The Institute of Materials, Minerals & Mining

Schools Affiliate Scheme

Issue 32
Summer Term 2009

NEWS

A busy end to a busy year

As this is the last newsletter for this academic year I thought it would be a good time to reflect on our activities over the last twelve months and look at how we can help you in the upcoming academic year.

We have all been very busy since September and the changes within the Team since January have meant that we have had to adjust to new roles and new locations. We are also on the hunt for new staff to deliver talks in schools. You can find out more about these part-time roles on page 6.

In November last year the Autumn Open Day programme was as successful as ever and once again this autumn the materials departments will be opening their doors to support your teaching. You can get a reminder of the dates for the 2009 season of events on page 3.

Following on from Smart Materials, Smart Move in Grantham last May we ran another conference on smart materials in Exeter in March and this too was a great success. You can read about the next event at the University of Manchester on 07 October on page 2.

The pull-out article on the centre pages of this issue looks at a relatively new material called QTC (Quantum Tunnelling Composite). David Lussey, the inventor of this material, spoke at the conference in March and he was the most enthusiastic speaker I have seen for some time. This article reviews his presentation and considers everything you need to know about this unusual stuff!

I thought in this issue it might be worth reminding you of how you can make the best use of your membership of the Scheme, so there is a list of benefits on page 5, along with the visit booking diary and list of available dates on page 4.

Towards the back of this issue you can find the final part of the exam question master class on alloys and a summary of some of the other resources that I have come across in the past few months.

Finally, I must apologise for the delay in the production of this issue, I hope it was worth waiting for. As usual if you have any comments or suggestions please get in touch. Have a great summer and we look forward to working with you next term!

This newsletter is written and edited by Dr Diane Aston, Education Co-ordinator.
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EVENTS FOR TEACHERS

Flying High with Materials in Manchester

Wednesday, 07 October 2009

The first of hopefully a number of events that we are planning to run in the 2009 – 2010 academic year will be held at the University of Manchester on 07 October 2009. Flying High With Materials will be your one-stop shop for finding out everything you ever wanted to know about how and why materials work! It will cover the fundamentals of materials, such as how structure is related to properties and how structure can be controlled through processing, with an overall theme of aerospace.

The day will start with technical presentations on metals, polymers, ceramics and composites. These will be presented by experts in their fields from industry and academia in a way which will help to put often quite challenging concepts in to a more real-life context. After lunch you will have the chance to ask any other questions you have that may not have been answered already, during a general discussion session. Before tea Toby White, our resident Minerals and Mining expert will give delegates a whistle-stop tour round the occurrence and extraction of nickel and titanium and their use as the shape memory alloy Nitinol. The final session of the day has been designed to give you something to take back to the classroom. Prof Philip Withers and his team at Manchester have developed a teaching resource called 'So you think you can design a jet engine' which takes a 3D tour through a jet engine and uses this application as a context for looking at the importance of materials selection.

A provisional timetable is shown below, and you should have received full details and a registration form in June.

0900 to 0915	Arrival and registration	
0915 to 0930	Welcome and introduction	Diane Aston
0930 to1015	Metals	Dr Robbie Hobbs
1015 to 1100	Polymers	Dr Alicia Chrysostomou
1100 to 1115	Coffee	
1115 to 1200	Ceramics	Andy Duncan
1200 to 1245	Composites	*tbc*
1245 to 1330	Lunch	
1330 to 1415	Open Q&A session	All speakers
1415 to 1445	Rocks to Rockets	Toby White
1445 to 1500	Tea	
1500 to 1645	So you think you can design a jet engine project	Prof Phil Withers
1645 to 1700	Feedback and close	Diane Aston

For more information contact Dr Diane Aston by emailing diane.aston@iom3.org.

AUTUMN OPEN DAY PROGRAMME 2009

This year we are organising the 8th series of Autumn Open Days on behalf of the UK's Materials Departments. The Open Days are intended to support the teaching of the materials topics in physics, chemistry and design & technology A-level courses. These days are designed as an extension to your classroom teaching and will allow you access to facilities and equipment that you haven't got in school. Typically activities will include mechanical testing (tensile and impact testing), optical and electron microscopy, talks on materials and activities on smart materials. Some of the events are based around a whodunit theme where students have to investigate a crime using materials analysis techniques.

These events are free of charge for you and your students to attend, you just need to make your own transport arrangements and generally take place on Wednesday afternoons.

This year we are pleased to welcome Exeter on board and hope that this will make the events more accessible to schools in the South West. After a couple of years of building work and reorganisation, Liverpool are on board again this year too.

The following universities will be opening their doors this year and spaces are allocated to schools on a first come, first served basis so you would be advised to book as quickly as possible.

Venue	**Date(s)**	**Time(s)**
University of Birmingham	04, 11, 18, 25 Nov	1300 to 1530
University of Cambridge	15, 16 or 17 Dec	Am or pm
University of Exeter	04, 11, 18 Nov	1300 to 1700
Imperial College	04, 11, 18, 25 Nov	1230 to 1600
University of Leeds	04, 11, 18, 25 Nov	1230 to 1600
University of Liverpool	04, 25 Nov	1200 to 1530
London Metropolitan University	04, 11, 18, 25 Nov	Am or pm
University of Loughborough	03, 05 Nov	1300 to 1530
University of Manchester	04, 11, 18, 25 Nov	1400 to 1600
University of Newcastle	04, 11, 18, 25 Nov	1330 to 1530
University of Oxford	10 Nov	1000 to 1500
Queen Mary, University of London	28 Oct, 06 Nov	1330 to 1600
University of Sheffield	Tbc	
University of Swansea	03, 17 Nov	1300 to 1600

A full programme has been posted out with the conference information but if you would like to know more or find out the most up to date list of available dates contact Dr Diane Aston (diane.aston@iom3.org).

