrons are emitted from thousands of metal ‘micro-tips’, or even a diamond film, when an electric field is applied between the tips and a nearby phosphor-coated screen. Printable Field Emitters, based at the Rutherford Appleton Laboratory near Oxford, has come up with a novel idea employing low-cost composite materials deposited and patterned using screen printing and simple photolithography. This technology could produce affordable large displays in the 20 to 40-inch diagonal range suitable for TVs.

**Projection displays**

Finally, a completely different approach showing potential is to direct light from an image source using wave-guides through a glass or plastic sheet onto a screen. A clever variation of this is ‘the Wedge’ developed by Cambridge 3D Display. Light rays pass up a thin wedge-shaped glass plate and emerge at right angles at various points depending on the angle of entry. The beauty of this device is that it could be used to project any kind of micro-display – LCD or OLED, for example – onto a large screen.

All of the technologies described here still have drawbacks and no one yet knows which will win the big prize of flat screen TVs. It is likely that all of them will find niche markets. The next five years will certainly see a revolution in flat screen development.

**Electronic paper**

Imagine reading your newspaper on a plastic sheet, then feeding it through a device that erases the print and gives you a new page. Two American companies E Ink and Xerox are developing flexible, paper-thin displays embedded with tiny coloured beads that move or rotate in response to an electric field to create images. An electrically charged pencil (below) could even write on the reusable paper.

Nanomat, a spin-out company of University College Dublin, has gone one better in making chemicals that change colour when exposed to an electrical potential. Displays based on these electrochromic materials promise to give higher contrast.
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**FOR FURTHER INFORMATION CONTACT:**
Department of Higher Education and Research
The Institute of Physics
76 Portland Place
London W1B 1NT
UK
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More on liquid crystals can be obtained from:
http://sharp-world.com/sc/library/lcd_e/s1_1e.htm
Information on the companies and the technologies mentioned in the paper can be found as follows.
ZBD Displays: www.zbdisplays.com/technology.html
Screen Technology Ltd: www2.eng.cam.ac.uk/~tdw/stl.html
Cambridge Display Technology: www.cdtltd.co.uk/
Opsys: www.opsys.co.uk/
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