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Smart Materials- Teacher Notes.

These notes are intended to outline the content of the DVD and also suggest points that could form the basis of class discussion or further activities… these are indicated by coloured text.

Introduction

The introduction sets out to consider a brief history of smart materials highlighting how recently these materials have been developed, emphasising that the development of new materials was accelerated by man's exploration of space in the 1960s.

To many of our students 50 years is an almost incomprehensible timespan. It may be worth pausing after this section to help them realise that in the context of using and developing materials this is relatively recent.

It is also important to help students to have a clear idea of what smart materials are. The introduction to the DVD gives a definition of "Smart materials = materials that respond to changes in heat, light, pressure or other stimuli".
The difference between a "Smart" material and a "Modern" material (that does not necessarily react to its environment) can be confusing and could be the basis for a class discussion either at this stage or after viewing the examples in this DVD.

The discovery and creation of new smart materials is opening up a whole new world of possibilities....and it is the interactive nature of these materials that makes them so excitingto designers and consumers alike.

The DVD focusses on some resistant materials and technologies that are set to impact on our daily lives…

- QTC or **"Quantum Tunnelling Composite"** is an amazing material that is set to revolutionise gaming and computer interfaces…. And potentially much more besides.
- SMA **or "Shape Memory Alloys"** -familiar to many when uses in glasses frames but here we look at the use of this material to prototype "smart cooker knobs".
- OLED (Organic Light Emitting Diodes) are light emitting panels made from organic (carbon based) materials that emit light when electricity is applied. This section explores how "printed lights" will completely change the face of car and building design.
- Thermochromatic pigments. Materials that change colour in response to changing temperatures. Here is a look at how these smart materials can and help our world safer and even keep counterfeiters at bay.

QTC – 3D touch screens

A little background…
"Instead of carbon, QTC contains tiny metal particles, but it does NOT work by percolation. Instead, electrons 'pass' through the insulation by a process called quantum tunnelling – hence the name of the material. To explain this effect, we have to appeal to quantum theory and think of the electrons as waves. In classical physics, the electrons cannot pass through an insulation barrier, but according to quantum theory a wave can – and this is what happens in QTC. To some extent we have to suspend belief, because the world seen through quantum theory appears so much at odds with its common sense counterpart. (Another way of describing the quantum tunnelling effect is to say that a probability exists of electrons at point A - one side of the insulation barrier - appearing at point B - the other side. This is all very weird – but demonstrably true.)" From www.mindsets.co.uk

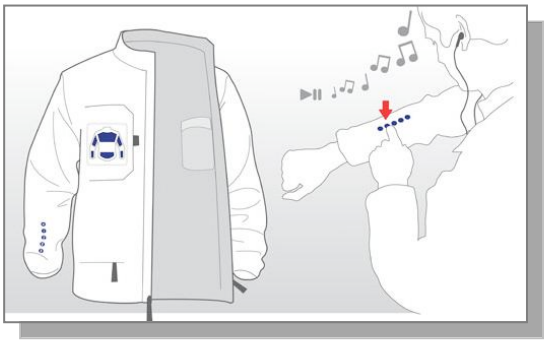
This section of the DVD looks QTC. A material that was discovered by chance in 1994. Although there have been applications developed that make use of this materials unique properties it is only recently that a transparent version has been developed. The combination of the smart properties and the ability to see through the material is opening up new possibilities for interactivity.

At this point it might be worth reinforcing students understanding of conductors and insulators.. and that QTC has the magical property of being able to be both! i.e. "What makes QTC special is that the harder you press it, the better it conducts electricity".
The quantum physics is probably beyond what the students need to know about this material but this might be an opportunity to find out (in simple terms) how it really works!

A brief "history" of how NASA was among the first organisations to make use of QTC's properties is looked at next. In particular how they created a series of soft switches that enabled astronauts to control helmet fans and other equipment whilst wearing bulky gloves.