THE SAS PAGES

Visit diary

Toby and I have been very busy so far this term, trying to fit in as many visits as possible. This is where we have been and where we will be going before the summer break!

April		12	Hereford Cathedral School	19	Sellafield Schools Day
20	Royal Grammar School	13	King James I College	22	London Met Uni PST
20	QEGS, Penrith	18	Chiltern Edge School	23	Chosen Hill School
21	Spennymoor School	22	Grangefield School	24	St Olave's School
22	La Sainte Union School	26	University of Wales	25	STEM event NSLC
23	Heolddu School	27	Bath Spa University	29	John Leggott College
27	Highfields School	***June***		29	Billericay School
27	King Edward VII School	03	Hereford Cathedral School	30	ISS Basildon
28	Brownedge St Mary's RC High School	04	IOP Rugby Meeting & NSLC Science Careers Fair	***July***	
29	Lutterworth College	09	Dumpton School	02	Caldicot School
May		10	Salters Chemstry Camp, St Andrews	03	ASE National Sci Tech Conf
01	Braunton School	11	St Leonards School	05	RSC Summer Camp
05	Plymouth High School for Girls	11	STEM Event SLC W Mids	06	Stockton Sixth Form College
06	Radley College	14	Napier Uni PST	07	STEM Event SLC S West
07	Reading Blue Coat School	15	Pembroke School	13	Manchester PST
11	King James School	16	Graham School	14	Cardinal Newman School
11	QEGS, Penrith	18	Sellafield Teachers course	15	Sundorne School

Visit by Diane Aston, or Toby White.

We are expecting a great demand for both materials and geology talks in the new academic year and until we recruit additional staff to help support visits I am afraid that we are going to have to limit each member to just one visit per membership period. I know this may cause some inconvenience for some schools, however, it is only fair that all members have equal access to us.

I know that many of you are already planning your autumn term diary so here are the dates that I have available:
September: 08, 09, 10, 16, 17, 23, 28, 29, 30
October: 08, 09, 16, 21, 23, 26, 27, 30
November: 02, 03, 11, 12, 13, 17, 18, 19, 23, 24, 25
December: 02, 03, 04, 08, 09, 10, 14, 15, 16
Toby only works for the Institute two days a week and I know he is very busy with other commitments during the autumn. These are the dates that he *cannot* offer:
September: 02, 07-11, 14-18, 22, 23, 28-30
October: 05, 07, 12-15, 19-23
November: 12, 18
December: 08

In February our new Education Administrator joined the team. Sarah Harrison is now looking after the visit diary so if you would like to book a visit, find out more about the sessions we can offer or get the most up to date list of available dates you should contact her by emailing sarah.harrison@iom3.org or 01476 513886. As much as possible we will be sending out booking forms by email from now on to save on paper and postage. Please let us have your email address at the time of booking.

Making the most of your SAS membership

Although our visits to schools are the most popular aspect of Scheme membership as they allow direct contact with teachers and students, don't forget about the other benefits you receive as a member of the Scheme. We are always looking for ways that we can improve our service to you and if you have any suggestions for topics or formats for resources, new titles for presentations, ideas for newsletter articles, themes for conferences or anything else that you think would be helpful please get in touch (diane.aston@iom3.org) and we will do our best to take these on board. We are now sending a questionnaire out with your renewal notice so that you can tell us your views. Please do take a few minutes to complete and return this as we really do read them and try and address the issues that are raised!

Here is a quick reminder of the benefits of membership, just in case you have forgotten!

- Resource. Hopefully you have found the resource for schools joining or renewing their membership in the 2008-2009 academic year useful. We were very proud of the 'Nitinol Bone Plate' book and hope that it has boosted your knowledge and that you have been able to incorporate aspects of it into you teaching. The new resource for schools joining or renewing their membership in the 2009-2010 academic year is another book in the same style on bridges. This looks at the history of bridges, why particular designs suit particular locations, in-depth chapters on the materials used (cement and concrete, iron and steel, bricks and future materials) and individual case studies on special bridges such as the Humber Bridge (opened in 1981 and the longest single span suspension bridge in the world for 16 years), Millau Viaduct (a truly breathtaking structure which speeded up the journey between Paris and the Mediterranean coast) and the Maidenhead Railway Bridge over the River Thames (constructed by Brunel in 1838 and for a long time the flattest and widest brick arch bridge in the world). We are also starting to think about the resource for 2010-2011 and at the moment are considering something based around materials used in sports equipment to tie in with the London Olympics in 2012. If you have any suggestions as to what you might like to see included in this please get in touch.
- Materials World. This is the journal which is sent out to the whole of the Institute's membership. Although it is not designed specifically for schools we hope that you find it useful for bringing your knowledge up to date and showing your students examples of real materials research. If you really do not find it worth reading let me know and I will ask for you to be removed from the mailing list.
- Scheme specific newsletter. I hope that you have found the new newsletter format an improvement. Each issue we try to make you aware of as many good courses and resources as we can, in addition to providing some technical information. If you have any suggestions for articles or features please let me know.
- Access to your nearest local society. The Institute has around sixty local societies dotted around the UK and as members of the Scheme you have an open invitation to attend their monthly meetings. You can see a programme of events for your region by visiting www.iom3.org/content/local-societies and these talks are an excellent way for you to make contact with experts working in your area. Many of the local societies also have an interest in supporting school education and if you want to find out if your nearest society can help out with a particular project or equipment or an event you can find their contact details on the website too.
- Access to our Materials Information Service. This is a helpline that will allow all you materials, minerals and mining related questions to be answered! If you want to know

what something is made from or how it is made or want to know where to source a material, MIS may be able to help. You can contact the team by emailing mis@iom3.org, and please let them know that you are a member of the Schools Affiliate Scheme. They are also happy to answer queries from students, but do ask if the entire class is doing the same project that they only send in one co-ordinated enquiry rather than 30 identical requests! The questions need to be specific too, it is no good asking about steels for example as this is a huge field. The enquiry would need to focus on one particular aspect such as stainless steels in medical use or steels used for car body panels.

