

As quick as a flash

Paul Calvert

To get the most out of the large capacity of optical fibre communication networks, one wants to be able to switch the signal on and off as fast as possible to transmit the maximum number of noughts and ones. Liquid crystals take several milliseconds to switch, and so are too slow. Lithium niobate is now used and can switch in fractions of a nanosecond. But to get to the desirable switching times of a picosecond or less, one has to rely on the rapid movement of electrons in molecules. Conjugated aromatic molecules offer the most promise for large changes of refractive index, induced by a redistribution of electrons in an electrical or optical field. However, nothing wholly suitable has yet been found. Nothing daunted, C. S. Winter *et al.*, from the British Telecom Research Laboratories, now suggest¹ that nickel dithiolenes shows great promise.

As described in a previous News and Views², one possible optical switch is a Mach-Zehnder interferometer in which a light signal is split into two: one side travels through an optically active material whose refractive index is modified by an electric field. The increased index slows the light in this arm until it out of phase with the signal in the other arm when they recombine. With the field on, the two arms subtract to give zero; with the field off they add.

Stegeman *et al.*³ have proposed figures of merit for nonlinear optical materials to balance the efficiency of refractive index change against the loss of signal due to scattering or absorption. Unfortunately the best available material on this basis is silica which has a low nonlinear coefficient but extremely low optical absorption and scattering. A device made from silica would have to be enormously long to get the half-wavelength retardation needed to switch the signal off.

Materials can be made with very large nonlinear coefficients (χ_3) if they have an absorption peak at the wavelength of the test laser, but the figure of merit is low because of the high absorption. A better approach might be to move the peak absorption wavelength away from the laser wavelength (usually Nd-YAG light at 1.064 μm) until scattering of the light by nonuniformities in the film becomes the dominant loss mechanism. Winter *et al.*¹ suggest a compromise of putting the absorption peak at slightly shorter wavelengths than the laser and have tested two nickel dithiolate compounds absorbing at around 750 nm. The combination of a big nonlinearity and low absorption gives a figure of merit, W , of about 5. This figure, W , is the maximum refractive index change, at light intensities high enough to start damaging the material, divided by the absorption coefficient and the wavelength. It should be at least 3 and ideally more than 12 for good switching.

The materials most studied to date are the polydiacetylenes. Measurements on the *p*-toluenesulphonate substituted diacetylene produced a W of 0.15, away from the absorption³. Polydiacetylene films can be prepared by direct polymerization of a film of monomer but this results in high levels of scattering. Changing to a soluble polydiacetylene allows the film to be spin-coated onto a surface from solution, with much more uniform films and less scattering. Poly-4BCM (another diacetylene derivative) can be put down in this way with a W that has been quoted⁴ as 1.5. Unfortunately there is a catch. As the scattering is reduced two-photon absorption becomes a problem. This arises because the very high laser intensities allow absorption corresponding to twice the photon energy of the laser (532 nm wavelength). As this is in an absorption band of the red polydiacetylene, two-photon absorption is quite strong. Original estimates suggested that W could reach as high as 100, but this now looks unlikely.

The nickel dithiolates studied by Winter *et al.*¹ show low absorption at 532 nm and two-photon absorption does not seem to be significant. A further improvement in their efficiency might come from tuning the structure to shift the absorption peak up or down to optimize the balance of absorption and non-linearity. It will also be necessary to build them into a polymer structure so that good clear films can be readily cast from solution. Scattering is prohibitively high for the films of crystals that can be made now. This also means that solution measurements on dithiolates are not really a fair comparison with actual waveguides made of diacetylenes because real waveguides are likely to have much more scattering, especially with early experimental samples.

Given all this it is not obvious that a W of 5 from a solution is going to be better than the diacetylene value of 1.5 measured on a real film. It is also likely that other undesirable effects, including degradation, will manifest themselves as we get closer to actual devices. It is clear that we are currently tuning molecular structures to optimize a fairly simple combination of spectral properties and we ought to have more predictive ability than we seem to have. What have the theoretical chemists been doing all these years? □

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3. Stegeman, G. I., Zanoni, R. & Seaton, C. T. *Mat. Res. Soc. Symp.* **109**, 53–64 (1988).
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Food on the hop

Now that biodegradable plastics are at last becoming available, Daedalus is widening the search. He is trying to produce a good biodegradable rubber. DREADCO's chemists point out that like rubber, many proteins exist in a folded-chain configuration, and some are highly elastic — like water-plasticized gelatin (table jelly) and elastin (the energy-storing component of the leg tendons of jumping animals like fleas and Kangaroos). The shape taken up by a given protein molecule is hard to predict, so rational design and synthesis of an elastic protein would be forbiddingly difficult. Instead, the DREADCO team are partially hydrolysing elastin, gelatin and other promising natural proteins, and recombining the fragments into novel 'artificial' (rather than fully synthetic) materials. Already they have produced a protein rubber so biodegradable that it is actually edible.

It seems a pity to waste such an unusual product on tyres, insulation and erasers, so DREADCO's marketers plan to launch it as a foodstuff. They are reluctant to label it as a mere imitation meat. 'Substitute' or 'ersatz' products seldom acquire much dignity or sales; besides, the broiler industry already has a commanding lead in the production of rubber chicken. So the hunt is on for some uniquely valuable application for elastic food. Suggestions made to date include: pre-stressed 'novelty nibbles' that snap and ricochet beguilingly around inside the mouth when bitten; an all-edible elastic-powered clockwork mouse to give domestic cats the thrill of the chase without its cruelty; edible balloons for children's parties and edible rainwear for fetishists; boil-in-the-bag products that let you eat the bag as well; and (inspired by the pop-up toaster) a pre-stressed steak and a jumping sausage with meltable internal restraints, which leap dramatically out of the frying pan when they have reached the desired cooking temperature. But the main customers for specialized, outlandish, expensive foods are, of course, slimmers.

A number of slimming foods are designed to absorb water in the stomach, thus swelling up and giving the impression of fullness. Daedalus is devising an edible foam rubber which looks a bit like brown rice, but with grains that swell immensely once they have been swallowed. The slowly digestible foam core of each piece is compressed within a rapidly digested protein-rubber coating. In the stomach, the coating digests and ruptures, the foam expands wildly, and the consumer feels misleadingly full. Until the expanded pieces have been digested, they cannot even proceed into the narrow entrance to the small intestine. As long as they fill and block his stomach, the consumer continues to feel completely bloated. It may be hours before he can face another helping. David Jones