The same technology has been used to control MP3 players and i-pods in ski jackets.

A research project or homework activity could be given to students to find "real life" applications of QTC.



In the video clip David Lussey (the inventor of QTC) explains the principal of how this material behaves.
This can easily be reinforced in the classroom/workshop as QTC can be obtained from various suppliers including www.mindsetsonline.co.uk (formerly MUTR).

The video explains that the simplest touch screens use the same technology you'll find in a Nintendo DS…Two conductive plates are held apart by a layer of spacer dots. Pressing the screen separates the dots, allowing the conductive plates to touch together. This technology is working as a switch in 2 "dimensions" ie on/off and position.
Replacing the spacer dots with a layer of QTC adds a third dimension to the interactivity…. i.e. the pressure that is placed on the surface.

Next…Video demo….It's still new technology but adding the dimension of pressure is likely to open up all sorts of new interactive possibilities...
Some students might find this difficult to grasp… an analogy that might be useful here is with electronic keyboards/pianos… the simplest ones play a note at the same volume each time a key is pressed… the 3rd dimension would in this case be that pressing a key softly could produce a quiet note and a firm press a louder one.

At this point the presenter explains that clear QTC can be placed in front of screens… QTC is a relatively new smart material… BUT an even more exciting and very new development is that it can now be made transparent making it more sensitive but the main way QTC is set to revolutionise gaming and other interactivity comes when you increase the number of conductive points.

By the time students watch this clip the clear QTC version of this sensor will already be a reality and that's got the games industry buzzing.

A possible extension/homework task…"Can you think of other applications other than in gaming and computers?"

SMA - Shape Memory Alloys

This section of the DVD focusses on Shape Memory Alloys. These are also known as smart metal, memory metal, memory alloy, muscle wire, smart alloy. SMA is an alloy that "remembers" its original shape: after being deformed it will return to the pre-deformed shape by heating. This material can be used as a lightweight, solid-state alternative to conventional actuators such as hydraulic, pneumatic, and motor-based systems. It is the “super elasticity” of these alloys that the designers utilise.

This can easily be reinforced in the classroom/workshop as SMA can be obtained from various suppliers including www.mindsetsonline.co.uk (formerly MUTR).

At this point it may be good to check the students understanding of “Alloys” and that an alloy’s physical properties can be very different from those of the constituent metals. A discussion or comparison of the differences/similarities between alloys and composites might be useful for students at a higher level.

The introduction to this section illustrates some of the ideas being trialled by NASA that use SMA. Among the concepts are wings and aeroplanes that change shape when they're in the air. It makes them faster and more fuel efficient – bringing potentially huge benefits for the airlines of the future.

Note the image here is taken from a NASA clip. A possible homework/extension task related to this could be to ask students to research existing products and applications of SMA

At this point the video demonstrates a bent piece of SMA wire straightening out when an electrical current is applied to raise it above its threshold temperature (that is the temperature at which its properties change) – it enters what's called a super-elastic state and remembers what shape it was.
In discussion with the students it may be a point to emphasise and/or clarify that it is the heat that changes the shape not the electricity.

The example that follows shows a familiar use of SMA- glasses frames. It illustrates that by making SMAs with different threshold temperatures, designers have been able to make use of their super-elastic powers... at room temperature the glasses frame is springy. But by cooling the glasses down below their threshold temperature and their super elastic properties disappear...they don’t spontaneously spring back to their original shape until warmed up again.

But it's not just the shape retention that makes memory alloys useful.

The second demonstration illustrates that when they reach their threshold temperature some Shape Memory Alloys also shrink by up to 5% - exerting a significant pulling force – this is when they are used as muscle or smart wires, these SMAs are increasingly being used as low cost actuators or switches.
Some students may think that it is the spring shape that is providing the pulling force. It may be worthwhile discussing that this shape is used to “amplify” the distance that the wire contacts by.

