Kibworth Mead Design Technology

Modern & Smart Materials

Modern materials must not be confused with smart materials. When you see a question ask about modern materials you MUST NOT answer talking about smart materials.

When you think about smart materials, think about being clever and REACTING to something – modern materials don't do that.

In this guide it will cover:

- Modern Materials
- Examples of Modern Materials
- Smart Materials
- Examples of Smart Materials

At the back the Do Nows from lessons (with answers) will be included as well as example exam questions. Your teachers will be happy to mark these exam questions for you or you can use the mark schemes on the AQA website to help you.

Modern Materials

Modern materials are materials that have been invented to serve a purpose or a material that has relatively recently been discovered.

Aluminium is classed as a modern material due to its more recent discovery. Stainless steel is steel alloyed with aluminium to improve its properties.

In this guide we will study:

- Bio-degradable Polymers
- Flexible MDF
- Titanium
- Fibre Optics
- Nanomaterials
- LCD
- LED
- Metal Foam

For the GCSE exam you need to have a basic understanding of them all as you could be asked a multiple-choice question in Section A about them. You need to know at least two in more detail and talk about their use/application for potential Section B questions.

<u>Bio-degradable Polymers</u>

Biodegradable polymers are made from vegetable starches, often **corn-starch.**

Biodegradable polymers are often called corn-starch polymers!

Common varieties include:

- Polylactic acid (PLA) commonly used in 3D printing filament
- Polyhydroxybutyrate (PHB) under the trade name Biopol™

The polymers may not biodegrade in a landfill site however due to the need for soil. Natural bacteria are needed to break down the polymer very quickly with no harmful chemicals released

Flexible MDF

Made in the same way as standard MDF, but with grooves cut across the width or length of the board.

These grooves go through most of the thickness leaving about 2mm of the MDF intact.

This process allows the board to become flexible. Timbers aren't flexible and will crack when bent so flexible MDF allows for modern curved designs when you need the properties of timber like toughness.

Titanium

Titanium has high strength-to-weight ratio. It is very lightweight, tough and stiff (doesn't bend).

It has excellent corrosion resistance and doesn't react with most chemicals. This is why it is often used for joint replacements as it won't react in our bodies and cause further problems.

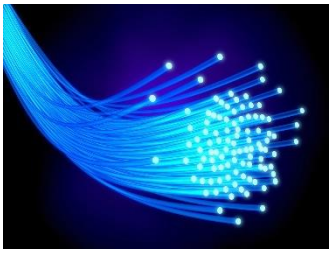
Nanomaterials

Nanomaterials mean that the material is normally between 1 and 100 nanometres but could be up to 1000 nanometres in at least one dimension!

This is about a million times smaller than a grain of sand!!

These materials exist on an atomic or molecular scale and have potential benefits for scientific studies. Their use in electronics has helped aid miniaturisation whilst improving conductivity

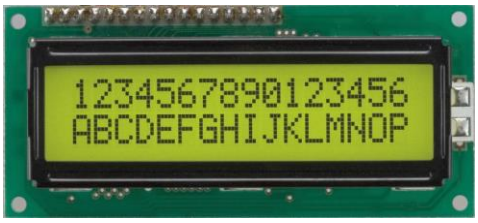
Fibre Optics



Optical fibres allow digital information to travel as pulses of light along thin glasses strands at very high speed.

The inner glass core is little thicker than a human hair and can transmit light along its length by reflecting it off the wall of the cladding.

LCD – Liquid Crystal Display



They offer a low-cost and low-power method of displaying information. There are two varieties, monochrome and full colour.

The liquid crystals will align in a predetermined way when an electric voltage is applied to them.

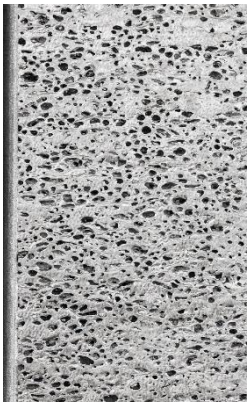
LED – Light Emitting Diode

LED screens are considered better than LCD screens due to the brightness, colour contrast etc.

They both actually use LCD technology, however LED TVs use light emitting diodes as the back light for the TV.

This has allowed screens to become even thinner!

Metal Foam



Metal foams are very lightweight compared to solid metals but still have the properties of the main metal it is made of… including strength!

