Creating a colourful life

Pigments of the future

Selected for the Royal Society's SUMMER SCIENCE EXHIBITION 07

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Background

Brightly coloured pigments are widely used in printing, colouring plastics, art and paints. In fact if you look around you they are everywhere! Pigments are also employed, less obviously but equally as importantly, in other applications where the optical properties are more specialised. Examples include security marking of documents such as banknotes and in smart, reactive coatings for plastics and glass. We, as colour scientists, are constantly searching for new improved pigments – these might be brighter stronger colours, they may be more environmentally friendly (as many traditional pigments can be toxic) or they may show special effects such as lustre or colour changing abilities.

Pigments of the future

(i) Smart and colour changing pigments

Thermochromic compounds, which change colour when heated, are well known and some recent household applications have included irons and kettles that indicate when they are hot. Other materials can change colour when exposed to sunlight or ultra-violet (UV) light, these are known as photochromic materials. One potential use of such compounds is in security marking – on, for example, banknotes or passports. At present, many pigment materials that fluoresce under UV light are used in such applications but these are becoming more widely copied by counterfeiters. Thus the search for new, smarter, colour-changing pigments continues.

Figure 1: *The mineral hackmanite from Greenland – before and after exposure to ultra-violet light*

We are currently developing several new specialist materials with these properties. One material is the analogue of a natural mineral found in Greenland (figure 1). When exposed to UV light this material changes from colourless to purple/blue in a few seconds and then fades slowly back to white.

We have been studying this phenomenon in the laboratory in order to understand its origin and then replicate it in synthetic materials. The colour change occurs when the UV light excites an electron from one species in the material and the electron then gets trapped elsewhere in the structure (figure 2). This electron can then absorb visible light producing a brightly coloured material before eventually returning to its original site, whereby the material reverts to colourless. By tuning the composition and structure of the materials we have been able to make materials which become pink or blue when exposed to UV light. These materials are also extremely stable and can be coloured and then bleached many thousands of times. As well as applications in security marking, such materials could be used in sunscreens, blinds and smart windows/lenses to reduce the transmitted sunlight, as well as fun applications, such as jewellery and nail varnish.

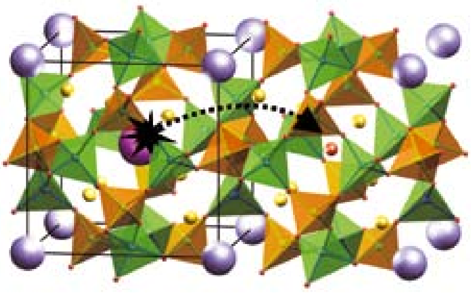

Figure 2: *Schematic showing the key structural elements of hackmanite that allow it to change colour – an electron (represented by an orange-brown sphere) is transferred from the ion (magenta) on the cage on the left and becomes temporarily trapped*

(ii) Environmentally friendly red and yellow pigments

Ceramics, plastics and glasses are coloured using inorganic pigments which can withstand the high processing temperatures that would destroy their organic counterparts. Traditionally such inorganic pigments use heavy metals to produce vibrant colours such as red (cadmium selenide), yellow (lead chromate), purple and green. Such heavy metal pigments are damaging to the environment as they can be toxic to prepare, use and destroy.

Further information

Our websites

www.materialschemistry.co.uk

www.lboro.ac.uk/departments/cm/staff/dann.html

Resources about and introduction to pigments

www.creatingacolourfullife.com

Effect pigments

www.merckserono.net/servlet/PB/menu/1052180/home.html

Figure 3: *Top: Some brightly coloured pigments recently synthesised in our laboratories. Bottom: 'Lapis Sunlight' a recently discovered colour-travel pigment*

Recently, we have been instrumental in producing some new pigments that have the bright colours and the temperature stability of the traditional inorganic pigments, but are inherently non-toxic. These materials are based on a simple niobium stannate system with small amounts of sulfur incorporated to tune the colour. The pure oxide is vibrant yellow, but by increasing the sulfur content of the mixture the colour can be tuned through orange to red (figure 3). One interesting point about the pure oxide is that it is also thermochromic. Although yellow at low temperature, above 50°C it changes rapidly to bright red. Thermochromic pigments have many safety applications and are used in autoclaves, babies bottles and refrigerators.

(iii) Lustre pigments.

Iridescent and pearlescent pigments are widely used in the cosmetic industry and automotive paints. Most notable recent advances have been in "colour-travel" pigments which change colour depending on the viewing angle (figure 3). We are researching new pigments of this type by employing new coatings on mica such a metal phosphates and oxide-nitrides.

(iv) Pigments for reducing overheating

Almost half the sunlight reaching the Earth's surface is in the infra-red (IR) region, that is we cannot see it but we feel it as heat, and it contributes significantly towards the warming of the Earth's atmosphere, figure 4. The effect is most apparent in buildings and greenhouses where the IR radiation contributes to high temperatures but is of little use in, for example, photosynthesis.

Developing materials that absorb or reflect this infra-red portion of sunlight is thus a major goal as these pigments can be used in coatings and plastics to reduce the level of heating inside buildings. We are developing such materials – especially those which are colourless and do not absorb in the visible part of the spectrum. Research focuses on modifying materials which normally strongly absorb visible light and are thus intensely coloured. By altering their structures and compositions it is possible to change them so they absorb only in the near infra-red – ie just beyond visible red light (figure 4). These materials are colourless allowing visible wavelengths to pass while absorbing the unwanted heat radiation. Additional applications of such materials include their incorporation into plastics for laser marking; an infra-red laser may be used to write into such transparent plastics containing the pigment as absorption of laser radiation causes the plastic to char where the laser beam is directed.

In the future we intend to develop pigments that are strongly infra-red reflecting – that is they would reflect the unwanted part of the solar spectrum back into space. Such materials may have a part to play in combatting global warming.

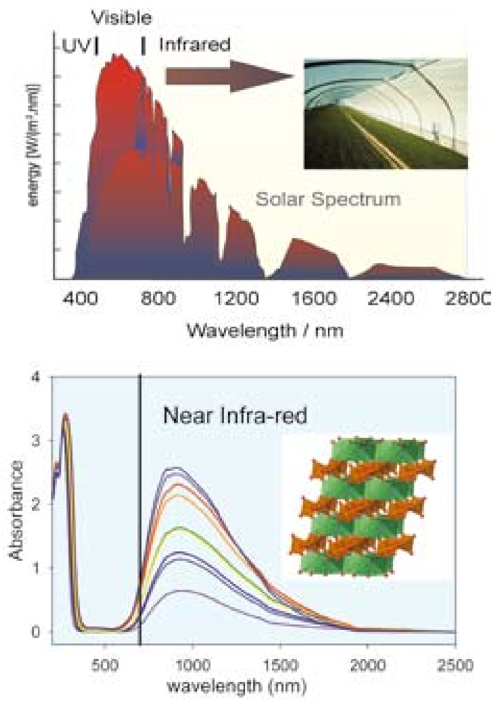

Figure 4: *Top: the solar spectrum showing the large component in the IR region; inset a poly-tunnel greenhouse which frequently overheats due to such radiation. Bottom: the near-IR absorbing properties of some new pigments showing practically no absorption in the visible region; inset the structure of new IR absorbing pigment*