The DVD now shows an example “real life” application of SMA. The project makes use of SMA’s properties in an automatic gas cooker shut off knob. This project has been developed and prototyped by the medical engineering department at the Royal United Hospital in the UK city of Bath.

The team has developed a system linking smoke and gas sensors, a control box and sprung loaded cooker knobs. The idea was that when dangerous levels of smoke or leaking gas were detected, the control box would activate a mechanism inside the knobs releasing the spring and physically turning them to the safe off position.

The video clip shows how an SMA actuator controls the release of the spring.
In this project the control knob was developed for people with the symptoms of dementia, it may be worth at this point clarifying that this describes a set of symptoms which include loss of memory, and problems with communication. A follow up discussion/task could be to investigate other scenarios where this technology could be useful.

A possible extension/homework task…“Can you think of other applications other than safe cooker controls?”

Organic Semiconductors (OLEDs)

A little background information….An organic semiconductor is an organic material (carbon rather than silicone) with semiconductor properties. A semiconductor is a material with electrical conductivity somewhere between that of a conductor and an insulator…. As used in transistors and microchips.
Amongst these semiconductors are OLEDs or organic light emitting diodes. An OLED is made with thin layers of organic material. This layer emits light in response to an electric current.

In the introductory section the clip introduces students to the recent history of semiconductors and illustrates this through the development of semiconductors since the days of early space exploration. It draws a comparison of modern everyday technology and what the Apollo astronauts had available to them. What will this technology be like in another 40 years' time?.... Perhaps a good discussion point and an opportunity for some imaginative designing?

The next section contains an explanation of how OLED panels are constructed and how they operate.
During this explanation the person refers to..nanometres "One nanometre is one billionth of metre (1/1000000000 of a metre, or 0.000000001 of a metre).. it may be useful to help students grasp the scale of things!!
It continues explaining that OLEDs make use of a property called electroluminescence (EL) – when you electrically charge certain polymers they emit light.

A brief history of existing EL technology follows. It was first discovered in the 1950s but screen printed EL inks weren't bright enough to use for lighting so uses were limited. The new polymers give off much more light. They can also be tuned to create different colour light and they're more efficient and environmentally friendly than conventional lights...

Most students should be aware of the importance of sustainability and environmental issues, Modern EL technologies could help. This could again be the basis of class discussion or an extension/homework task.

The following section of the DVD details some of the research and development being carried out to enable the mass manufacture of OLED devices. It explains about the need for clean rooms and the evaporation methods by which thin layers of materials are made in the OLEDs.

Some suggested uses of OLEDs in the design of cars and buildings are presented. A student design task could be to think of new applications for these panels.

Thermochromic Materials

A little background information…
Thermochromic Materials are part of a family of smart materials where there are colour changes in response to a change in their environment. In this case the colour change is due to a change in temperature. Similar materials may respond to light (photochromic), electricity (electrochromic), cathodochromic (an electron beam)….. etc.

The introduction to this section of the DVD looks at a way in which thermochromic materials are used to ensure that food in supermarket chiller cabinets is maintained at the correct temperature. It looks at safe, cost effective and simple ways of keeping our food safe using these materials.

An explanation follows of how cheap printing techniques can be used with thermochromic liquid crystal materials and layering to produce chiller labels.

An opportunity here for students to explore other applications of this technology to other uses.

In the next clip a different material is demonstrated where instead of a single colour change (as in the chiller labels) a whole range of colours can be displayed representing different temperatures.

(note. This effect can often be seen in forehead thermometers…a few of these can be a useful resource!)

The scientists in the next part of the video demonstrate how these colour changes van be "tuned" by combining different types of liquid crystal. both the point at which the colour transformation begins and the range it covers can be adjusted. By blending the liquid crystals with gelatine it is possible to create a protective wall around the liquid crystal droplets – a process called microencapsulation.