- Visits. These are very popular and book up quickly. We try to update the content of our presentations in line with requests from schools and over the summer I am hoping to put together a new presentation which should be available from the start of the new term. This talk will be on smart and modern textiles as this is an area that we regularly get asked about. For more information please get in touch.
- First notice of conferences and events for teachers. As you will have already read, we hope to put on more events for teachers over the coming year. These are free for all teachers from member schools to attend, so please do share the information about these with colleagues from other departments!

Are you just what we are looking for?

Owing to the expansion of our education activities the Institute is seeking to recruit enthusiastic communicators to deliver materials-related curriculum content in secondary schools around the UK and support the function of the existing education team.

The successful candidates will have an in-depth knowledge of materials and the ability to convey this in an exciting and relevant way to young people. Although experience of working in the schools sector would be useful, it is not essential as full training will be given.

These are part-time roles and will involve considerable travelling on a regional basis to work with members of our very successful Schools Affiliate Scheme.

For further details and job descriptions contact Dallas Dinsmore, Personnel, Institute of Materials, Minerals & Mining, 1 Carlton House Terrace, London SW1Y 5DB, telephone 020 7551 7364 or email Dallas.Dinsmore@iom3.org.

A match MADE in Heaven!

A couple of years ago the Materials and Design Exchange (MADE) was launched with the aim of bringing together materials scientists, engineers and technologist with the design community. This partnership has proved to be very successful and a large number of MADE events have now taken place. MADE is part of the Materials Knowledge Transfer Network (KTN) funded by Government through the Technology Strategy Board, forging a link between designers and other sectors of the KTN concerned with metals, plastics, textiles and the full range of modern materials. The core partners of MADE are the Institute of Materials, Minerals and Mining, the Royal College of Art (RCA), the Design Council, the Institution of Engineering Designers (IED) and the Engineering Employers Federation (EEF South). It is free to sign up to the MADE network and you can find out how to do this by visiting www.iom3.org/content.made. Over the years a number of useful publications have been produced by MADE and enclosed with this newsletter you should find a rather beautiful booklet on Natural materials. I thought the technology teachers amongst you might find this particularly useful!

QUANTUM TUNNELLING COMPOSITE
Kitchen science at its best!

At our Smart Materials, Smart Move conference in March we were lucky enough to meet David Lussey, the man who developed QTC and set up Peratech Ltd to investigate its properties. The whole audience was gripped by David's presentation and I have to say it is some time since I saw such an enthusiastic presenter.

For the benefit of those who could not make it to Exeter, this article looks and the what, how, why and where of this remarkable material.

What is Quantum Tunnelling Composite?

Put simply, Quantum Tunnelling Composite (QTC) is a type of polymer matrix composite. It is made by mixing finely divided nickel powder with an elastomeric binder, typically a silicone rubber. This in itself is nothing particularly special, but QTC is unusual in that its electrical resistance varies with applied pressure. In its unstressed state the material is a near perfect electrical insulator, however once pressure is applied the material begins to conduct and if sufficient pressure is applied metallic levels of conductivity can be achieved.

How was Quantum Tunnelling Composite discovered?

Like many great scientific discoveries, QTC was a bit of an accident! David Lussey was trying to create a type of conducting adhesive for a security system by mixing nickel powder with silicone bathroom sealant in his kitchen. He glued two metal plates together with this particular mix and connected them in a circuit. Nothing happened; the material was a really good

What is a composite?

A **Composite material** can be defined as an engineered material made from two or more constituents with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure. Composites can either be described by the type of matrix material, which is often the continuous phase, or the second phase material which is often the discontinuous phase. For example a glass fibre-epoxy composite could be described as a polymer matrix composite (as the epoxy resin forms a continuous phase within the material) or a glass fibre reinforced composite (as the glass fibres make up the second phase). By changing the type, size, shape and amount of the second phase used, the properties of the composite can be tailored to meet the needs of a particular application.

Polymer matrix composites (PMC)

These include glass, carbon and Kevlar fibre reinforced materials where the matrix material may be a thermosetting polymer resin or a thermoplastic such as polypropylene. These materials have been in use for many years and they can have a huge range of properties. One of the key factors influencing their properties is the way in which the fibres are arranged. Traditional 'fibreglass' uses short, chopped fibres, whereas more modern materials use woven glass or carbon cloth. The properties can be fine tuned by changing the way the fibres are woven together.
Carbon fibre composites are now extensively used in a wide range of applications, including aircraft body panels, F1 car body shells, sports equipment (bicycle frames, golf club shafts, fishing rods, oars etc.), prosthetic limbs and armour.

Metal matrix composites (MMC)

In these materials the metal matrix may be mixed with another metal, a polymer or a ceramic in the form of particles or fibres. Magnesium is often used as the matrix material for MMCs used in space applications. By creating a MMC physical properties such as density, wear resistance, coefficient of friction, or conductivity can be controlled. MMC are used in a range of automotive applications, particularly for cars used in competition. They are also used in hard wearing tools (such as cobalt reinforced with tungsten carbide particles), tank armour and fighter aircraft landing gear.

