# Filthy CDs and the big picture

**David Baker** proposes an alternative use for your obsolete audio CDs

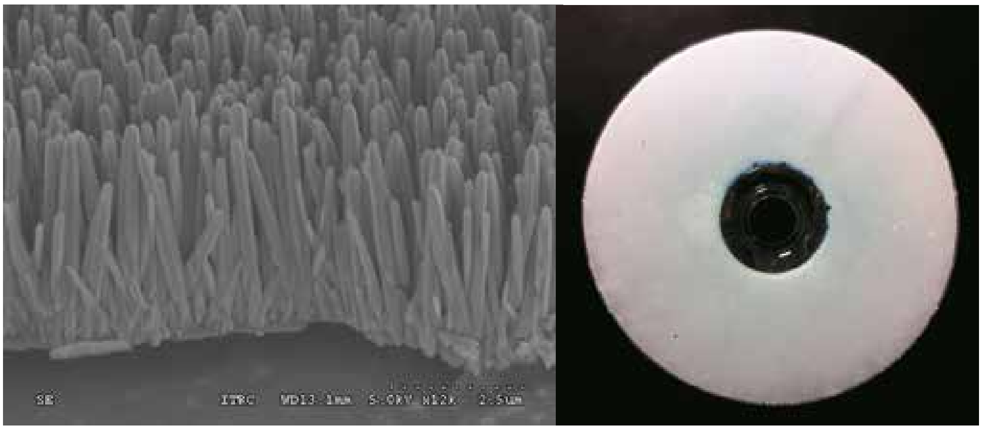



**Figure 1** The large surface area of a CD is an ideal platform to grow upright nanorods

Din Ping Tsai, National Taiwan University

Wait! Don't throw away those unwanted audio CDs just yet. They may be virtually redundant given the ubiquity of MP3 and other music files and their players, but new research points the way to a potential alternative use for those old discs, other than as bird-scarers or tea-coasters. Another recent piece of research describes a new type of lens that could provide high-resolution panoramic images of far better quality than any existing lens system. These innovative ideas were highlights of the Frontiers in Optics 2013 conference held in Orlando, Florida on October 6-10, and are described below.

Zinc oxide is an inexpensive semiconductor material that can act as a photocatalyst in the presence of ultraviolet light to break down organic molecules such as those present in sewage. While some research has already been done on the possibilities of using this process commercially, Din Ping Tsai, of the National Taiwan University, and his colleagues at the National Applied Research Laboratories and the Research Center for Applied Sciences, both also in Taiwan, are the first to realise the potential of growing nanorods of the material on a CD.

The large surface area of a CD is an ideal platform to grow these upright nanorods, about one thousandth of the width of a human hair (Figure 1). CDs are also designed to be durable and spun rapidly and, when used in this way, drops of contaminated water falling onto treated discs will spread out into a translucent film, speeding up the decontamination process when exposed to UV light. To date the research team has built a small test plant with a volume of approximately one cubic foot. Effectively it comprises a zinc oxide-coated optical disc, a UV light source and a re-circulation system to further break down the pollutants.

To gauge the efficacy of the unit, Tsai and his team performed a test run using a solution of methyl orange dye, a standard organic compound often used in the evaluation of photocatalytic reactions. The results showed that a half-litre solution of dye treated for an hour broke down over 95 per cent of 'contaminants', and that this prototype device could treat 150ml of waste water per minute. This sounds promising, but there are two potential problems: the use of methyl orange as a test substance substituting for sewage, and the question of scale.

Although methyl orange is commonly used for photocatalytic analysis, it is completely water-soluble unlike sewage, which contains lots of oily material, bacteria and solids in suspension, a combination that would possibly coat or clog the nanorods. Also, the loss of colour in methyl orange is generally taken to be the signal of its breakdown in these photocatalytic processes, but it may be that only the chromophore element is disrupted and not necessarily the organic part. As for scale, the prototype hints at a system that is compact, low-energy and efficient when compared with other photocatalytic waste treatment methods; but that is still only likely to be suitable for small projects of cleaning water contaminated with domestic sewage, urban run-off, industrial effluents and farm waste. However, Tsai has hopes for improving the efficiency of the new system and its speed, possibly by creating layers of stacked discs: so the day may arrive when disposing of your audio waste can help the environment.