The thermochromic properties of liquid crystal were first developed about 50 years ago, but these days it's not the only thermochromic material available.... The next part of the clip explains that… Rather than using liquid crystals, "Chameleon inks" use a combination of fats to reveal different coloured layers below or conceal them with their own colour.

Unlike liquid crystals, fat based thermochromic materials can also be turned into pigments. This means that they can then be added to plastics and used to make things like baby feeding spoons that change colour if the food is too hot.
These products are readily available and make a good "hands on" classroom demonstration.

The final part of this section explores other uses for this and similar technologies that are already on the high street. Hot/cold labels on food products for example…. And also the related "hydrochromic" material with a rather unusual use!

A possible extension/homework task…"Can you think of other applications of thermochromic materials?"

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Smart Resistant Materials

Quantum Tunnelling Composite

Shape Memory Alloys

Organic Semiconductors (OLED)

Thermochromic Pigments

Project Title	

Student	
Teacher	
Class/Group	
Date	
Current Level	

Produced By- Dave White. Head of D&T Clevedon School

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Introduction

- In this project you will be designing and modelling a new and innovative product. The product you design should demonstrate a new use for one of the **smart materials.**
- Throughout the project you will have opportunities to show your **Personal Learning and Thinking Skills (PLTS)**. There is a symbol showing which of which PLTS are most likely to be used on each page.
- This project also gives you the opportunity to move your **National Curriculum Level** higher.
- Self Assessment overviews for both PLTS and National Curriculum Levels are available towards the back of this booklet. You can use these to check what you can do to improve your work.

- Much of the work on this project will be annotated sketches and drawings of your design ideas. However it can produced using a computer and CAD software… you can put evidence of your work in this booklet by doing screen captures and printing extra pages or you could use an electronic version of this booklet to create a simple e-portfolio

- The Design Brief might be given to you or should be negotiated with your teacher.
- Ideas and inspiration for design projects can be found on the Pumpkin Interactive DVD.

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Brief & Specification

- Design Brief

- Design Specification

On this page you should record your Design Brief and Specification. Remember that the Brief is a short statement that sets the task.
The specification says exactly what the finished product must be like and what it will do.
If you are writing the specification as a result of doing your own research you will need to come back and fill in this section later.

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Research and Investigation

On this page you should record evidence of any research and investigation that you carry out for this project.
You will need to find out about …."end users" of the product; how the smart materials work and how this will influence your designs; Similar existing products that you could use to base your ideas on.

Independent enquirers

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Mood Board

Gather images, material samples, colour swatches, inspiring words and anything else that helps “set the scene” for your design work.
Sketch or stick items on this page…. Or if you do this by gathering information from the internet copy and paste items to a blank page and add it to you design booklet.

Self-managers

Creative thinkers

Independent enquirers

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Initial Design Ideas

Team workers

Effective participators

Creative thinkers

Use this space to SKETCH your first ideas and thoughts.

Produce a spider diagram to help structure your thoughts.

You could use the 4x4 and SCAMPER design tools to help you generate and develop ideas

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CAD Design Work

You should perhaps consider using CAD to produce your design. On this page you should show evidence of your initial CAD work. Use screen shots or printouts to show your first design ideas produced using CAD

Creative thinkers

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Design Development

Use this space to show how you design develops. This could include any changes to the shape and size of the product, improvements to the way it works etc. Use screen shots or printouts to show any changes that happen throughout the design process.

Reflective learners

Creative thinkers

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Specification Check

Check your design against your specification… does it still do what it is supposed to do? Do you need to modify your design further to make sure it fits your specification?

Reflective learners

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Final Design

This page should include an orthographic drawing of your final design. If you have used CAD to produce your design this should be fairly easy. Copy/Paste, screenshot or print out a copy of your final design including dimensions. You could also produce a 3D rendering of your design

Creative thinkers

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Preparation for Modelling

Self-managers

Creative thinkers

To prepare your design for modelling you will need to think about what materials you have available. Will the model be a realistic prototype, or will it demonstrate the function of the design?.. Or both?