Ceramic matrix composites (CMC)

Concrete is the most commonly used composite, in fact it is the most widely used man-made material in the world. In this case the ceramic matrix is reinforced with ceramic particles in the form of sand and aggregates. Other CMCs are made by mixing metal particles with the ceramic powder to produce improved electrical conductivity. Bone is a natural CMC in which hydroxyapatite (a calcium phosphate based mineral) is reinforced with collagen (a natural polymer) fibres.

insulator. However, he noticed that when he flexed the plates a current could flow. After some time experimenting he realised he had found something which was very special and took his discovery along to Durham University where more research could be carried out to explore the properties of the material further.

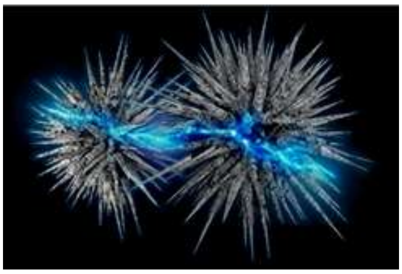
Since its discovery in 1995 the properties of QTC and the mechanisms behind them have been investigated and it is now used in a wide range of applications.

Why is Quantum Tunnelling Composite better than conventional conducting composites?

Conducting polymer matrix composites have been around for some time, but using carbon powder as the conducting filler materials. These materials will always conduct to a small extent as the smooth, spherical carbon particles are always touching and there is always a continuous conduction path. Their resistance drops as pressure is applied as more particles can touch each other creating a greater number of conduction pathways. In its unstressed state a carbon composite may have a resistance of a few thousand ohms, reducing to a few hundred when pressure is applied. QTC has a resistance greater than $10^{12}\Omega$ in its unstressed state, reducing to less than 1Ω when pressure is applied. So it can be seen that the difference in conductivity is much more extreme in QTC and a factor of ten change in resistance in QTC can be achieved with considerable less deformation, making it far more pressure sensitive than conventional carbon composites.

How does Quantum Tunnelling Composite work?

In a conventional conducting composite the spherical carbon particles are always touching to a greater or lesser extent. As pressure is applied more particles come into contact increasing the number of conduction paths and decreasing the electrical resistance of the material.



In QTC the particles do not actually need to touch each other; conduction occurs via quantum tunnelling (see box on quantum tunnelling). The nickel particles are not smooth spheres, rather they are a complex irregular shape with spikes all over. The particles are surrounded or wetted by an insulating layer of silicone rubber which prevents them from touching even when pressure is applied. The spikes on the particles allow a higher concentration of electrons to build up at their tips and this decreases the width of the potential barrier in quantum tunnelling. This reduces the distance and energy needed for the electron charge to tunnel through and allow a current to flow. Increasing the pressure on the material pushes the particles even closer (without touching) allowing a greater number of conduction paths (it decreases the effective potential barrier and increases exponentially the probability of tunnelling) and this regime therefore permits a sliding scale of resistance with applied pressure (see schematic diagram below).

The applied voltage also has an influence on the properties of QTC. At low applied voltages the electrons only have a small amount of energy and cannot tunnel across sizeable gaps between particles in significant numbers. Thus in the unstressed state the material is a near perfect insulator. Applying pressure decreases resistance by reducing the gap between the particles and increasing the probability of tunnelling.

If the applied voltage is greater the electrons carry more energy and when a higher enough voltage is applied the probability of tunnelling increases significantly, allowing conduction in the unstressed state. If the voltage is sufficient QTC will switch to a conductive state which can be maintained when the applied voltage is removed.

For most sensing and switching operations QTC is operated outside this switching regime, usually at voltages less than 40V.

Where is Quantum Tunnelling Composite used?

QTC is an inert material that is durable and not affected by humidity. It is currently available in a number of forms – pills, granules and inks for coatings, and is easy to process. It can be integrated with conventional 'hard' electronics relatively easily and used to replace mechanical components which are less robust. The resistance of QTC changes when pressure is applied In addition to simple compression the change in resistance may be achieved by pulling, twisting, or bending.

QTC can be used as a switch or sensor and has found a large number of applications in a wide variety of sectors. Peratech have worked with companies from NASA to Marks and Spencer and many products containing the material are now commercially available.

QTC in Toys and Games

QTC may be used to replace existing switches and sensors in games controllers and computer

What is Quantum Tunnelling?

Quantum Tunnelling is a complex concept which can be quite difficult for the scientific layman to understand. It is concerned with the probability of an electron passing through or tunnelling through a potential barrier – a region where there is a sudden increase in potential or an electric field blocking the path of the particle. Classical physics and quantum physics give different explanations for what happens when an electron comes across such a potential barrier.

A useful analogy

Imagine standing on a harbour at high tide watching the waves in the rough sea break against the sea wall. If the height of the waves (h) is greater than the height of the sea wall (H)you will get wet as they can overcome the barrier. If the height of the waves is less than the height of the sea wall you'll remain dry. This is fine in the world of classical physics, which states that if h<H there is no chance of the water getting across the wall.
However, in quantum physics you would need to make sure you were wearing your raincoat! Those of you that have spent time playing at high tide like me will know that if a wave with h<H approaches particularly quickly, there is a chance it will splash over the wall even though it is not as tall as it. Thus giving you a surprise and wet feet!
This idea can be scaled down to atomic level where our wave becomes an electron and our sea wall a potential barrier.