## New horizons

Conventional wisdom in photography is that one can use a wide-angle lens to capture a panoramic view, at the cost of some detail; or, if high-resolution detail is required, it must be at the expense of field of view. Now a team led by engineering professor, Tom Ford, at the University of California, San Diego (UCSD), have utilised the properties of monocentric lenses to build a device that produces an image that maintains high resolution over a wide field.

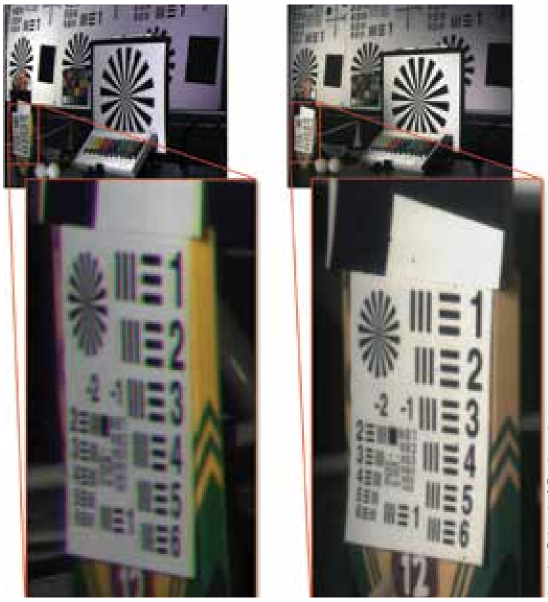
Monocentric lenses have surfaces that are all concentric about a common centre; the UCSD system uses two concentric spherical shells of glass of different refractive indices. The principal and nodal points, and the optical centre all coincide at this common centre. While such a lens yields zero astigmatism or coma across the image – aberrations that seriously affect wide-angle lenses – the problem is that the image is spherically curved, of radius equal to the focal length of the lens. The first monocentric lens design was described by Sutton in 1859, and an improved version, using a high-index flint glass outer shell and lower-index crown glass for the internal ball lens was suggested by Baker in 1942. Waidelich, in 1965, proposed a compact, high-resolution, two-glass monocentric endoscopic lens, but monocentric lenses in general remained little more than a theoretical curiosity because of the imaging problem.

It has proved difficult until now to find a way of using efficiently a hemispherical image. In modern terms the challenge has been to convert this optical output into an electrical signal that registers the information faithfully onto a planar camera sensor. Ford and his team appear to have found a potential solution by using a dense array of glass optical fibre bundles to convey the optical information to electronic sensors. The fibres are


Figure 2

polished to a concave curve at one end to align precisely with the lens surface. The researchers have demonstrated that potential problems in focusing the image are not an issue as changes in axial distance between fibres and lens do not distort the image. Using a design that features a 'virtual stop' to control stray light, achieved by limiting light transmission in the image transfer optics, as opposed to having a physical aperture stop at the centre of the lens, further maximises the field of view. For a physical aperture, at 60-degree incidence (120-degree field of view), the aperture is reduced in width by 50 per cent with a corresponding decrease in light transmission, and diffraction-limited resolution. The virtual aperture solution allows uniform illumination and resolution over a 160-degree field of view.

An account of the investigations that led to the design of a prototype lens of 12mm focal length giving a field of view of at least 120 degrees, connected to a five-megapixel image sensor by a single imaging fibre bundle (Figure 2) is given in a paper by Stamenov, Agurok and Ford, 'Optimization of two-glass monocentric lenses for compact panoramic imagers: general aberration analysis and specific designs' (*Applied Optics*, Vol 51, No 31, pp7648-61, November 1, 2012).



Jacobs School of Engineering

Figure 3

The potential of this system is easily envisaged. The advantage of its compact nature, both in size and weight, compared with a traditional wide-angle imaging system is plain (Figure 2). But the superior resolution of the monocentric system is just as remarkable (Figure 3). There could be many applications for this technology, not least in smartphone cameras and unmanned aerial surveillance vehicles. The project is also part of the 'SCENICC' (Soldier Centric Imaging via Computational Cameras) programme funded by the Defense Advanced Research Projects Agency, which hints at likely further military applications. Ford and his UCSD team are now assembling a 30-megapixel prototype to be followed, next year by, says Ford, 'an 85-megapixel imager with a 120 degree field of view, more than a dozen sensors, and an F/2 lens – all in a volume roughly the size of a walnut'.

**David Baker** is an independent optometrist