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Final Product Prototype

If possible produce some photos of you product model being made.

Print out and add in a photograph of your final product… preferably with it being used by the person it was designed for.

Self-managers

Creative thinkers

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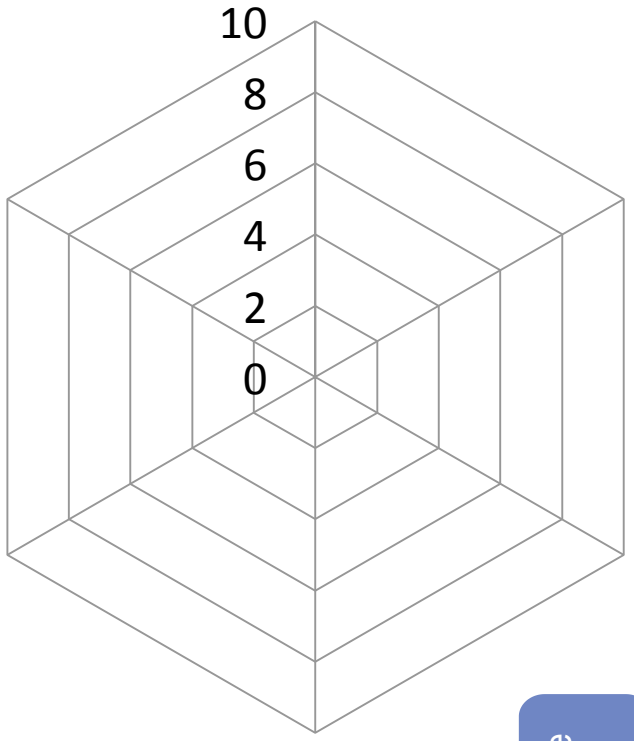
Evaluation

Check your design against your brief and specification…. Does it do what you intended? How well does it do it?
Use Cafeque to further help with your evaluation. A graphic way to help visualise the effectiveness of your design is to produce a radar diagram (That's where I draw the line). Don't forget to check with an "end user" for their views on the product.
Don't forget to say how you could improve your design if you were to do it again



Reflective learners

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Self Evaluation with PLTS

Against each of the Personal Learning and Thinking Skills (PLTS) Give yourself a RAG rating (Red – something I need to work on; Amber – I'm OK at this; Green – Something I'm doing very well). Circle the appropriate words.
It would be a good idea to do this several times throughout the project to see if anything changes.

Independent enquirers I can identify questions to answer and problems to resolve Red Amber Green I can plan and carry out research Red Amber Green I can explore problems from different points of view Red Amber Green I can decide which information is relevant and useful Red Amber Green I can back up conclusions, using evidence. Red Amber Green	**Creative thinkers** I can come up with ideas and explore possibilities Red Amber Green I can ask questions to get new ideas Red Amber Green I can connect my own and others' ideas in interesting ways Red Amber Green I can question what I and others think is true Red Amber Green I can try out alternatives or new solutions Red Amber Green	**Reflective learners** I can assess myself and others, identifying opportunities and achievements Red Amber Green I can set targets and assess whether I have met them Red Amber Green I can accept feedback and criticism without getting upset Red Amber Green I can look back at what I've learned to help with new challenges Red Amber Green I can talk about my learning to teachers and other students Red Amber Green
Team workers I can work with others towards common goals Red Amber Green I can take on different roles in a group Red Amber Green I can be fair and consider others' feelings Red Amber Green I can take responsibility for myself Red Amber Green I can be supportive and give feedback to others. Red Amber Green	**Self-managers** I can try new ways of doing things and change when it is necessary Red Amber Green I can work towards goals and not just give up when things get difficult Red Amber Green I can organise time and resources, and decide what is important to do first Red Amber Green I can ask for the help I need Red Amber Green	**Effective participators** I can discuss worries and work out what needs to be done Red Amber Green I can suggest simple and straightforward ways to achieve a task Red Amber Green I can see way to improve my work as well as other people's Red Amber Green I can sort out arguments and get people to agree on what to do Red Amber Green