The World according to Classical Physics

In Classical Physics the electron is considered to be a particle. Consider what happens when this approaches a potential barrier (such as when it reaches the boundary between a conducting and insulating material). If the energy of the electron is greater than the energy of the barrier it can cross, but if it is less than the energy of the barrier it is repelled and cannot cross.

The Quantum Tunnelling explanation

In Quantum Physics particles can also be considered as waves and there is a small probability of the electron crossing the barrier by tunnelling through it. In QTC the barrier is the thin layer of insulating silicone rubber separating the nickel particles. As the waveform of the electron hits the barrier (i.e. the insulating material) its amplitude decays exponentially. If it has reduced to zero by the time it reaches the other side of the barrier it will not exit. This represents QTC in the unstressed state. When pressure is applied the thickness of the silicone is reduced, i.e. the width of the barrier decreases. In this case the amplitude of the electron's waveform has not decayed to zero by the time it reaches the other side and there is a finite chance that it can escape with a reduced amplitude, thus it has tunnelled through the barrier.

mice to give increased sensitivity for greater control. It can be used to make flexible, portable musical instruments such as drum kits and keyboards and can be incorporated in to cuddly toys as a switch which plays a message when the toy is squeezed. It can be used in interactive dance mats and the Wii board takes advantage of the pressure sensing ability of this material.

QTC in Sport

QTC can be used as a sensor in many areas, from force sensors in training dummies for boxing to fencing jackets which incorporate touch sensors. Insoles made from QTC can be inserted in to training shoes to monitor and evaluate the weight distribution of athletes whilst running. These soles are very thin and can easily be placed inside ordinary training shoes.

QTC in Medicine

QTC sensors can be incorporated into the cuffs of blood pressure machines to ensure that they are tightened correctly to reduce inaccurate readings. It maybe used to replace a gas pressure sensor in a respiratory monitor which records the expansion and contraction of the chest whilst breathing. A QTC sensor can be used as a chest compression monitor to facilitate the delivery of effective CPR. The sensor detects the frequency and force or the compressions.

QTC in Clothing

Wearable applications include mp3 player controllers built into the sleeves of jackets. These allow the wearer to discretely change track, adjust the volume etc. by pressing QTC switches incorporated into the garment. The switches are flexible, durable and washable and attach to the mp3 player via a connector in the inside pocket.

QTC in Tools

QTC may be incorporated into the handles of power tools to act as a cut out switch or variable controller. The switches are controlled by touch and are more sensitive than conventional mechanical switches.

QTC in Robotics

QTC can be used as durable finger pads in prosthetic / robotic hands which allow the amount of pressure being applied to be controlled. Peratech have been working with NASA to develop pressure sensitive gloves for the next generation Robonaut.

QTC in Keyboards

QTC can be used to make a flexible, durable, portable QWERTY keyboard which can be connected to a mobile phone, laptop or other device using Bluetooth.

Where can I find out more?

www.peratech.com, the website of the Company set up by David Lussey, is an excellent source of information about QTC.

SEP also produce a booklet about this material with ideas for how it can be used in school. Small pills of QTC suitable for use in classroom experiments can be obtained from TEP and SEP too. For more information visit www.sep.org.uk, www.tep.org.uk or www.mutr.co.uk.

A COLLECTION OF USEFUL INFORMATION AND IDEAS!

I am regularly asked if I can help to promote this Scheme or that, or let our members know what has been going on in their area. To this end, here is a collection of some of the things I have come across in the couple of months or so...

Discover! a Saturday club with a difference.

The Welsh arm of WISE joined forces with Careers Wales Cardiff and Vale Education Business Partnership (EBP) three years ago to create a six week Saturday club. Discover! offers taster sessions of technical careers to 24 school girls in the process of choosing their options. This year the original Cardiff and Vale based Discover! expanded to eight sessions including DNA analysis, developing an artificial hand, mineral based textile design, using the Faulkes Telescope and analysing snot as well as industrial visits to Aberthaw power station, a civil engineering project on the M4 and the British Airways Maintenance Depot.

In addition, WISE received funding from the Welsh Assembly Government to allow Discover! to run in Swansea and Gwent this year in association with Careers Wales West and Careers Wales Gwent EBPs. This has tripled the number of girls given access to the Saturday club and increased the range of topics explored.

Although several technical aspects are explored through the sessions, materials and materials science can be seen as an underlying trend, and is particularly evident in one of our new sessions - “CSI Swansea” hosted by the Materials Research Centre in Swansea University.

At this session, the students are introduced to a “crime scene” where a materials scientist developing a highly advanced material has been murdered and her research and specimens are stolen. The students use materials science techniques to analyse the clues and identify the criminal! These techniques include scanning electron microscopy and energy dispersive x-ray analysis, Fourier transform infrared spectroscopy (FTIR), chromatography, and finger printing using a number of historical and current techniques.

The incredible success of Discover! is entirely due to the enthusiasm and commitment of the volunteers, parents and students who give up their Saturday mornings to run, ferry and take part in the sessions! For more information please contact Vicky Stevenson by emailing stevensonv@cardiff.ac.uk.

Fantastic Plastics at the Thackray Museum

When most people visit museums, they expect to find themselves immersed in history. But at the Thackray Museum in Leeds, our historical medical collections have been brought right up to date with a project on medical plastics. With support from IOM3 we have developed a brand new gallery, full of innovative plastic objects, and we are now finishing a set of school resources to round off the project.

The Thackray Museum has been open to the public since 1997, and has made a name for itself as a collection of national importance, and also a great place for people of all ages to explore the history of medicine. However, the sciences of medicine and healthcare are constantly moving forward, and we are keen to ensure that we keep pace!