- As little as 25% of the mass of the solid metal is used
- The air pockets are made by injecting gas into liquid aluminium or titanium
- They are 100% recyclable

Frequently made from aluminium and titanium. They are extremely lightweight.

Name	Appearance	Characteristics	Uses
Polylactic Acid PLA	Smooth or textured finish, dependent on the production method, easily colour	Widely used in 3D printers as reels of filament, it is non-toxic, easily moulded and fully biodegradable	Bottles, pots, disposable food and drink containers, pens, phone cases and 3D printed items.
Polyhydroxy-butyrate PHB Biopol™	Smooth or textured finish, easily coloured	Stable, stiff, quite brittle, non-toxic, easily processed and moulded, has limited chemical resistance, fully (but slowly) biodegradable.	Bottles, pots, household items disposable food containers
Flexible MDF	Light brown, grooves cut on one side and smooth on the other	Flexible in one direction along the cut groove, easily shaped into natural curves and waves, easily finished, can be laminated and veneered, not good in wet conditions.	Modern furniture, curved and wave-shaped forms for interior spaces, interior walls and room dividers
Titanium	Light grey, can be polished to a mirror finish	High strength to weight ratio, anti-corrosive, can be easily formed and welded, hypo-allergenic (causes fewer allergic reactions)	Jewellery and watches, medical uses such as joint and dental implants, aircraft, spacecraft and sports car parts.
Fibre Optics	Clear glass fibre core in a glass cladding, covered with strengthening fibres and a plastic jacket	Flexible cable capable of transferring digital data at extremely fast speeds, light and images can be sent and received	Data transfer cables, endoscopic cameras, novelty and bespoke lighting displays
Metal Foam	Metal foams can have a closed or open cell structure, and are the same colour as the base metal	Strong, lightweight, electronically and thermally conductive, very porous, good sound absorption	Medical implants, aircraft and car parts, lightweight load-bearing structures, impact absorption in vehicles.

Smart Materials

These are materials that REACT to something!! An external stimulus or input.

This means the material can change how it works, how it looks depending on what happens to it. They can react to heat, moisture, pressure, light etc.

Smart materials REACT and change!

VS

Modern materials DON'T – they are designed to stay as they are.

In this guide we will study:

- Thermochromic pigments
- Photochromic pigments
- Self-healing materials
- Shape memory alloy
- Quantum Tunnelling Composite

For the GCSE exam you need to have a basic understanding of them all as you could be asked a multiple-choice question in Section A about them. You need to know at least two in more detail and talk about their use/application for potential Section B questions.

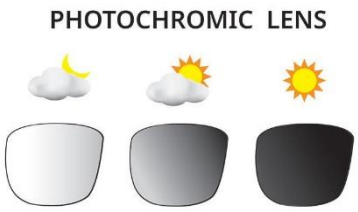
<u>Thermochromic Pigments</u>

These pigments, inks and dyes react to heat by changing colour at specific temperatures!

A colour change can indicate that a specific temperature has been reached for example a product could turn red to indicate it is too hot.

These can be both reversable or irreversible depending on the product needs.

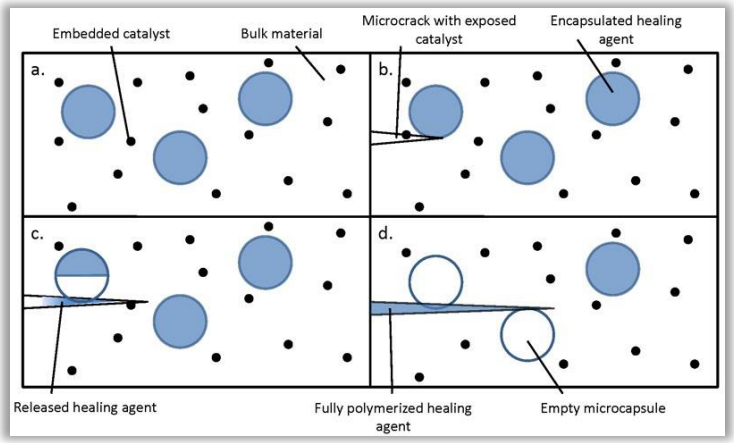
Photochromic Pigments



These pigments, inks and dyes react to light by changing colour!

It is the UV rays that effect the colour change. The longer it is exposed, the darker it becomes until its maximum is reached. This is caused by the reaction of light sensitive particles.

Self-Healing Material



Self-healing polymers and bio-concrete are two examples of materials that can respond to stress fractures (a force) and repair themselves.