Team workers
Reflective learners
Self-managers
Effective participators
Creative thinkers
Independent enquirers

With thanks to Priory School, Weston-Super-Mare, UK for the PLTS Rag rating table

National Curriculum Levels

Use this page to check your National Curriculum Level… you can also use it to see what you need to do to progress.
Your Teacher will also use this page tp indicate the level they think you have achieved

Level 4 Things I need to do to reach this level	☑
I can gather the information I need independently and use it to give me a number of ideas.	
I can develop ideas for my products, bearing in mind that I must suit the needs of the user, as well as considering sustainability.	
I can show alternative ideas using sketches, models and/or ICT, and make the best choice,using what I already know.	
I can outline what I am going to make, and how I'm going to make it.	
I can select and use the right tools/utensils and equipment, when working with different materials to produce functional products.	
I evaluate my work as it develops, making changes where necessary, and stating why.	
Level 5 Things I need to do to reach this level	☑
I can develop an outline of a design specification/recipe using information gathered from a variety of sources.	
I can think of a number of imaginative ideas for products considering the users health and safety and sustainability.	
I can research a range of ideas using sketches, models and/or ICT, and make choices between them based on my knowledge and understanding.	
I can produce drawings with outline dimensions and sequence what I am going to do.	
I can select and use appropriate tools and equipment to measure, mark out, cut, and join a range of materials	
I can produce products of an acceptable quality, and function.	
I can evaluate my work as it develops, bearing in my original design.	
Level 6 Things I need to do to reach this level	☑
I can identify and use a range of information sources to research my product and develop a specification	
I can recognise the need to refine or change my ideas in the light of my research, user needs, health & safety, and sustainability.	
I can produce formal drawings/patterns/recipes with details of manufacture using a range of skills, including the use of CAD.	
I can sequence the manufacture of my product and use tools and equipment accurately. I can deal with problems along the way.	
Choosing from a range of materials, I can produce an appropriate standard of construction and finish	
I can evaluate my final product by comparing it with the original specification and suggest improvements.	

Level 7 Things I need to do to reach this level	☑
I can seek out relevant information sources to research details of my ideas. and produce a detailed specification	
My work shows originality, innovation and creativity, and I can change/modify my ideas in light of research, knowledge and understanding.	
I consider user needs, health and safety and issues of sustainability when making decisions about their products.	
I can annotate my design ideas and, where appropriate, model them in order to help development. I communicate my ideas using a range of skills including the use of CAD.	
I can order and sequence the manufacture of my product, and use tools and equipment safely with increasing precision. I can make changes in the light of unforeseen problems.	
I am able to choose from a range of materials and produce products to a high standard of construction, and finish	
I can evaluate the final product, comparing it with the original specification, and identify possible improvements.	
Level 8 Things I need to do to reach this level	☑
I am able to focus keenly in selecting and using appropriate research materials, and in exploring and evaluating existing products.	
My work shows originality, innovation and creativity in the designs I produce.	
I can cross-reference ideas in my specification to my research.	
I can use high-level communication skills – detailed annotation of development sketches; accurate drawings and CAD models.	
I consider limitations of cost, user preferences, health and safety, and sustainability in my designs and manufacture.	
I can sequence manufacture, and can independently select equipment, and materials.	
My products are made with precision and a high standard of manufacture and finish	
I use a range of evaluation strategies, including detailed testing against the specification, considering user response and future developments.	
Exceptional Performance Things I need to do to reach this level	☑
I can systematically seek out information to help my design thinking. I recognise the needs of a variety of client groups. I can combine design ideas and concepts from my research to reach creative, innovative and original design solutions that satisfy conflicting demands, including issues of sustainability.	
I can draw on all my knowledge and understanding to reach the best solution. I do this through modelling, and can communicate to others the key features of my design. I can produce a detailed specification	
I can produce and work from plans that show how each stage of making is achieved. I can identify how to make best use of time and resources available.	
I can work to a high degree of precision to make products that are healthy, sustainable, reliable, robust and fully reflect the requirements of the specification	
I can devise my own evaluation procedures and use them to indicate ways of improving my products. I can then implement any necessary improvements.	