The Fantastic Plastics gallery, opened in May 2008, arose out of interest from, and consultation with the plastics industry. It combines historical items with modern medical equipment and fun hands-on exhibits. Visitors come face to face with items as diverse as a blood transfusion kit from Adolph Hitler’s yacht, a silicone breast implant, and the PVC tubing to be found throughout hospitals. In the process, they discover what a difference plastics have made to healthcare, why they are the perfect materials for so many jobs, and gain an alternative perspective to some of the negative views of plastics put across by the media.

A series of schools' resources compliments the new gallery. Medical plastics are a great topic for children of all ages, tying in with the 'materials and their uses' and 'how science works' aspects of the curriculum, while allowing the museum to branch further into science, a subject that we are keen to explore. We have already developed two web games for 7 to 11 year olds, found at www.thackraymuseum.org/games. These let children explore the different implants that help people to live their lives and how plastic equipment has made operations safer and more effective.

We are now finishing a set of resources for GCSE students (14–16 year olds), including two more web games and a set of loans boxes. Two experienced and creative science teachers have ensured that these resources really achieve what schools want.

The loan boxes contain plastic medical equipment and activities, which can be borrowed by schools who want new and exciting ways of teaching science. These will allow students to get really hands-on in their investigations. Many of the objects are items which students (and even teachers) will have heard of, but never actually seen, including false eyes and teeth! Also included is cutting edge plastic surgical equipment and common items such as catheters and blood bags. A final pilot this term will ensure that the boxes are just right before schools around the country start to borrow them from September.

So, for the Thackray Museum, plastics really have been fantastic, giving our visitors a great new gallery, a set of games to bring our website to life, and school resources to be proud of! For more information please contact Elee Kirk by emailing elee@thackraymuseum.org.

What do you think of the new Science GCSEs

The QCA are collecting views on the science GCSEs introduced in 2006. They would like to hear from teachers and students that have been working with the new courses and have devised two online questionnaires. If you are willing to get involved you can find the teachers survey at https://www.surveymonkey.com/s.aspx?sm=RD_2fwHNxA6fgVCUqqmznnvg_3d_3d and the pupil survey (designed for year 12 students that have just come through the system) at : https://www.surveymonkey.com/s.aspx?sm=ryWAdYu8U6nTAi55WbFj4A_3d_3d

National Subject Profile for Materials

The Higher Education Academy and the UK Centre for Materials Education have produced a national profile for the discipline of Materials Science and Engineering in higher education.

The profile uses both publicly accessible data and information provided in extensive surveys of the Materials teaching community. It provides a definitive analysis of how, where and to whom Materials is taught at both undergraduate and taught-postgraduate levels in UK universities. It contains carefully sourced information about:

- numbers, demographics and trends of students enrolled on, and graduating from, UK Materials programmes
- the UK's provision of Materials programmes
- the curriculum content and teaching methods used on Materials programmes
- the views and attitudes of academics teaching Materials, and recent Materials graduates
- how the Materials discipline has evolved in Higher Education, and the context in which it now operates.

You can download the whole document or read the key findings at http://www.materials.ac.uk/subject-profile/report.asp

EXAM QUESTION MASTER CLASS - Alloys

The idea for this article came from a question in the AQA GCSE Science A, Unit C1a Higher Tier paper from June 2007. The multiple choice question was as follows:

"Pure copper is quite soft. It can be made harder by mixing it with zinc. This is because...
1 the copper atoms cannot now easily slide over each other.
2 the zinc atoms attach themselves strongly to the copper atoms.
3 the zinc atoms form strong bonds with the copper atoms.
4 zinc is harder than copper."

The Education Committee felt that this opened the door for an important and wider discussion on metals and alloys and how they can be strengthened.

In Issue 31 the structure of simple alloys was discussed. The article covered bonding and crystal structure, substitutional and interstitial alloys, microstructure and how alloys of different compositions can be represented through phase diagrams.

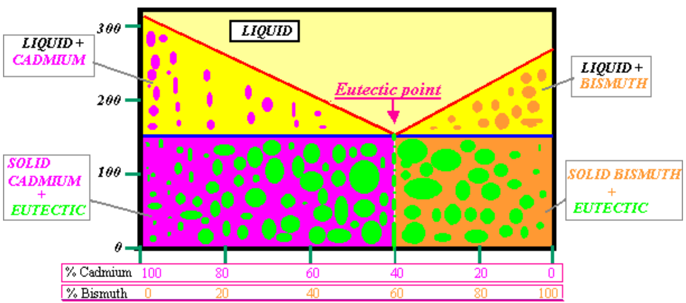
In this issue we will consider the microstructure of different alloys and how this can be changed with composition and cooling conditions. In the final article in the next issue strengthening mechanisms will be considered.

How does the microstructure of an alloy develop?

In the previous article in issue 31 we considered what happens when a pure metal cools from the molten state. In summary, crystals form on nucleation sites throughout the melt and these grow independently as the liquid cools and the solidification process progresses. The planes of atoms in these crystals grow in the form of dendrites which are not all oriented in the same way. When the arms of adjacent dendrites impinge on each other they cannot grow any further lengthwise so they start to thicken up. Once the metal has completely solidified all evidence of these dendrites disappears and the microstructure appears as grains separated by boundaries, where the planes of atoms in adjacent crystals have not met up perfectly.