Self-healing polymers contain microencapsulated resin-based adhesives that are released and activated when stress fractures are caused.

Resin fills the crack and hardens, leaving a small bubble behind instead of a long fracture.

Shape Memory Alloy

Most materials have some form of memory, meaning that they will try to resist deformation or spring back to their original shape.

Shape Memory Alloy (SMA) take this a step further; they can remember a pre-set shape and return to it despite being dramatically reshaped.

The stimulus for returning to the pre-set shape is heat or electricity.

Quantum Tunnelling Composite

This smart material has the ability to be either a conductor or an insulator.

It works because there are billions of conductive nanoparticles inside a polymer without touching each other.

When no pressure is applied the material is an insulator, but when pressure is applied, the conductive particles move closer together and it becomes a conductor.

Examples: Variable speed controls for power tools and home appliances, touch-sensitive pads for interaction with computers and mobile technology, flexible keyboards and wearable technology.

Name	Reaction	Characteristics	Uses
Thermochromic Pigments	Heat	Pigments in the material respond to temperature by changing colour.	Thermometers, temperature gauges, clothing, novelty items
Photochromic Pigments	Light	Pigments in the material respond to UV light by changing colour.	Clothing, sunglasses, novelty items
Shape Memory Alloy (Nitinol)	Heat or Electricity	A shape can be set when heated to 540 degrees C. It can then be deformed and will return to the original shape at 70 degrees C.	Frames for glasses, dental braces, surgical equipment.
Self-Healing Material Bio-concrete	Force	Microcapsules inside the material will react when broken, filling the crack with a resin.	Concrete roads/paths

Quantum Tunnelling Composite (QTC)	Pressure	Insulator when not under pressure but when pressure is applied it becomes a conductor.	Touch electronic devices.

Do Now Questions

Why was metal foam created?

Metal is heavy so creating metal foam makes a very strong but lightweight material

What does LCD stand for?

Liquid Crystal Display

Why were fibre optics created?

To improve data and information transfer

What is a modern material?

Materials that have been invented to serve a purpose or a material that has relatively recently been discovered.

Give an example of a modern material

Aluminium, biodegradable polymers (PLA, PHB), flexible MDF, titanium, nanoparticles.

What else are biodegradable polymers called?

Cornstarch polymers

What does photochromic material react to?

Light

What does thermochromic material react to?

Heat

What does a smart material do that a modern material doesn't?

React and change properties (function, aesthetics etc)

Which modern material allows metal to be lightweight but still strong?

Metal Foam

Which smart material becomes a conductor when put under pressure?

QTC – Quantum Tunnelling Composite

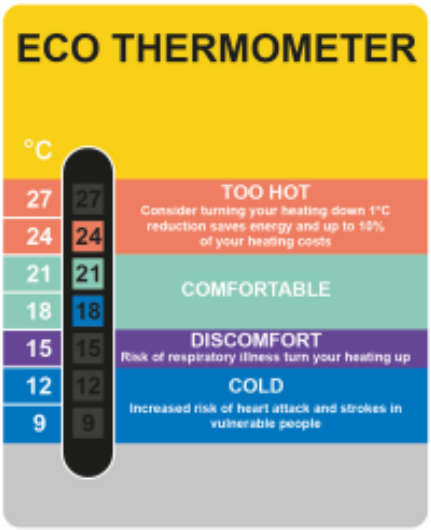
Which modern material is used in TV screens?

LCD – Liquid Crystal Display

GCSE Exam Questions

June 2023 Paper (Mark scheme - [Mark scheme: Paper 1 - June 2023 (sanity.io)])

1 0 Identify the colour-changing smart material used in the thermometer below.



A Liquid crystal display ⬭

B Nanomaterial ⬭

C Photochromic pigment ⬭

D Thermochromic pigment ⬭

[1 mark]

June 2022 Paper (Mark scheme - [Mark scheme: Paper 1 - June 2022 (sanity.io)])

1 1 . 1 Name **one** specific modern material.

[1 mark]

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1 1 . 2 Explain why the use of modern materials improves the function of products.

[2 marks]

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November 2021 Paper (Mark scheme - Mark scheme: Paper 1 - November 2021 (sanity.io))

0 9 A smart material is one which

A conducts electricity. ⬭

B protects against fire. ⬭

C reacts to a stimulus. ⬭

D waterproofs fabric. ⬭

[1 mark]