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Help and reference

- Watch the DVD carefully… there is a lot of information to help you with this project… you may be able to watch parts of it again to refresh your memory.
- Think carefully about doing some additional research. Try to find out everything you can about the smart materials. Your teacher may be able to give you a few clues, websites to visit etc.
- Remember that this project is about creativity and innovation… don't copy ideas from other people! It's a great opportunity to show off how good a designer you are

Progress Tracker

A	R	B	R	C	R	D	R	E	R

Shade in each part of the above bar to help you keep track of your progress through the project

A Understand and Choose
I have identified all the questions that I need to answer in this project and the problems that I need to sort out.

B Planning and Researching
I carefully planned my research and have carried this out. I understand how this project will help my learning.

C Exploration and Doing
I have explored a number of issues, key events and questions. I have considered a number of different points of view.
I have explored at least three different ideas and I have tried more than one approach to complete this project.

D Review and Improve
I have assessed how my project meets the success criteria. I feel confident to make improvements to progress to the next stage.

E Share and Celebrate
I have submitted my project and received feedback from my peers, parents/ guardians, teachers and tutors. I know what I did well and how to improve.

R Reflect
I have reviewed my progress and acted on the outcomes

Team workers
Reflective learners
Self-managers
Effective participators
Creative thinkers
Independent enquirers

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Spare Page

Team workers

Reflective learners

Self-managers

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Creative thinkers

Independent enquirers

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Smart Materials- Useful links and resources.

General Smart Materials

Wikipedia http://en.wikipedia.org/wiki/Smart_material

http://www.design-technology.info/alevelsubsite/page11.htm

BBC Bitesize
http://www.bbc.co.uk/schools/gcsebitesize/science/edexcel/designerproducts/smartmaterialsrev1.shtml

QTC or "Quantum Tunnelling Composite"

Samples of QTC can be purchased from www.mindsets.co.uk and a free datasheet is available for download.

Wikipedia http://en.wikipedia.org/wiki/Quantum_Tunneling_Composite

Peratech Limited was established in 1996 to exploit QTCs http://www.peratech.com/

QTC clear http://www.peratech.com/pr_qtcclear.php

SMA or "Shape Memory Alloys"

Samples of SMA can be purchased from www.mindsets.co.uk

Wikipedia http://en.wikipedia.org/wiki/Shape-memory_alloy

Technology student http://www.technologystudent.com/equip1/sma1.htm and http://www.technologystudent.com/equip1/sma2.htm

TEP Publication http://www.tep.org.uk/PDF/Mech%20V1.2%20(Master)/tsf17-19.pdf

SEP Booklet can be purchased here
http://www.mindsetsonline.co.uk/index.php?cPath=18_177_515

http://www.imagesco.com/nitinol/nitinol-index.html

OLED (Organic Light Emitting Diodes)

Samples of Electro Luminescent (EL) material and the driver circuit can be purchased from www.mindsets.co.uk … note this EL material is not the same as the OLEDs in the DVD but it does display similar properties.

Wikipedia http://en.wikipedia.org/wiki/OLED

OLED info http://www.oled-info.com/oled-light

MIT video OLED displays http://techtv.mit.edu/videos/3175 (not recommended for students)

Thermochromatic pigments.

Samples of thermochromic pigments can be purchased from www.mindsets.co.uk

Wikipedia http://en.wikipedia.org/wiki/Thermochromism

Mindsets downloadable pdf www.mindsetsonline.co.uk/images/SMARTCOLO.PDF