This scenario is fine for pure metals and alloys in which the constituents are completely soluble in each other in the solid state as well as the liquid state. However, if the ingredients are not completely mutually soluble in the solid state the case becomes more complex and a number of possibilities arise. In order to make this a little easier to understand let us consider a few simple examples:

The Bismuth – Cadmium System

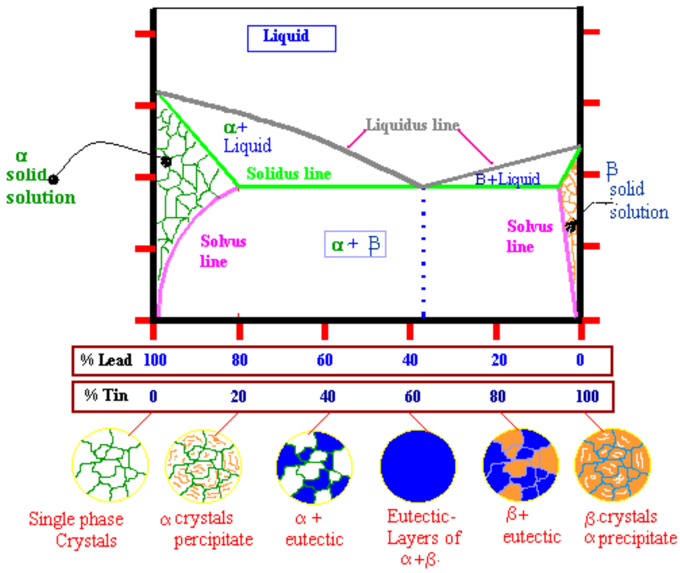


These two metals are completely soluble in the liquid state in all proportions, but become insoluble in the solid state. The Thermal Equilibrium Diagram (TED) or Phase Diagram for this system is shown right. This diagram also shows schematically the phases that are present at different compositions. If an alloy containing 40% cadmium and 60% bismuth by weight is cooled form the liquid state. At 140°C a eutectic structure forms which is made up from alternating layers of pure cadmium and pure bismuth. If an alloy containing 80% cadmium and 20% bismuth by weight is cooled from the liquid state crystals of pure cadmium will begin to form and the remaining liquid will become correspondingly depleted in cadmium (i.e. bismuth-rich). As the temperature drops dendrites of cadmium continue to grow. When the temperature reaches 140°C the liquid remaining between the arms of the dendrites solidifies with the lamellar eutectic structure so the final microstructure consists of primary cadmium crystals and the eutectic structure. If an alloy consisting of 20% cadmium and 80% bismuth were cooled the opposite would be true and the final microstructure would consist of primary bismuth crystals surrounded by the eutectic.

The Lead – Tin System

In this case the two metals are completely soluble in the liquid and have limited solubility in the solid state. Lead can dissolve a small amount of tin creating a solid solution known as α and tin can dissolve a small amount of lead to create a solid solution known as β. The eutectic in this case is a lamellar arrangement of the solid solutions α and β rather than the two pure metals. If an alloy containing 60% lead and 40% tin is cooled from the liquid the α phase forms first and when the eutectic temperature is reached the remaining liquid solidifies as the α+β eutectic phase. If the alloy contains 20% lead and 80% tin the final microstructure will contain primary β and the eutectic.

Consider now an alloy containing about 90% lead and 10% tin. As the liquid cools initially crystals of α form in the melt. As the temperature drops below the solidus line (bright green) the structure is completely made up from these crystals of α. However, when the temperature drops below the solvus line (pink) the α can no longer dissolve so much tin and a solid state precipitation reaction takes place. Precipitation of β occurs on grain boundaries and other nucleation sites within the structure leading to a structure containing primary α and precipitated β.



Systems containing intermediate phases

In certain cases intermediate phases occur in addition to solid solutions. These range from secondary solid solutions to true intermetallic compounds and further complicate TEDs. The iron-carbon system contains such an intermediate phase in the form of iron carbide (Fe_3C) which is known as cementite.

What effect does cooling rate have on microstructure?

In all of the cases above it has been assumed that equilibrium cooling conditions prevail, that is the cooling rate is slow enough for the most stable phases to form. However, increasing cooling rate can have a number of consequences. If the alloy is cooled faster from the melt more nucleation sites tend to be present and individual crystals do not have the chance to grow so much before they impinge on their neighbours, thus giving a microstructure with a smaller final grain size. If the cooling rate is sufficiently fast the metal or alloy does not crystallise at all and an amorphous metal 'glass' is formed.

If an alloy where there is limited solubility is cooled rapidly solid state precipitation may be prevented leading to a metastable supersaturated phase. At room temperature the system does not have enough energy to allow the diffusion required for solid state precipitation, however, if the temperature is raised the precipitation of the second phase can be controlled. Heat treatments such as this can be used to ensure precipitation of the second phase is coherent, particularly where precipitation under equilibrium conditions produces an incoherent phase.

Rapid cooling such as water quenching may also lead to the formation of non-equilibrium phases with very different properties from the equilibrium phases and these may be used to provide strengthening.

In the final article in the next issue we shall explore how a range of different mechanisms can be used to provide strengthening in metals and alloys.

Where can I find out more?

My favourite book as an undergraduate metallurgy student was "Engineering Metallurgy" by RA Higgins (published by Edward Arnold). I have had a look on Amazon and it doesn't look like it is still available, but if you can get your hands on a second hand copy I would as it is an excellent text for teachers and possibly some more able sixth formers.

You may find "Materials Science for Engineers" by Anderson, Leaver, Leevers and Rawlings useful. This is along the same lines as Engineering Metallurgy but covers all materials.

The DoITPoMS web-site, produced by the University of Cambridge has some excellent teaching and learning packages based around this topic and is has an on-line micrograph library. You can find it at www.doitpoms.ac.uk.

I also found a couple of other web-sites which contained some useful information: www.soton.ac.uk/~pasr1/, www-g.eng.cam.ac.uk/mmg/teaching/phasediagrams/index4.html and http://www.rmutphysics.com/charud/scibook/crystal-structure/Eutectic%20alloys.htm.

THE MINERALS AND MINING PAGE...

After a fairly quiet term in the autumn, 2009 has been crazy so far. Many of the schools which joined the scheme through AngloAmerican and Rio Tinto's generous sponsorship have requested visits. So there have been visits from Arbroath in Scotland to Truro in Cornwall. I also had my 1st lesson in Northern Ireland, visiting Foyle and Londonderry College.

Since Easter a number of schools have used me to do revision sessions on various aspects of mining and ore genesis. I particularly enjoy talking about the natural resources we have in the UK and how they were formed. I tend not to focus on oil and gas, but I have plenty of material on ores (tin, copper, lead, zinc, etc.), aggregates and industrial minerals (barites, fluorspar, etc.).

I'm expecting to be pretty busy during the autumn this year, due to the fact that mining in the OCR specification is now in the A2 component. If you would like me to come and deliver material relevant to this, can I suggest you book me as soon as you can, as I suspect I will fill up my dates fairly quickly.

A number of schools have asked if I could talk a little bit about careers and opportunities for geologists. I try to give a broad overview of the different areas that geologists get involved in, but I confess that I do emphasise the applied aspects of geology (mining engineering, minerals processing, engineering geology, petroleum geology, etc.), as this is where most of the jobs and opportunities remain. Even at a time of economic crisis, there are still jobs available for those that want them, particularly in the overseas mining sector.

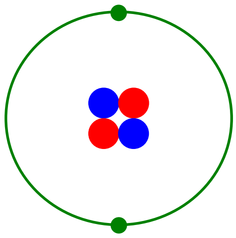
This year's sponsorship from Anglo and Rio means that there are now many schools where the geology teacher is the named member of the Schools Affiliate Scheme. One of the things I've been doing is to suggest to a geology teacher who wants to book me for a lesson or two, that they approach the head of science or D/T in their school, to see if they would like me to also do some lessons on Materials Science. This has resulted in a number of science and D/T departments joining the SAS for themselves and taking advantage of all the benefits. This might be worth considering in your school.

I'm looking forward to slightly less travelling over the summer, but I'll still be working. At the University of Leeds where I also work, we are preparing for a number of new courses which are aimed at people already working in various parts of the mining and quarrying industries. This includes a programme for a company based in Switzerland, so there'll be even more travelling from September onwards!

I look forward to meeting up with many of you at the Earth Science Teacher's Association conference in Southampton during September and visiting some of your schools.

Toby

HELIUM



- Helium has atomic number 2 and atomic mass 4.00. It boils at 4.22K and freezes at 0.95K, the lowest melting point of any element.
- It is a colourless, odourless, tasteless, non-toxic, monatomic gas at room temperature and is the second least reactive element after neon.
- Helium atoms consist of 2 electrons (green), 2 protons (red) and 2 neutrons (blue) and it can be found at the top of the noble gases in the Periodic Table.

- Helium is the second lightest element in the Universe and most helium was formed during the Big Bang. Helium is still being created by nuclear fusion in stars.
- In 1868 the French astronomer, Pierre Janssen, observed a bright yellow line, wavelength 587.49nm, in the spectrum of the chromosphere of the sun and he thought that this belonged to sodium. Later the same year Norman Lockyer, and English astronomer, observed the same line and concluded that although it was close to the lines for sodium, it must belong to an element that was found in the sun, but not known on Earth. Lockyer and chemist Edward Frankland named the element helium after the Greek word for the sun, *Helios*.
- In 1865 helium was first isolated by Sir William Ramsay, a British chemist. He treated the mineral cleveite with mineral acids, in the search for argon. On testing the gases liberated he observed the same yellow spectral line as Janssen and Lockyer and concluded that the element must be helium.
- Despite being so common in the Universe as a whole, helium is pretty rare on Earth. Helium can easily drift out of the atmosphere due to its low density.
- On Earth helium is created by the natural radioactive decay of some elements, as the alpha particles that are emitted consist of helium nuclei. This radiogenic helium is commercially extracted from the natural gas in which it is trapped in concentrations of up to seven percent, by low temperature fractional distillation. Many of these deposits occur in the southern states of North America, in Kansas, Texas and Oklahoma.
- For many years the United States was the biggest producer of helium, extracting 90% of the total extracted. The remainder was produced by Canada, Poland, Russia and Algeria.
- The specific heat capacity and thermal conductivity of helium are greater than all other elements except hydrogen and it diffuses through solids three times faster than air. These are all due to its low atomic mass. Helium is unusual in that it heats up when allowed to freely expand; most gases cool down.
- Helium is commercially available in both gas and liquid form and it has a variety of uses.

- Since helium is less dense than air it is used for filling balloons and airships where it is much safer than hydrogen.
- It is used in rocketry to displace fuel and to condense hydrogen and oxygen to make rocket fuel.
- Helium is added to the air mixture used by deep divers ass it has low solubility in nervous tissue and can reduce the effects of narcosis.
- Barcode readers use neon-helium lasers.
- Helium is used as a shielding gas when growing silicon and germanium crystals and is useful in supersonic wind tunnels.
- A persons voice sounds higher in pitch after inhaling helium as the speed of sound in helium is much faster than in air.